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CHEYENNE BOTTOMS: AN ENVIRONMENTAL ASSESSMENT

By

Kansas Biological Survey
Kansas Geological Survey

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by:

Kansas Biological Survey

and

Kansas Geological Survey

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Preface

This report is the culmination of almost two years of work by a team of talented and dedicated professionals, working in concert to evaluate the status of an important natural resource. We are fortunate that Cheyenne Bottoms Task Force and the Kansas Fish and Game (KFG) Commission had the insight to realize and promote the need for such a study. Their recognition of the importance of Cheyenne Bottoms both to the people of Kansas and to the wildlife that depend on the marsh resulted in the initiation of this environmental assessment. I am optimistic about the future of Cheyenne Bottoms, and am confident that this investigation will provide Fish and Game with the information necessary to develop wise and rational decisions concerning that future.

I would like to take this opportunity to express my appreciation to Don Huggins of the Kansas Biological Survey (KBS), who served as the project manager. Don was responsible for organizing this enormous undertaking into a coherent, relevant study. I doubt this study would have come to fruition without Don's insight, passion and motivation.

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Edward A. Martinko
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CHAPTER 1: INTRODUCTION

Mark Griffith and Gary Welker

"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually near the surface of the land or the land is covered by shallow water" (Cowardin et al., 1979). These ecosystems occur throughout the world and are valuable assets to wildlife and man. Wetlands are very efficient converters of solar energy into plant biomass. Their productivity is among the highest of all ecosystems. Whittaker (1975) compares the net primary productivity of swamps and marshes to that of tropical rain forests (2,000 g/m/yr and 2,200 g/m/yr, respectively). Factors that influence productivity are nutrients, climate, soil or sediment conditions, and water flow (Odum, 1978).

Wetlands provide habitat for an array of birds, mammals, amphibians, reptiles, fish, and invertebrates. Many species not normally associated with wetlands derive nutrients or use the cover of wetlands sometime in their annual life cycle (Fredrickson, 1982). Approximately 20% of all plant and animal species on the Federal government's threatened or endangered lists depend on wetlands for food and/or habitat (O.T.A., 1984).

Aesthetic, recreational, and educational wetland values cross over and intertwine with one another to a point of interdependency (Smardon, 1983). Many people enjoy and value wetlands for their intrinsic qualities, regardless of economic and/or ecological services obtained. In 1980, 28.8 million people (17% of the U.S. population) visited wetlands to observe, photograph, or feed wildlife (Tiner, 1984). Recreational activities associated with wetlands are numerous and in many states revenues derived from these activities support

wetland conservation efforts. Wetlands also provide excellent opportunities for education and scientific research in such areas as limnology, ornithology, anthropology, and hydrology.

In times of heavy precipitation, wetlands act as sponges, holding or storing excess flood waters and thus protecting property downstream. The interception, storage, and controlled release of storm waters reduce large runoff peaks that produce flood damage (Mitsch and Gosselink, 1986). Surface water velocities are also reduced; decreased velocity will reduce the erosion potential of the storm water.

Wetlands may also improve the quality of the water passing through them. By retaining pollutants, permanently or temporarily, such as excess nutrients (i.e. phosphates and nitrogen), toxic chemicals and pathogenic organisms, the quality of water flowing through a wetland system can be improved (O.T.A., 1984). Excess nutrients are used to support emergent plant growth. Organic and inorganic particulate matter tends to settle out, thus decreasing turbidity. Some pollutants "trapped" by wetlands can be converted to less harmful states by biochemical processes.

Some wetlands are important as sites of ground water recharge. Their importance for recharge depends on numerous factors, including precipitation, geographic location, season, type of wetland, water table location, and soil type (Tiner, 1984). An important factor is the permeability of the clay layer usually found in a wetland system.

We have only recently come to appreciate wetlands. For most of the United States' history, wetlands have been synonomous with wastelands, only fit to be drained, dredged, or filled. A lack of historical data makes the assessment of this wetland destruction difficult. In the last 200 years, an estimated 30-50% of wetlands in the contiguous United States have been

destroyed (O.T.A., 1984). From the mid-1950's to the mid-1970's, 11 million acres were converted, which is an average of 550,000 acres per year. Inland wetlands constituted 97% of the losses in the 20-year period. Agricultural conversions were the major factor in the loss of wetlands (80%). These conversion activities included clearing, land leveling, drainage, ground water pumping, and surface water diversion. Construction of impoundments and large reservoirs, urbanization, mining, road construction, and dredging were other practices resulting in wetland devastation. Presently, wetlands cover approximately 90 million acres of our nation's mainland, which is about 5% of the lower 48 states' land surface.

In Kansas, wetland destruction also has occurred in significant amounts. A 1955 survey reported that Kansas wetlands covered some 204,000 acres. In 1978 an estimate of 122,400 remaining acres indicates a 40% loss of wetlands in Kansas over the 23-year period (U.S. Environmental Protection Agency (U.S.E.P.A., 1980).

The quantification of the economic values of wetlands is difficult and complex. Tangible economic benefits such as flood control, erosion protection, water quality enhancement, ground water recharge, agricultural harvests, wildlife harvests, and recreational returns are a few of many wetland values that either create a dollar value or savings. Although the economic value placed on our nation's wetlands is difficult if not impossible to determine, these unique ecosystems are considered to be of high economic value. In a U.S.E.P.A. article, U.S. Senator John Chafee stated that "wetlands contribute $20-40 billion a year to the national economy (Chafee, 1983)." In 1980, 5.3 million people spent $638 million on hunting waterfowl and other migratory birds (Tiner, 1984). It has been estimated that in 1975,

recreational fishing expenditures in quest of wetland-associated species was $13.1 billion (Peters et al., 1978).

Cheyenne Bottoms is the premier wetland in the state of Kansas. The Cheyenne Bottoms Wildlife Management Area (C.B.W.M.A) is located in Barton County, approximately 6 miles northeast of the county seat, Great Bend (figure 1.1). The management area covers 19,000 acres in the lower portion of a 41,000-acre basin, Township 18 South, Ranges 12 and 13 West. The management area incorporates most of the marsh currently existing in the basin. In 1942 the Kansas Fish and Game Commission initiated the purchase of land with federal aid provided by the Pittman-Robinson Act of 1937. The area was partially opened to the public in 1952 and was officially dedicated in 1957 (Schwilling, 1985).

Cheyenne Bottoms is a manipulated freshwater wetland and consists of five pools separated by a system of earthen dikes (fig. 1.1). According to the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al., 1979), the Cheyenne Bottoms wetland classification is as follows: SYSTEM Lacustrine, SUBSYSTEM Littoral, CLASS Emergent Wetland, SUBCLASS Persistent, DOMINANT TYPE Typha, WATER-REGIME MODIFIERS Artificially Flooded, WATER CHEMISTRY Mixosaline-Alkaline, SOIL Mineral, SPECIAL MODIFIER Impounded. Currently the dominant plant is the narrow-leaf cattail (Typha angustifolia).

Cheyenne Bottoms provides habitat for numerous species of birds, mammals, reptiles, amphibians, fish, invertebrates, and plants. The area offers a variety of habitats such as rangeland, farm land, creek beds, tree rows, and of course, marsh. The marsh at Cheyenne Bottoms is extraordinarily productive and hence an extremely important source of food for migratory birds. Out of the 417 species of birds known to occur in Kansas, a minimum of 328 species

have been documented at the Bottoms (Chapter 16). Six species of birds on the federal endangered and threatened species lists regularly use Cheyenne Bottoms: Whooping Crane, Piper Plover, Snowy Plover, Least Tern, Peregrine Falcon, and the Bald Eagle. Three birds, the Swainson's Hawk, Ferruginous Hawk, and the Long-billed Curlew are under consideration for listing as threatened species. Cheyenne Bottoms is of particular importance to shorebirds. The International Shorebird Survey (Manomet Bird Observatory) considers the Bottoms one of the most important stopovers for shorebirds in the Western Hemisphere.

The abundance of wildlife in this unique Kansas ecosystem provides good recreational and educational opportunities. Cheyenne Bottoms has been managed primarily for waterfowl hunting. Other hunting includes pheasant, snipe, rail, and deer. Birdwatching, limited fishing, and trapping are other activities pursued at the Bottoms.

The Bottoms is an excellent educational resource for midwestern schools, clubs, and organizations. Field trips from colleges and universities in and out of the state of Kansas regularly visit the Bottoms. Through the years, various research studies have been carried out at this wildlife management area.

The Cheyenne Bottoms Wildlife Management Area is a tangible and quantifiable economic asset to Barton County and the state of Kansas (see Chapter 19). The Bottoms has a positive effect on all sectors of the Barton County and Kansas economies. Hunters, bird watchers, fisherman, trappers, students, and nature enthusiasts generate thousands of dollars through travel, lodging, food, and general merchandise expenditures. Economic impacts can be quantitatively traced from Bottoms-related activities to such sectors of the

Kansas economy as agriculture, mining, construction, durable and nondurable goods manufacturing, wholesale, finance, insurance, and real estate.

Historically, land use in the Cheyenne Bottoms watershed has been mostly agricultural. Census data for 1939 and 1982 for Barton County reveal that agricultural land use comprises 98.8% and 97.6% of the county, respectively (U.S. Department of Commerce [U.S.D.C.], 1942, 1982). Urban or built-up land uses (transportation, residential, commercial, industrial, etc.; Anderson et al., 1976) along with sparse riparian forest along Blood and Deception creeks constitute the remaining few percentages of land use in the Cheyenne Bottoms watershed. Although agriculture has constantly remained as the dominant land use, agricultural practices within this broad category are dynamic. These changing agricultural practices have a fundamental effect on the water supply for Cheyenne Bottoms.

General guidelines for establishing Cheyenne Bottoms as a wildlife refuge were developed and acquisition of the wetland was initiated in 1942. Total acquisition of Cheyenne Bottoms was completed in 1956. Development in the 1950's and 1960's (table 1.1) included a system of diversion dams and canals to transmit water from the Arkansas River, Dry Walnut Creek, and Walnut Creek. Other major developments included an outlet canal and the construction of several miles of dikes to divide the wetland into five pools. Figure 1.1 shows the system in its current configuration.

Table 1.1--Outline of structural development projects at Cheyenne Bottoms.

Project	Initiated	Completed
Inlet Canal-Walnut Creek to Cheyenne Bottoms	5-30-49	4-10-50
Walnut Creek Diversion Dam	2-21-50	12-19-51
Outlet Canal	5-19-51	10-31-53
Dikes and Control Structures	6- -51	10- -53
Inlet Canal-Arkansas River to Walnut Creek	7-19-55	6-25-56
Arkansas River Diversion Dam	8-21-56	8-5-57
Pumping Facilities	8-3-64	12-30-64

Cheyenne Bottoms has been managed primarily to provide food and habitat for waterfowl during migration and to provide hunting opportunities for Kansas hunters. The dike system and canals were constructed to provide a reliable source of water and to facilitate water storage, exclusion, and transfer within the Bottoms. The present water supply from the Arkansas River and the two Walnut creeks is far less reliable now than it was when the system was developed.

Currently Cheyenne Bottoms is perceived as suffering from two problems that threaten its value and perhaps even its existence as a wetland. The first of these may be called the water problem. Because the delivery of water from the Walnut creeks and the Arkansas River is compromised, management of Cheyenne Bottoms has become much more difficult. Water now is diverted into Cheyenne Bottoms whenever it is available, instead of at the times it is most useful. As the water budget of Cheyenne Bottoms depends more and more on local (within basin) rainfall, the configuration of existing structures becomes less and less ideal for efficient management.

The second problem may be called the vegetation problem. Currently much of Cheyenne Bottoms is either covered with rank stands of cattail or composed

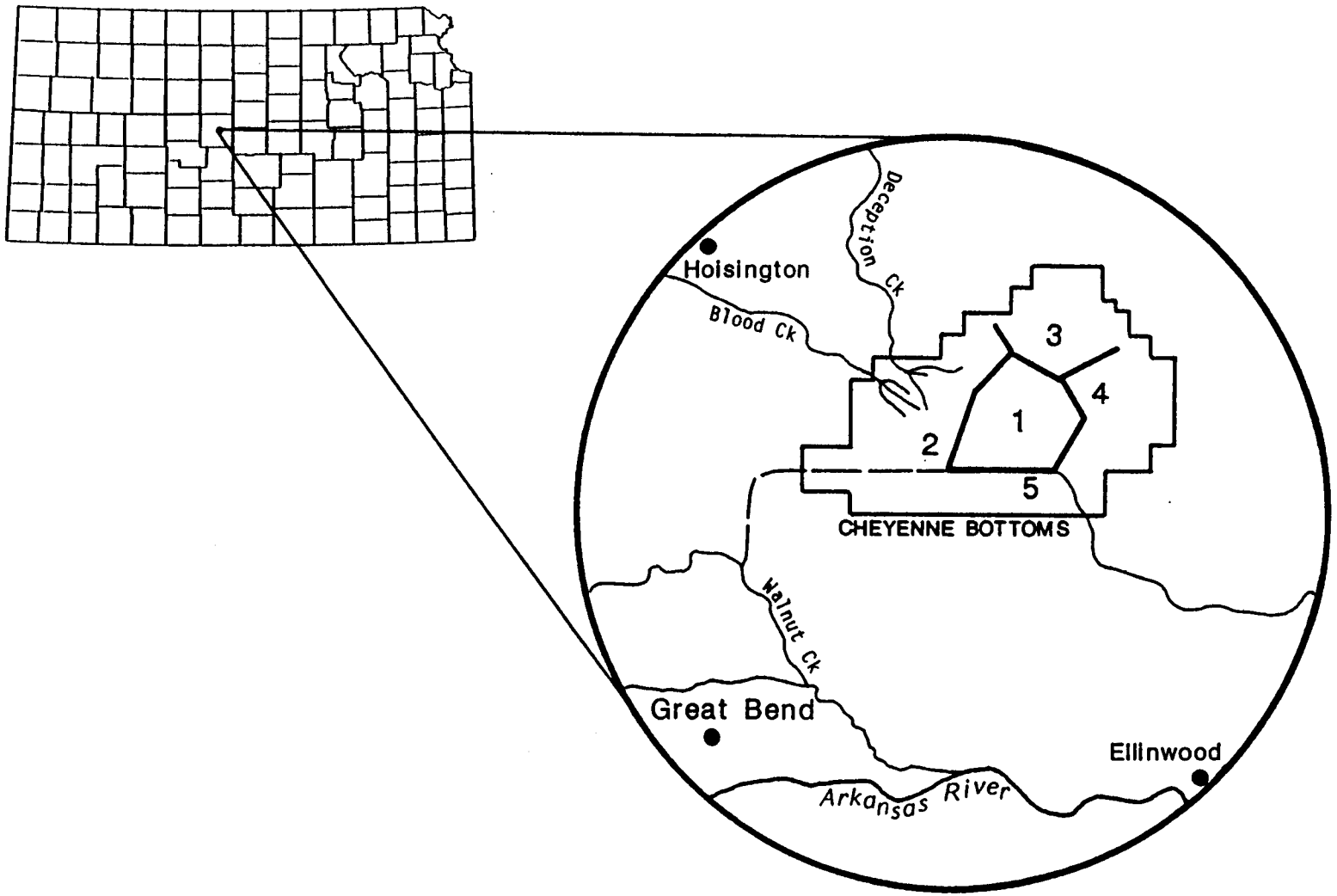

Figure 1.1 - Location Map of the Cheyenne Bottoms Wildlife Management Area.

of expanses of undesirable annuals, in contrast to its previous, more diversified vegetative structure. These dense continuous stands of cattails do not provide as good a wildlife habitat as previously existed, and also remove great quantities of water from the marsh through transpiration. Often, annuals such as aster dominate areas and provide limited food resources for most wetland species.

Because of these problems and because Cheyenne Bottoms recently became recognized as an extremely important habitat for a variety of migratory birds in addition to waterfowl, the state of Kansas was motivated to authorize the feasability study culminating in this report.

This study officially began 1 July 1985, although the groundwork and preparations began well before that date. The first phase was scheduled to be conducted up to 1 July 1986, with a budget of $120,000. Additional funding of $60,000 was granted for completion of the project by 31 December 1986. Appropriated funds were divided accordingly between the two major investigating agencies, Kansas Biological Survey (KBS) and Kansas Geological Survey (KGS). Portions of the study were subcontracted to the Institute for Public Policy and Business Research and to several individual specialists.

This study focused on a systems approach to management. Briefly, management should attempt to maintain the health and diversity of the marsh as a whole, as well as providing for the specific needs of target species. Cheyenne Bottoms target species should minimally include waterfowl, migratory shorebirds, and endangered species. The systems approach is best explained with a functional model (figure 1.2). Wetlands are transitional lands between terrestrial and aquatic systems where water is at or near the soil surface, or the land is covered with shallow water. Nutrients, energy, and biota are constantly moving through wetlands as they pass between the terrestrial and

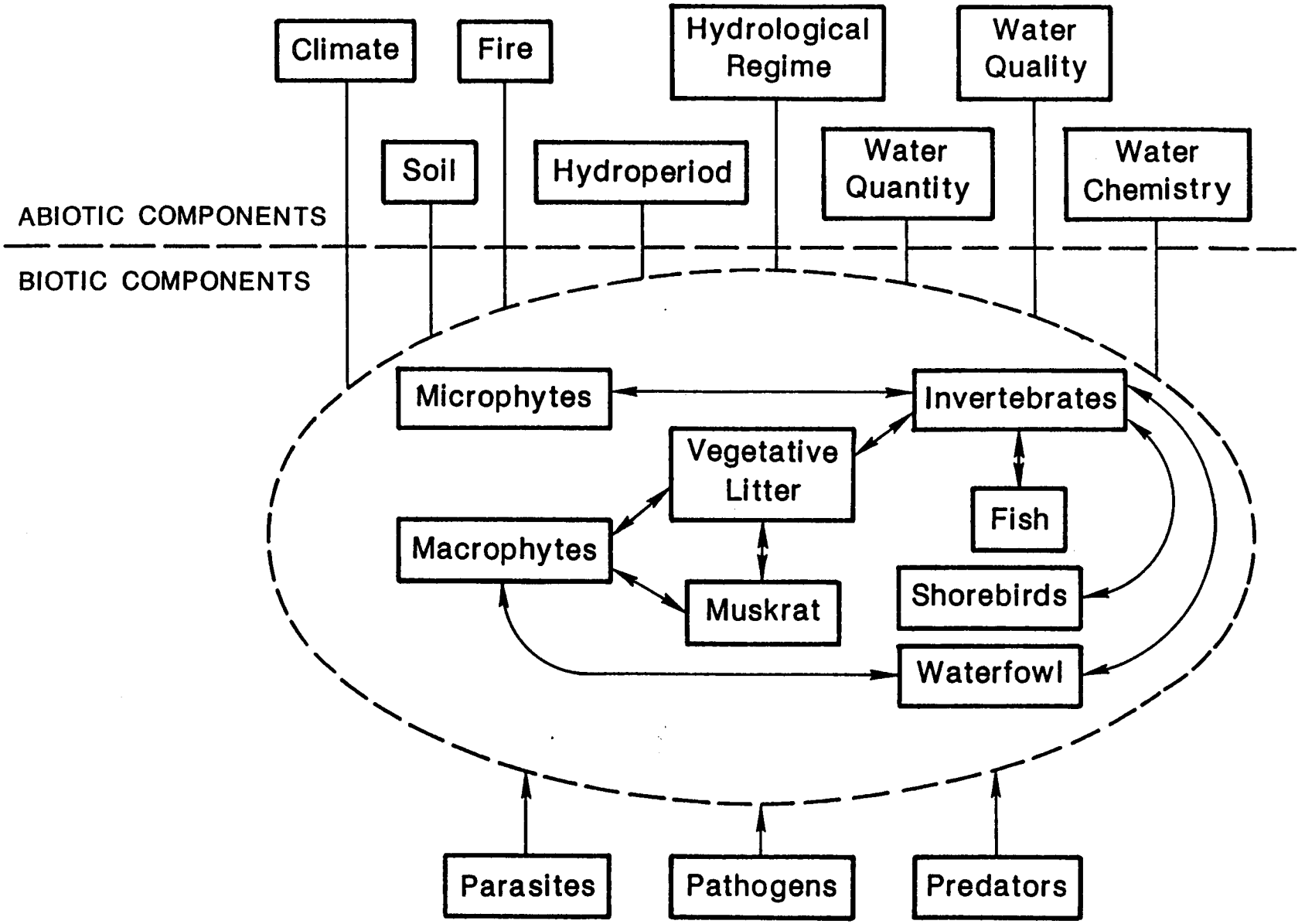

Figure 1.2 - Model of Wetland Components.

aquatic systems (Likens and Bormann, 1974). The major biotic components within wetlands include microphytes (algae), macrophytes (emergent plants), vegetative litter, invertebrates, and vertebrates. Abiotic factors include soil, climate (temperature, light, wind), fire, and hydrological regime (water input, water loss, water movement), as well as water quality, quantity, and chemistry. Parasites, pathogens, and predators are external biotic factors that influence the wetland biota. The interactions among and between these major components are illustrated in figure 1.2.

This report summarizes the results of the environmental assessment of Cheyenne Bottoms. Chapters 2 through 11 address aspects of the geology, hydrology, and water chemistry of Cheyenne Bottoms and associated waters. Chapter 7 describes land use patterns and trends in the Cheyenne Bottoms watershed and evaluates their influence on water supply to the Bottoms. Chapters 12 through 17 catalog and evaluate the biota of Cheyenne Bottoms, and Chapter 18 is an ecological overview, integrating the biological findings into a more unified picture of the marsh as an ecological system. Chapter 19 is an analysis of the economic impact of the users of Cheyenne Bottoms on the economy of Barton County and Kansas. In Chapter 20, the physical structure of Cheyenne Bottoms is evaluated from an engineering perspective. Finally, in Chapter 21, a series of modules of potential improvements are presented, evaluated, and organized into several options for future management.

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CHAPTER 2: CHEYENNE BOTTOMS GEOLOGY

Lynn Vogler, Glenn Fredlund and William Johnson

INTRODUCTION

Cheyenne Bottoms is a small, elliptical-shaped, basinlike feature located near the center of Kansas in the Plains border section of the Great Plains physiographic province (fig. 2.1). It occupies an area of approximately 64 square miles and lies principally in T18S and R12 and 13W. It is surrounded on the north, south, and west sides by steep-sided bluffs composed of sandstone and clay or limestone that are Cretaceous in age. The bluffs attain a height of 100 feet (30 meters) or more above the basin floor (Bayne, 1977). The east and southeast sides of Cheyenne Bottoms are surrounded by low walls composed of dune sand and unconsolidated sand and silt that are Pleistocene in age. Altitudes of the land surface ranges from a high of 1,806 feet (542 meters) along Blood Creek to a low of 1,793 feet (538 meters) on the southeast side of the basin.

DRAINAGE

Blood and Deception creeks on the northwest and north, respectively, are the major streams draining into Cheyenne Bottoms (fig. 2.1). Both are intermittent streams, flowing only during spring runoff and during times of precipitation. After entering the basin, the streams spread out to the point where distinctive channels are found for no more than a short distance. Surface drainage from Cheyenne Bottoms is through the outlet canal on the southeastern side of the basin where it eventually enters Little Cheyenne Creek. Additional water is obtained for Cheyenne Bottoms from the Arkansas River, Dry Walnut Creek, and Walnut Creek, entering the basin through the inlet canal from the south.

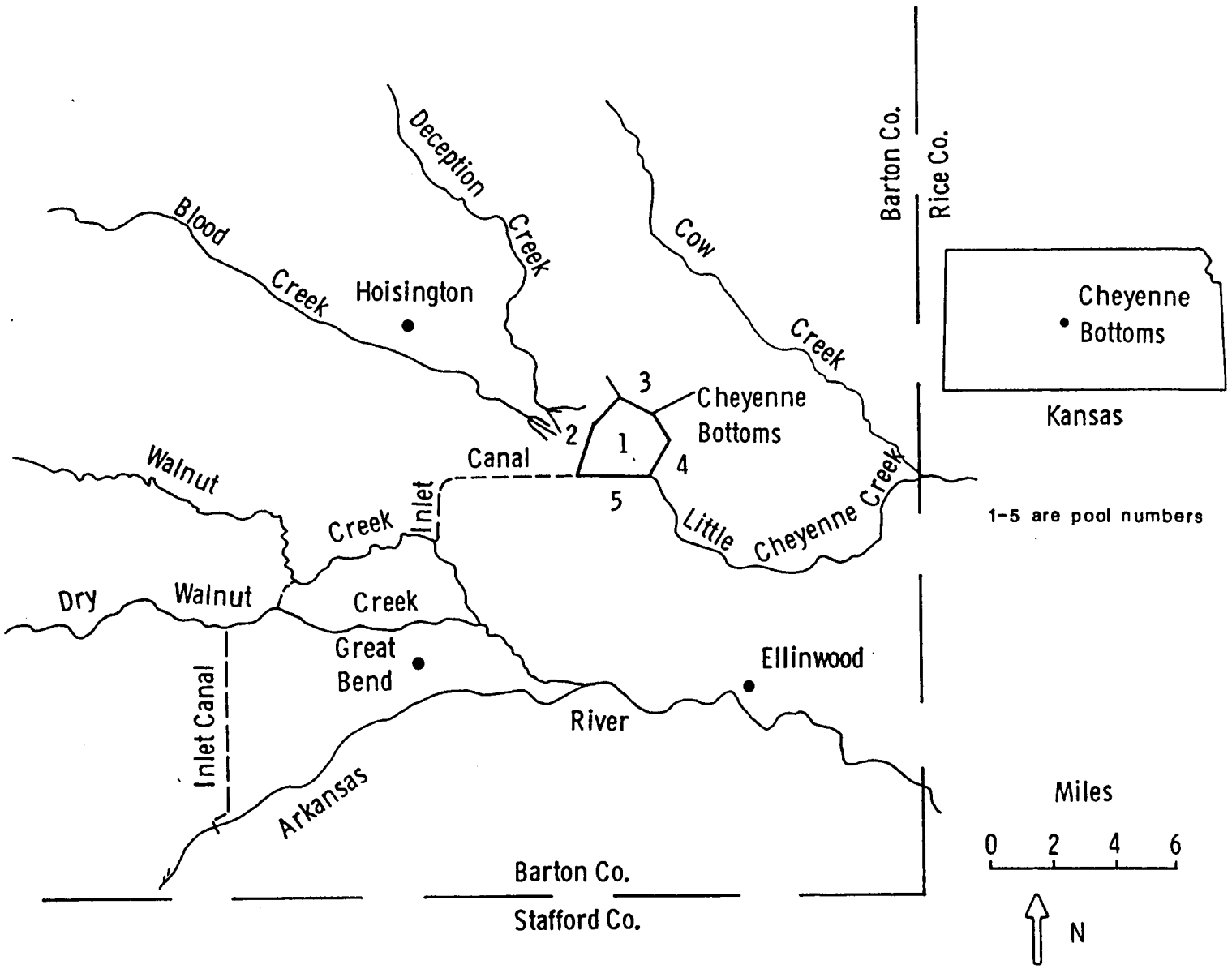

Figure 2.1 Location Map for Cheyenne Bottoms Wildlife Area

GEOLOGIC HISTORY

The description of general geology of the area is taken from Bayne, 1977. Cheyenne Bottoms is located in an area that during the Precambrian consisted of isolated hills that rose several hundred feet above the lowlands. Beginning at the Paleozoic, the area was subjected to intermittent periods of transgression and regression of marine seas; subsequently, there were periods of deposition and erosion. Early Paleozoic deposits consisted primarily of marine limestones, shale, and sandstone. Prior to deposition of pre-Mississippian sediments, upward warping of early Paleozoic sediments occurred along a northwest-southeast axis. The anticlinal structure resulting from this upward warping has been named the Ellis Arch. Earlier Paleozoic sediments were eroded after the elevation of the Ellis Arch, exposing the isolated Precambrian hills. Mississippian shales and limestones were deposited by another invasion of the sea. Prior to deposition of Pennsylvanian sediments, central Kansas, including the area of Cheyenne Bottoms, was again uplifted and warped to form what is today called the Central Kansas Uplift. Following this period of uplift, erosion removed the Mississippian sediments from the area.

Following the post-Mississippian erosional period, there was a reinvasion of the sea, with the area remaining submerged except for short periods during the late early Permian at which time the continental "red beds" were deposited. Lack of Triassic, Jurassic, and earliest Cretaceous sediments suggests that they were either not deposited or were eroded. Also, several hundred feet of Permian "red beds" were eroded during this period. Following erosion of the "red beds," the Early Cretaceous Cheyenne Sandstone was deposited marginal to the advancing Cretaceous sea, followed by the marine Kiowa Shale, and the Dakota Sandstone deposited along the margin of the sea as

it withdrew. Early Late Cretaceous time saw the area resubmerged, and the deposition of a thick sequence of limestone, shale, chalky shale, and chalky limestone. Withdrawal of the Late Cretaceous sea marked the end of marine transgressions to present time.

During the majority of the Tertiary Period, erosion resulted in the loss of several hundred feet of sediment. The Pliocene epoch saw the deposition of the Ogallala Formation; however, it was eroded to a large extent during the Pleistocene epoch. Much of the area's present topography has resulted from erosion and deposition that occurred during the Tertiary Period.

Pleistocene history of the area is difficult to interpret, being marked by changing drainages and many periods of erosion and deposition. Presently, Cheyenne Bottoms is slowly filling with sediment brought into the basin from area streams. A later section of this chapter will discuss a recently collected core from the Bottoms.

AREAL GEOLOGY

Rock units exposed at Cheyenne Bottoms are principally Cretaceous in age and form the valley walls on the north, south, and west sides (fig. 2.2). Only the southeast side of the basin lacks Cretaceous exposures; here, sediments consist of loesses, silt, sandy silt, and fine sand that locally contains lenses of coarse sand and gravel. Fig. 2.3 and 2.4 illustrate and describe the general geology of Cheyenne Bottoms.

ORIGIN OF CHEYENNE BOTTOMS

Several mechanisms have been proposed to explain the formation of Cheyenne Bottoms. Haworth (1897), one of the earliest investigators, proposed that Cheyenne Bottoms formed as a result of stream erosion. Johnson (1901)

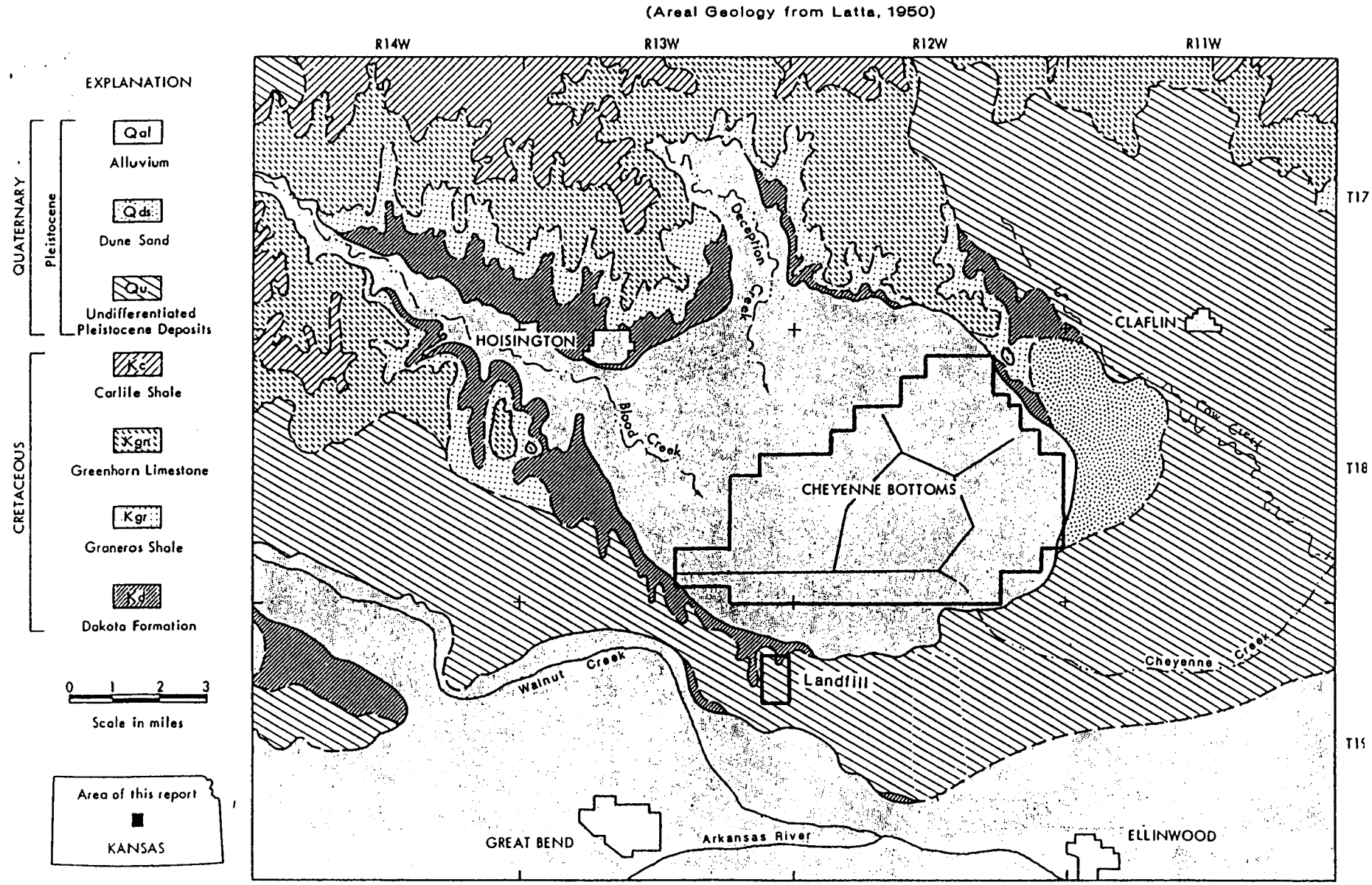

Figure 2.2 Areal Geology of Cheyenne Bottoms and Barton County, Kansas

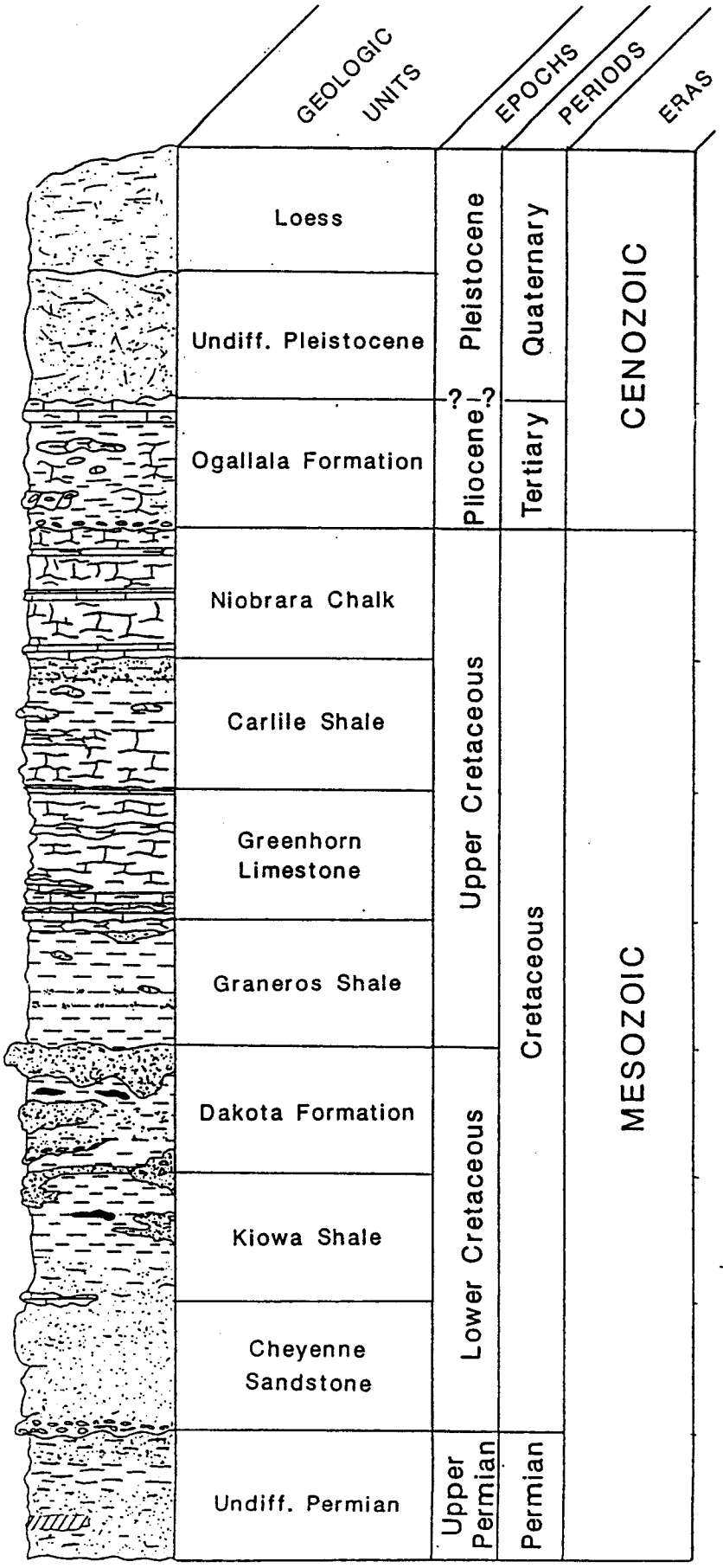

Figure 2.3 Geologic Column

Qal	Valley-fill deposits consisting of fluvial and eolian gravel, sand, silt, and clay.
Qds	Dune sands consisting of fine to medium grained quartz sand.
Qu	Undifferentiated deposits of eolian, fluvial, and colluvial deposits of mostly silt, occasionally overlying sand and gravel.
No	Ogallala Formation: Crossbedded, generally arkosic gravel, sand, and silt, locally cemented with calcium carbonate. Containing limestone, volcanic ash, opaline sandstone, and bentonitic clay.
Kn	Niobrara Chalk: Interbedded, soft, calcareous shale, chalk, and chalky limestone.
Kc	Carlile Shale: Chalky shale and thin beds of chalky limestone.
Kgh	Greenhorn Limestone: Chalky shale alternating with beds of hard chalk; contains thin beds of hard crystalline limestone.
Kgs	Graneros Shale: noncalcareous shale containing selenite, pyrite, and thin beds of fine-grained sandstone.
Kd	Dakota Formation: varicolored clay, shale, siltstone, occurring in alternating beds of ironstone and lignite.
Kk	Kiowa Formation: Light-gray to black shale and sandy shale, with beds and lenses of medium to fine-grained gypsum. The Kiowa does not crop out in Cheyenne Bottoms.
Kkc	Cheyenne Sandstone: Sandstone, very fine to fine to medium-grained siltstone, with some clay and shale, the Cheyenne Sandstone does not crop out in Cheyenne Bottoms.
P	Undifferentiated red beds consisting of red siltstone. shale, sandstone, with lesser amounts of gypsum, salt, anhydrite, limestone, and dolomite. The Permian red beds are not exposed in Cheyenne Bottoms.

Figure 2.4 Description of Geologic Units

and Bass (1926) suggested that formation of Cheyenne Bottoms was a result of removal of salt deposits by solution and subsequent subsidence.

Later still, Latta (1950) proposed that Cheyenne Bottoms formed as a result of the combined actions of subsidence, followed by stream erosion during the Pleistocene. More recently, Bayne (1977) suggested that Cheyenne Bottoms formed as a result of structural movement in the subsurface.

Bayne (1977) based his theory on structural contour maps of the Stone Corral Formation, the Hutchinson Salt Member of the Wellington Formation, the Winfield Limestone, the Heebner Shale Member of the Oread Limestone, and the top of the Precambrian surface. He discovered that when viewing only the maps showing the top of the Stone Corral and the top of the Hutchinson Salt, Cheyenne Bottoms could be attributed to either solution and subsidence, or to structural movement. However, if solution and subsidence were responsible, only the unit most affected by solution and the beds above would show evidence of distortion. When the remaining structure maps are viewed, it is evident that structural features present at shallow depths also are identifiable in the units at greater depths; in fact, a depression can be identified on the Precambrian surface. Structural movement is likely, therefore, to be the mechanism responsible for the formation of Cheyenne Bottoms. The probable time frame for the structural activity is believed to be between early Late Cretaceous time and latest Pliocene.

PRELIMINARY CORE ANALYSIS

For thousands of years, Cheyenne Bottoms has been slowly filling with windblown dust and waterlain sediments. Trapped in these sediments are fossils of the algae, crustaceans, mollusks, vascular plants, and other organisms which lived in and around the basin at the time of deposition. Over these thousands of years changes in climate have greatly affected the water

quality and ecology of the Cheyenne Bottoms wetlands and the surrounding region. These environmental changes can be seen in the changing fossil assemblages preserved in the sediments.

Today both man and the changing climate are affecting the stability and ecology of the Cheyenne Bottoms wetlands. The resulting change in water quality and its effect on the wetland ecology is of primary concern. One approach to understanding this problem is historical. In the past, climate has more than once caused the wetlands to shrink, resulting in increasing water salinity. Effects of these changes on water quality, primary microscopic limnetic and benthic organisms, and marsh vegetation are reflected in the fossil record.

This preliminary investigation of the sediments filling Cheyenne Bottoms has had two objectives: 1) documentation of the stratigraphy and age of the unconsolidated Quaternary sediments overlying the much older Cretaceous bedrock, and 2) exploration and assessment of the fossil record preserved in these sediments. These are necessary first steps in an investigation we believe will not only tell us more about Kansas natural history but may also aid in the understanding of current ecological problems at Cheyenne Bottoms.

AGE AND STRATIGRAPHY

Our current knowledge of Cheyenne Bottoms history comes from preliminary analysis and dating of a 60-foot core of sediments taken from near the center of the basin in November 1985. This core represents only about one-half of the total sedimentary record present in the basin. Previous drilling at a site near that sampled in 1985 documented over 100 feet of Quaternary sediments (Latta 1950, p.178). The sedimentary stratigraphy of the 1985 core closely matches that reported by Latta to the depth of 60 feet. We assume that the unsampled remainder of the sediments would also have matched those

from Latta's deep auger hole. It is hoped that a core of the complete Quaternary record will be obtained in the near future.

The age of the sediments filling the Cheyenne Bottoms basin seems to be far younger than suggested by the investigations of the bedrock deep below the basin (Bayne, 1977). Using two radiocarbon dates from the upper 35 feet of the 1985 core as a measure, the long-term rate of sedimentation is approximately 1 foot per 800 years. Assuming this rate of deposition, the lowermost Quaternary sediments documented by Latta (1950) are in the vicinity of 100,000 years old. Although this is geologically very young, the persistence of a wetland for such a long time is unique in the region.

Five major layers of Quaternary sediments have been identified (fig. 2.5). The lowermost two are known only from Latta's (1950) descriptions. Alluvially deposited sands and gravels attributed to the "Chase Channel" (Fent, 1950), compose the lowermost zone. A 40-foot-thick stratum of silts and sands lies above the Chase Channel sands. Because Latta reports these as being reduced, blue-gray in color, and containing mollusks, a wetlands depositional environment seems likely. The upper portions of this section are marked by a change from blue-gray to brown sediment, a change which may indicate wetlands drying and soil development.

The next layer up consists of about 30 feet of blue-gray clays and silts. Most of this layer is known from the 1985 core. A radiocarbon date of 30,220 (+740/-810) years before present has been obtained from near the middle of this zone. Fossils in these sediments indicate a shallow-water wetlands depositional environment. Both the stratigraphic position and age of this stratum are consistent with the Farmdalian substage of the final or Wisconsinan glacial period.

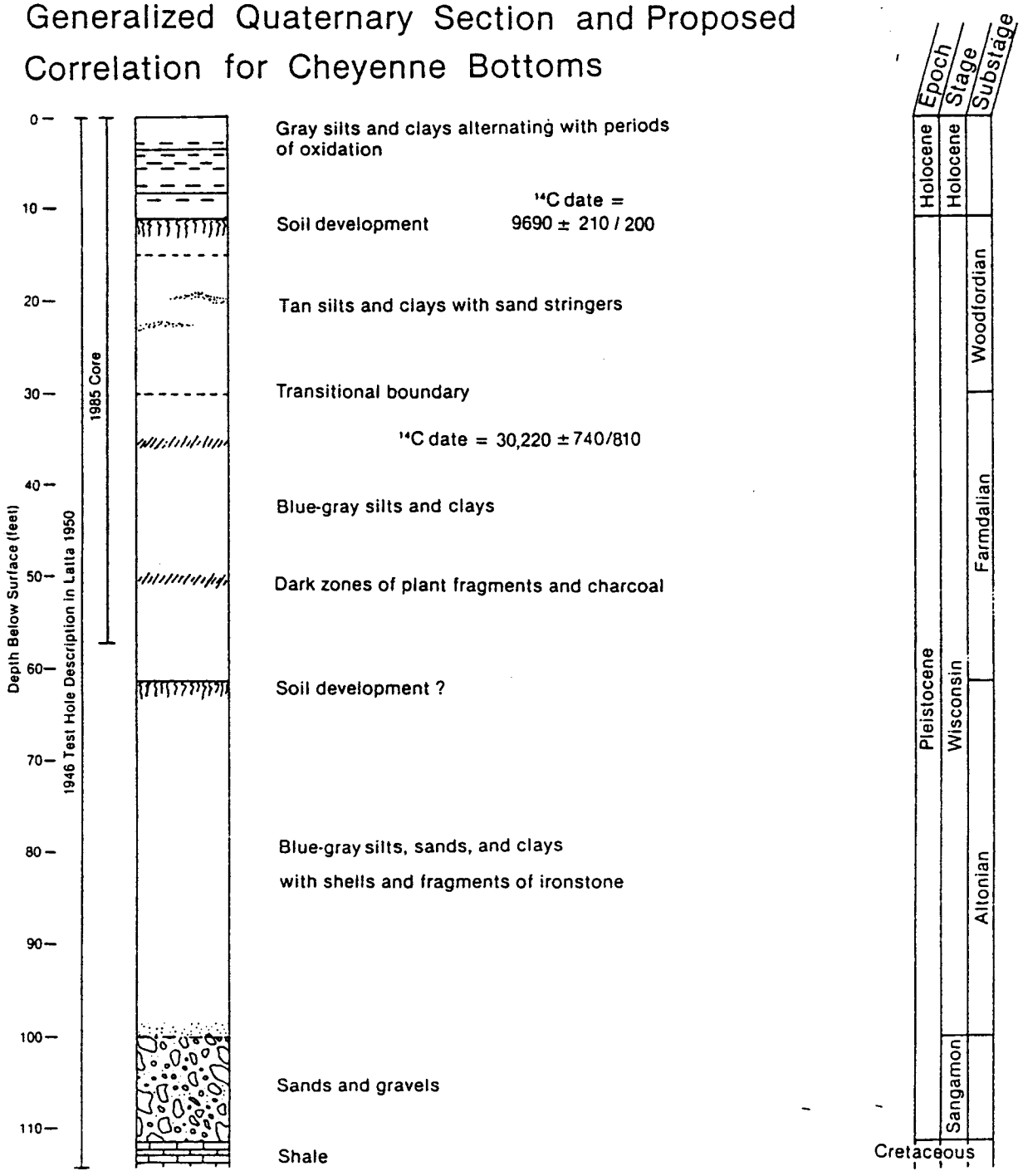

Figure 2.5 Generalized Quaternary Section and Proposed Correlation for Cheyenne Bottoms

The upper portion of the blue-gray clays grades into a 15-foot-thick layer of tan silts, sands, and clays. This zone may be equivalent to the windblown loess which blanketed much of Kansas during the Woodfordian, the last substage of the Wisconsinan. Fossil algae in these silty sediments indicate that a wetlands environment had persisted in spite of the increased sedimentation.

The uppermost 15-foot-thick layer contains several zones of alternating color, texture, and structure indicating repeated basin drying. The most pronounced and lowermost of these zones of basin drying and soil development has been radiocarbon dated at 9,690 (+210/-200) years before present. This marks the end of the last Ice Age and the beginning of the Holocene Period, and climatic conditions more akin to those of Kansas today. It is this uppermost, Holocene stratum including periods of aridity and wetlands drying, which offers the best analogs for the environmental change occurring in Cheyenne Bottoms today.

FOSSIL RECORD

A preliminary set of 18 samples taken from throughout the 60-foot core of Quaternary sediments has been analyzed for presence of fossils. A wide variety of fossil types occurs throughout the core. These include diatom frustules, freshwater-sponge spicules, chrysophycean cysts, Pediastrum colonies, mollusk shells, fungal spores and fruiting bodies, pollen and spores from vascular plants, seeds, charcoal, and other plant fragments, especially leaf-epidermal fragments from marsh plants. Although preliminary analysis has failed to demonstrate their presence, other fossil organisms such as cladocerans and ostracods also may be preserved.

Among the most commonly occurring and most important fossils for documenting Kansas natural history are the fossil pollen. Because these

fossils are windborne, changes in pollen assemblages reflect regional vegetation changes. Many researchers have doubted the antiquity of the Great Plains grasslands, speculating that they have existed only during the last 9,000 years. Pollen from Cheyenne Bottoms shows that during the late Pleistocene, trees including spruce, pine, maples, alder, and birch were indeed able to grow in central Kansas. However, these arboreal-pollen types are rare compared to grassland types such as sage, ragweed, chenopod, and grass. Although a thorough quantitative analysis of many more samples is needed, our preliminary survey of the Cheyenne Bottoms pollen data suggests that a grassland vegetation in central Kansas is not unique to the Holocene Period.

The fossil record also provides ancient parallels for current wetlands-management practices. In order to maintain a diverse plant community and productive wildlife habitat, seasonal drainage and burning of cattail marsh is regularly done at Cheyenne Bottoms, as it is in other managed marshes. Pollen of cattail (Typha latifolia) has been identified from most of the samples investigated, including the 30,000-year level. Other fossils, such as leaf fragments have not yet been identified but seem to be primarily from grasses, sedges, rushes, and other marsh plants. Thin layers of these partially burned leaf fragments, probably the result of marsh fires, are common even in the Pleistocene sediments. The preliminary interpretation of the fossil record indicates that regular burning was a part of the natural equilibrium of the marsh long before man intervened.

CONCLUSIONS

Cheyenne Bottoms offers a unique opportunity for documenting the Quaternary history of vegetation and climate of Kansas. Nowhere else in Kansas or the central Great Plains is there a suitable ancient wetlands basin

for such scientific research. Trapped within the sediments filling Cheyenne Bottoms are microscopic fossils and other traces documenting the history of Cheyenne Bottoms and the surrounding region. Of particular interest is the record of past environmental change parallel to that occurring today. Fossil algae, crustaceans, mollusks, pollen, and other botanical microfossils can be recovered. Changes in these fossils document past changes in water depth and quality and the local marsh vegetation and plant communities surrounding the basin. Understanding these past environmental changes may aid in our understanding of current changes. The great potential of this environmental record has really just begun to be explored.

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CHAPTER 3: WATER QUALITY

Donald O. Whittemore and Donald G. Huggins

INTRODUCTION

Surface- and ground-water samples were collected from the Cheyenne Bottoms study area to assess the present water quality and its relationship to both the natural state and the management of the Bottoms. Surface waters were collected by the Kansas Biological Survey from two small creeks draining into the western part of the Bottoms area and from each of the five pools of the wetland (fig. 3.1). Ground waters were sampled by the Kansas Geological Survey from 14 monitoring wells installed for this project in and surrounding the wetlands area (fig. 3.1). Specific locations and other site information and sample-collection dates are given in tables 3.1 and 3.2 for ground- and surface-water samples, respectively. The screened interval for all wells except site GW-E35B is the bottom 5 feet of the well. The well at site GW-E35B is screened from 5-8-feet depth. Waters were collected from most sites during both November 1985 and April or May 1986.

Samples for determination of nutrients and trace metals were acidified in the field. Both unacidified samples for the determination of other constituents and properties and acidified samples were refrigerated after collection and transported to the laboratories of the Kansas Geological Survey for analysis. The waters were filtered through 0.45-µm membrane filter paper before analysis. Charge-balance errors for dissolved constituent determinations in all samples were less than 2.3%. Major and minor dissolved constituent concentrations in the ground- and surface-water samples are given in table 3.3 and 3.4.

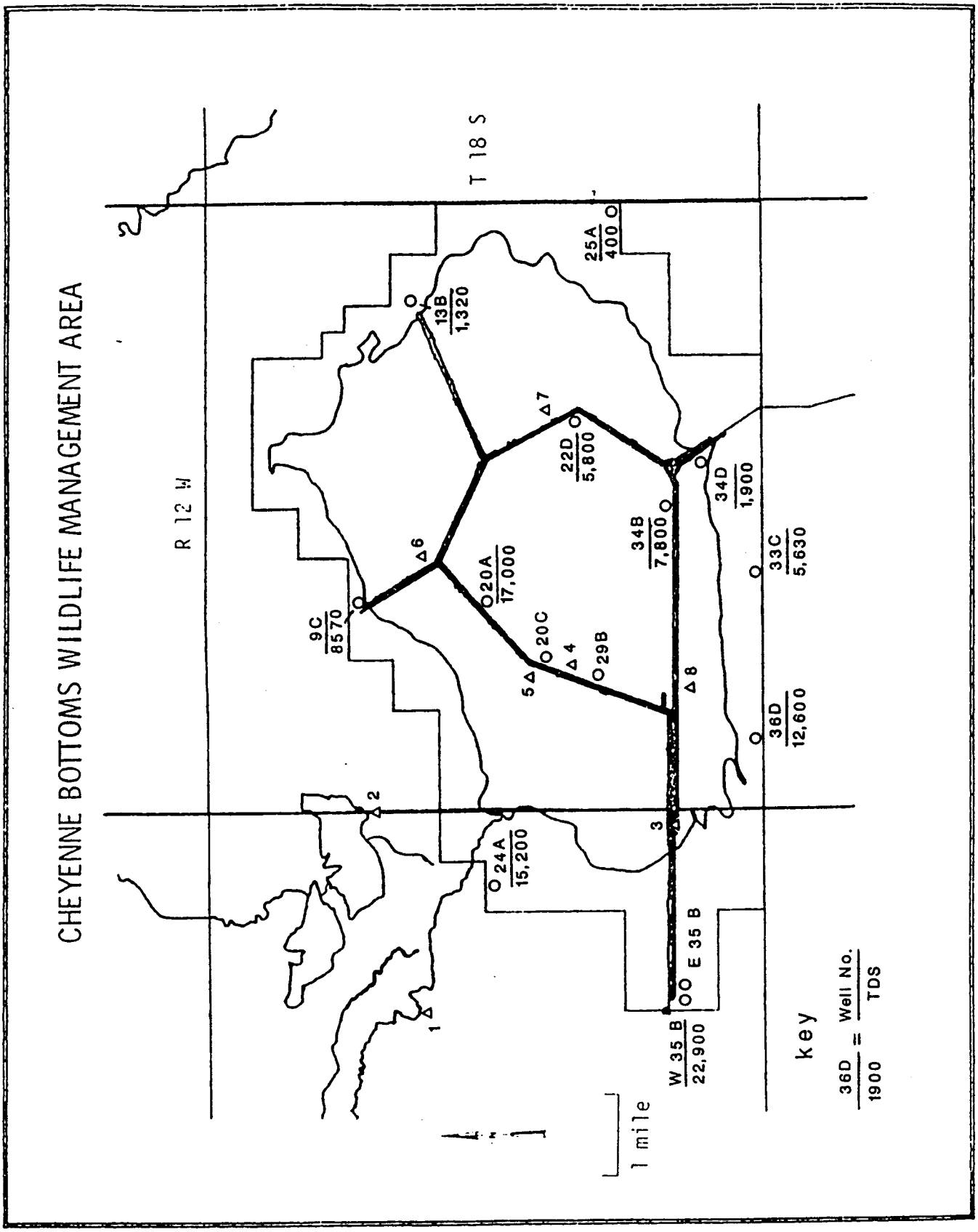


Figure 3.1 Groundwater (O) and surface water (Δ) quality sampling sites established in November 1985. Surface quality site #1 is for Blood Creek while #2 is located on Deception Creek. TDS is in mg/L for 15 foot wells.

Table 3.1-Site description and water quality for ground-water samples in Cheyenne Bottoms study area.

Site	Location	Well depth (ft)	Geol. unit	Sample date	Sp.C., lab umho/cm	pH, field	pH, lab	TDS mg/L	Water type
GW-9C	18S-12W-09CBBB	15	Alluvium	85-11-18	11800		7.8	8570	Na-SO4,Cl
GW-9C	18S-12W-09CBBB	15	Alluvium	86-05-22	11900	8.50	7.60	8580	Na-SO4,Cl
GW-13B	18S-12W-13BBCB	15	Alluvium	86-05-22	2130	7.20	7.85	1319	Na-HCO3,SO4
GW-20A	18S-12W-20ACAA	15	Alluvium	86-05-22	26700	7.25	7.50	17000	Na-Cl
GW-22D	18S-12W-22DDDD	15	Alluvium	85-11-18	9100		7.9	5960	Na-Cl,SO4
GW-22D	18S-12W-22DDDD	15	Alluvium	86-05-22	8680	6.80	7.85	5620	Na-Cl,SO4
GW-24A	18S-13W-24ABBB	15	Alluvium	85-11-18	24200		7.1	15330	Ca,Na-Cl
GW-24A	18S-13W-24ABBB	15	Alluvium	86-05-22	24000	6.75	7.05	15060	Ca,Na-Cl
GW-25A	18S-12W-25ADDD	18	Dune sand	85-11-18	831		7.9	399	Ca,Na-HCO3
GW-29B	18S-12W-29BCAD	72	Alluvium	85-11-19	11500		7.4	6320	Na-Cl
GW-29B	18S-12W-29BCAD	72	Alluvium	86-05-22	11100	7.15	7.40	6360	Na-Cl
GW-34B	18S-12W-34BBBB	15	Alluvium	85-11-19	14100		7.4	8500	Na-Cl
GW-34B	18S-12W-34BBBB	15	Alluvium	86-05-22	11300	6.70	7.35	7040	Na-Cl
GW-34D	18S-12W-34DBAD	15	Alluvium	85-11-18	2750		8.0	1558	Na-Cl
GW-34D	18S-12W-34DBAD	15	Alluvium	86-05-22	3420	6.80	8.00	2090	Na-Cl
GW-33C	18S-13W-33CCCC	15	Alluvium	85-11-18	9300		7.6	5620	Na-Cl
GW-33C	18S-13W-33CCCC	15	Alluvium	86-05-22	9090	6.75	7.55	5630	Na-Cl
GW-E35B	18S-13W-35BBBC-East	8	Alluvium	85-11-19	38500		7.5	24600	Na-Cl
GW-W35B	18S-13W-35BBBC-West	15	Alluvium	85-11-19	35500		7.4	22900	Na-Cl
GW-E35B	18S-13W-35BBBC-East	8	Alluvium	86-05-22	37300	6.85	7.30	24700	Na-Cl
GW-36D	18S-13W-36DDDD	15	Alluvium	85-11-18	18100		7.4	11700	Na-Cl
GW-36D	18S-13W-36DDDD	15	Alluvium	86-05-22	20100	8.25	7.50	13380	Na-Cl

Table 3.2-Site description and water quality for surface-water samples in Cheyenne Bottoms study area.

Site	Location	Site name	Sample date	Sp.C., lab umho/cm	pH, field	pH, lab	Water temp., deg. C	Dissolved oxygen, mg/L	Turbidity, NTU	TDS mg/L	Water type
1	18S-13W-15ADAA	Blood Creek	85-11-19	1980	8.3	8.1	1.8	9.0	2.2	1225	Ca-HCO3
1	18S-13W-15ADAA	Blood Creek	86-04-24	1580	8.4	8.1	21	7.4		916	Ca-Cl,HCO3
2	18S-13W-13AAAA	Deception Creek	85-11-19	555	8.5	7.4	1.5	8.8	24.0	319	Ca-HCO3,Cl
2	18S-13W-13AAAA	Deception Creek	86-04-24	1550	8.5	8.1	21	7.7		875	Ca,Na-Cl
3	18S-13W-36AAAB	Inlet canal	85-11-19	1360	8.6	7.6	3.0	14.4	33.0	749	Na,Ca-Cl
3	18S-13W-36AAAB	Inlet canal	86-04-24	12500	8.2	7.65	23	8.1		8060	Na-Cl
4	18S-12W-29BABD	Pool 1	85-11-19	4700	8.3	7.8	1.5	10.8	15.5	2760	Na-Cl
4	18S-12W-29BABD	Pool 1	86-04-24	7600	8.2	8.1	22	7.6		4570	Na-Cl
5	18S-12W-20CABA	Pool 2	85-11-19	3290	8.1	8.0	0	12.8	68.0	1947	Na-Cl
5	18S-12S-20CABA	Pool 2	86-04-24	8360	8.4	8.0	24	7.8		5150	Na-Cl
6	18S-12W-16ACCB	Pool 3	85-11-19	4000	7.8	8.2	0	14.8	34.5	2410	Na-Cl
6	18S-12W-16ACCB	Pool 3	86-04-24	10400	8.3	8.0	22	7.4		6680	Na-Cl
7	18S-12W-22DADC	Pool 4	85-11-19	3620	8.1	8.0	0	>15	12.0	2100	Na-Cl
7	18S-12W-22DADC	Pool 4	86-04-24	13700	8.5	7.85	25	8.4		8690	Na-Cl
8	18S-12W-32BBAD	Pool 5	85-11-19	3130	8.4	8.0	0	13.4	57.0	1806	Na-Cl
8	18S-12W-32BBAD	Pool 5	86-04-24	12100	8.5	7.8	25	10.3		7650	Na-Cl

Table 3.3-Dissolved-constituent concentrations (in mg/L) in ground waters in Cheyenne Bottoms study area.

Site	Alka-linity as CaCO3	Total hardness as CaCO3	SiO2	Ca	Mg	Na	K	HCO3	SO4	Cl	NO3 (as N)	NH4 (as N)	Ortho-PO4 (as P)	Br
GW-9C	676	1286	50	278	144	2430	<15	825	3630	1630	<0.02	0.2	0.16	2.1
GW-9C	716	1326	44	294	144	2460	<12	874	3630	1580	0.02	0.4	0.10	2.1
GW-13B	457	206	29	53	18	404	<2	558	335	206	0.05	0.2	0.02	0.2
GW-20A	201	4755	13	1120	476	4420	94	246	1450	9310	0.16	0.2	<0.02	5.8
GW-22D	586	989	40	253	87	1740	8.9	715	1960	1520	0.02	0.3	0.23	2.2
GW-22D	577	853	37	215	77	1650	<10	704	1700	1580	0.05	0.2	0.18	2.2
GW-24A	214	8988	80	2840	461	2120	<10	261	1150	8530	5.42	0.5	0.10	5.7
GW-24A	222	8901	38	2820	452	2030	17	271	1110	8440	4.74	0.3	0.15	7.4
GW-25A	232	213	23	70	9.5	58	2.0	283	24	68	1.31	<0.1	<0.03	0.14
GW-29B	188	1439	18	293	172	1780	16	230	384	3540	0.02	2.7	<0.03	0.72
GW-29B	192	1486	21	307	175	1810	31	235	395	3510	0.05	2.3	<0.02	1.4
GW-34B	524	1938	45	445	201	2460	50	639	1070	3960	<0.02	0.3	0.03	3.7
GW-34B	620	1428	39	338	142	2000	50	756	1060	3040	0.02	0.5	0.04	3.7
GW-34D	412	289	30	78	23	464	<2	503	215	501	<0.02	0.2	0.23	0.70
GW-34D	418	456	27	122	37	591	13	510	317	734	0.02	0.2	0.13	1.0
GW-33C	404	1328	38	344	114	1520	5.7	493	1030	2330	0.02	0.2	<0.03	1.9
GW-33C	430	1407	33	374	115	1480	22	525	1060	2290	0.05	0.2	<0.02	2.2
GW-E35B	397	8440	36	1900	898	5980	<20	485	2260	13300	<0.02	0.2	<0.03	17.0
GW-W35B	276	8533	34	1980	872	5270	<20	337	2110	12460	<0.02	0.2	<0.02	16.4
GW-E35B	404	8437	28	1930	879	5830	13	493	2230	13500	0.02	0.2	0.08	19
GW-36D	327	4280	40	979	446	2540	6.4	399	2120	5370	<0.02	0.2	<0.03	5.7
GW-36D	354	5190	34	1220	521	2820	18	432	2210	6350	0.02	0.2	<0.02	8.0

Table 3.4-Dissolved-constituent concentrations (in mg/L) in surface waters in Cheyenne Bottoms study area.

Site	Alka-linity as CaCO3	Total hardness as CaCO3	SiO2	Ca	Mg	Na	K	HCO3	SO4	Cl	NO3 (as N)	NH4 (as N)	Ortho-PO4 (as P)	Br
1	514	714	30	235	31	149	11	627	235	226	<0.02	<0.1	0.33	0.61
1	283	545	6.1	174	27	119	16	346	153	251	0.02	0.2	0.18	0.18
2	114	170	19	57	6.9	41	9.1	140	52	66	0.02	0.2	0.62	0.05
2	226	445	11	147	19	138	19	276	119	286	0.14	0.2	0.52	0.06
3	151	308	5.5	89	21	141	13	185	155	234	0.05	<0.1	<0.03	0.22
3	99	2962	8.6	756	261	1740	44	121	1880	3310	0.09	0.2	0.02	2.5
4	228	714	16	174	68	680	44	278	551	1090	0.05	0.9	0.20	0.94
4	161	1165	18	277	115	1170	50	197	1020	1820	0.07	0.2	0.03	1.8
5	223	633	18	173	49	423	22	273	449	679	0.04	0.1	0.20	0.56
5	136	1660	21	426	145	1160	45	166	1230	2040	0.06	0.2	0.02	1.1
6	233	722	15	197	56	552	27	285	542	879	<0.02	0.1	0.26	0.56
6	132	1952	13	492	176	1600	46	161	1610	2660	0.02	0.2	0.04	1.4
7	208	631	12	169	51	483	22	254	454	787	<0.02	0.1	0.20	0.57
7	133	2456	9.8	598	234	2170	64	163	1870	3660	0.11	0.2	0.08	2.0
8	199	574	18	156	45	406	19	243	392	651	<0.02	0.1	0.20	0.46
8	118	2632	12	662	238	1710	48	145	1650	3260	0.11	0.2	<0.02	2.6

RESULTS AND DISCUSSION

GROUND-WATER CHEMISTRY

The freshest ground water encountered in the well sites is from the sand dunes to the east of the wetland. This water contains less than 500 mg/L total dissolved solids (TDS), the recommended level for drinking water (table 3.1). The ground waters are fresh due to rapidly infiltrating precipitation, ground-water flow away from the zone of rapid infiltration, and relatively insoluble minerals comprising the bulk of the dunes. The chemical water type for this site is Ca,Na-HCO_3 mainly reflecting solution of calcite in the sediment.

Ground waters sampled from alluvium in the study area range from slightly saline (1000-3000 mg/L total dissolved solids [TDS]) to very saline (greater than 10,000 mg/L TDS; table 3.1). The ground waters with the highest TDS concentrations are in the western and southwestern part of the Bottoms, while the waters in alluvium with the lowest TDS are in the eastern part of the Bottoms. Based on two samples from depths appreciably greater than 15 feet (GW-20C and GW-29B) near a 15-foot-deep well (GW-0A) and the 8- and 15-foot-deep wells at GW-35B, the TDS values are higher at shallower depths. Most of the alluvial sites have waters of Na-Cl type, although SO_4 is high enough at some locations that the waters range to Na-SO_4,Cl type. The HCO_3 in ground waters at many alluvial sites is relatively high (approximately 500 mg/L and above; table 3.3) resulting in Na-HCO_3,SO_4-type water at site GW-13B. The water at site GW-24A has an unusually high Ca content and is Ca,Na-Cl in type.

The major constituent chemistry of the ground waters is also displayed graphically on trilinear diagrams in figs. 3.2 and 3.3. The cation diagram suggests that ion exchange on clays in the alluvial sediments could be controlling the differences in the relative amounts of Ca, Mg, and Na

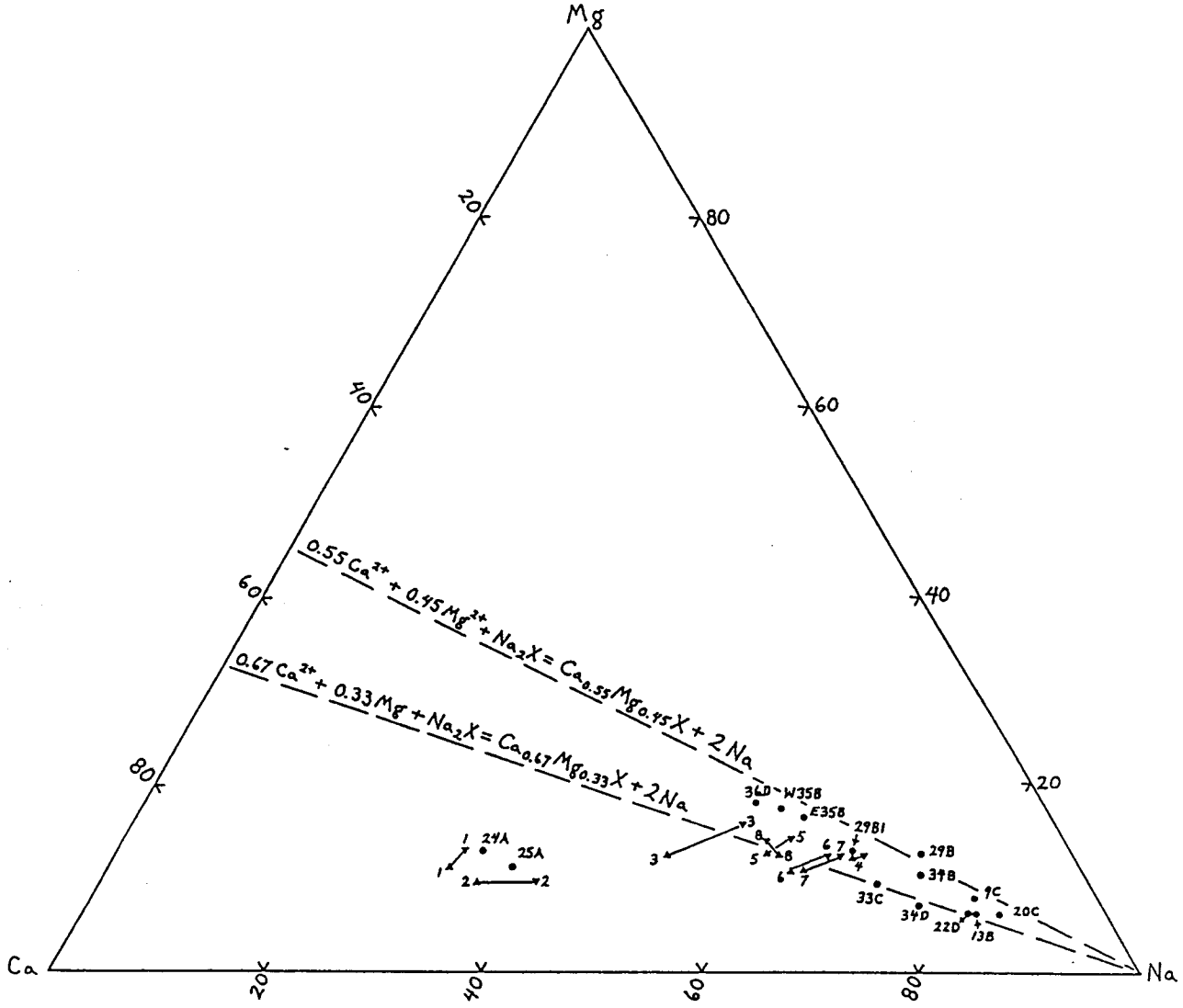


Figure 3.2 Ternary Diagram of Major Cations in Water Samples from the Cheyenne Bottoms Study Area. Individual points are labeled with site numbers. Dashed lines represent the path of simple ion-exchange equations as labeled, where X represents a clay-exchange site. Legend: ● Ground water, single sample or average of two samples; ▲ Surface water, collected November, 1985; ▼ Surface water, collected April, 1986.

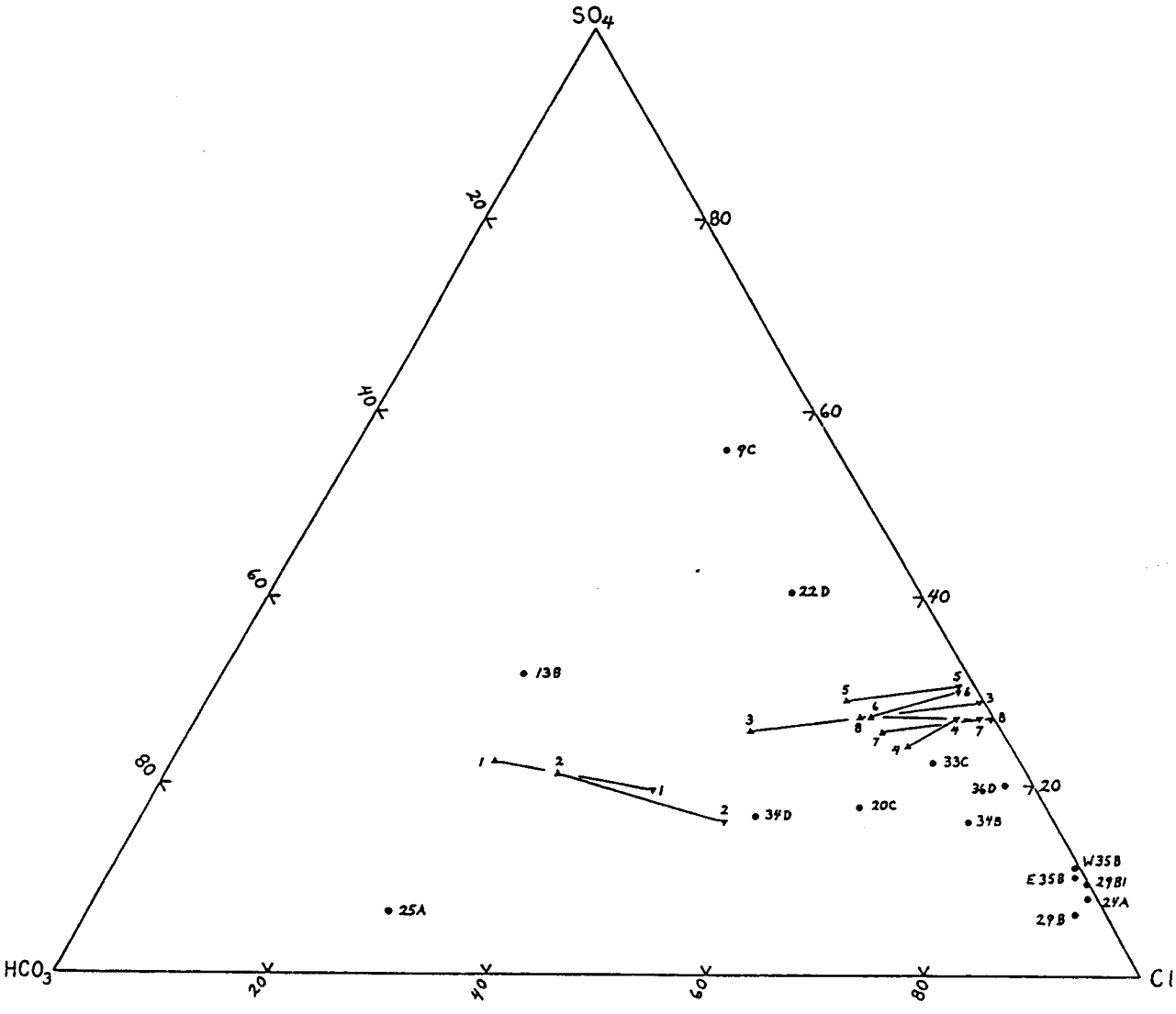


Figure 3.3 Ternary Diagram of Major Anions in Water Samples from the Cheyenne Bottoms Study Area. Individual points are labeled with site numbers. Legend: ● Ground water, single sample or average of two samples; ▲ Surface water, collected November, 1985; ▼ Surface water, collected April, 1986.

concentrations (fig. 3.2). The dashed lines in the diagram represent the zone of expected water types if simple ion exchange of Ca and Mg for Na occurs with ratios of Ca/Mg (in equivalents) in the range of 1.2-2.0 (or 2-3.3, if expressed as weight ratios) as observed for most of the alluvial waters. The points representing the ground waters are more widely separated in the anion diagram (fig. 3.3). In general, the anion patterns are produced by the wide range in the relative amounts of Cl and SO_4.

The chemistry of the ground waters is also largely controlled by calcite and gypsum equilibria. The solubility of calcite limits both the Ca and HCO_3 concentrations in probably all the ground waters, while the solubility of gypsum probably limits SO_4 as well as Ca concentrations in all of the shallow (less than 15 feet) alluvial waters in the western part of the Bottoms (sites 24B, E35B, W35B, 9C, 20A, and 36D).

Mixing diagrams based on Br and Cl concentrations can be used to assist in the identification of salinity sources. Most of the ground waters from the Bottoms area have Br/Cl ratios that place the waters above the typical mixing zone for freshwaters and halite-solution brines in Kansas (fig. 3.4). Saltwaters in the Permian bedrock and overlying alluvium in the northeastern part of the Great Bend Prairie to the south of the Arkansas River and two samples of water from the Dakota Formation several miles south of the Bottoms (shown on fig. 3.4) fall within this mixing zone of halite-solution sources of salinity. The deepest sample of ground water from the alluvium in the Bottoms had the lowest Br/Cl ratio of any of the ground-water samples collected from the Bottoms.

Formation waters in deep strata in Kansas (often associated with petroleum) generally have appreciably higher Br/Cl ratios than observed for the waters in the Bottoms alluvium. However, the source of part of the

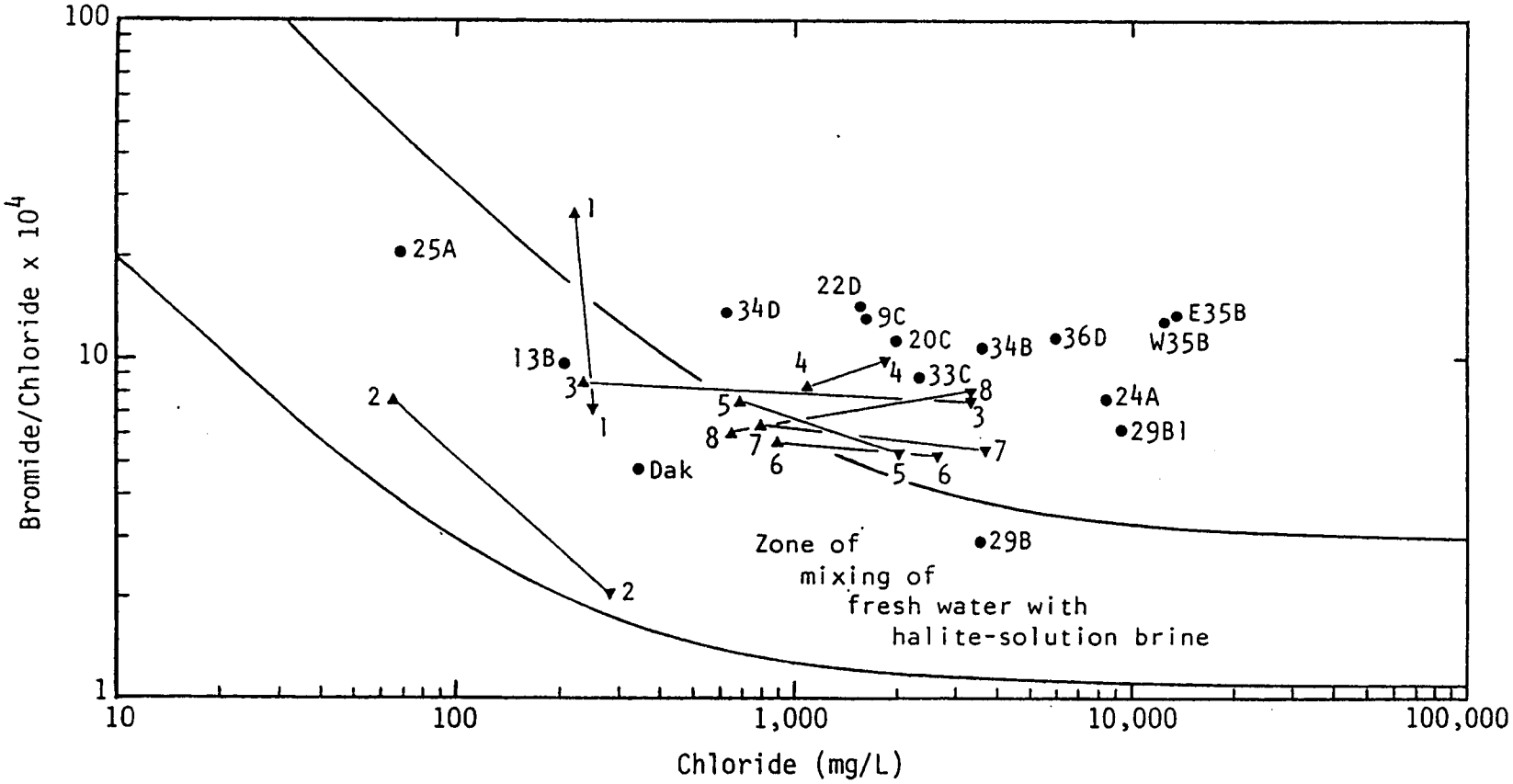


Figure 3.4 Weight Ratio of Bromide/Chloride Versus Chloride Concentration for Waters from the Cheyenne Bottoms Study Area. Individual points are labeled with site numbers. The point labeled "Dak" is for two samples from a monitoring well in the Dakota Formation between Great Bend and Ellinwood. The two curves are the boundaries of the mixing zone of fresh water with halite-solution brine for ground waters in the Great Bend Prairie. Legend: ● Groundwater, single sample or average of two samples; ▲ Surface water, collected November, 1985; ▼ Surface water, collected April, 1986.

salinity in the Bottoms ground waters is not thought to be a mixture of some of this deep-formation brine with shallower halite solutions, because the dissolved solids concentrations and Br/Cl ratios are higher at the shallow than the deeper depths in the alluvium. Although there is the possibility that oil-field brines from petroleum exploration or production may have entered the Bottoms area in surface runoff in the historical past, the effect of this is not expected to have been important. This is based on the relatively narrow range of Br/Cl. If oil-field brines were important, higher Br/Cl ratios would be expected in some of the ground waters, especially at site GW-24A near the general area where Blood Creek waters are expected to spread across the Bottoms during very high runoff periods.

The origin of salinity in the shallow ground waters is probably derived from the concentration of dissolved salts by evapotranspiration. Tens of thousands of years ago, the climate was more moist and more surface runoff reached the Bottoms area. (See chapter 2 of this report.) Since that time, the climate has become progressively drier so that today there is generally not enough runoff in the creeks entering the Bottoms to actually reach the managed pools in the center of the Bottoms. (See chapter 6 of this report.) In the last 10,000 years, most of the Bottoms surface was probably dry except during extended periods of atmospheric precipitation. Any runoff reaching the Bottoms and creating extensive pools would have evaporated during dry spells and left salt crusts on the surface and saline waters in the soils. During dry periods, evapotranspiration by plants could further concentrate shallow ground waters. Infiltrating rain water following dry spells could leach soluble salt crusts on the surface and carry these salts to the shallow subsurface. The higher TDS concentrations in the shallow ground waters in the western part of the Bottoms are probably derived from the greater amount of

runoff that has entered and evaporated in this area in the past, thereby providing a larger influx of salts.

One ground water (at site 24A) has an unusual composition (consistent in the samples collected in both November and May) in comparison with the other ground waters in the alluvium. The Ca content of this sample is very high and the NO_3 content appreciably higher than the other ground waters. The major constituent composition suggests that a source similar to saltwaters in deep formations such as oil-field brines might be important. These saltwaters generally have relatively low Na/Cl and high Ca/Na ratios in comparison with halite-solution brines. They also often contain several to tens of mg/L of NH_4 that can be oxidized in surface conditions to NO_3. However, the Br/Cl ratios for the two samples from this site are much lower than would be expected if typical oil-field brines in Kansas had contributed a major portion of the salinity (fig. 3.4). Another possible cause for the chemistry of this water could be the result of the concomitant processes of reduction of SO_4 and solution of gypsum in the sediment (as a result of lower SO_4 concentrations) causing increases in Ca values.

Dissolved nutrient concentrations (NO_3, NH_4, and ortho-PO_4) were very low (less than 1 mg/L) in all of the ground waters except at sites 24A, 25A, 29B, and 20A. Values for NO_3 were low to moderate at sites 25A and 24A, respectively, but still well below the drinking-water standard of 10 mg/L as N (45 as NO_3). Dissolved NH_4 concentrations were a few mg/L at sites 29B and 20A located at the western boundary of Pool 1. Trace-metal concentrations were determined in one ground-water sample collected from a site (36D) that is approximately 1 1/2 miles to the north and downgradient from the Great Bend sanitary landfill (table 3.5). The levels of dissolved trace metals were all low in this sample (and much less than primary or secondary standards for

Table 3.5-Dissolved trace-metal concentrations (in ug/L) in water samples in Cheyenne Bottoms study area.

Site	As	Cd	Cr	Cu	Pb	Ni	Se	Ag	Zn
				Ground Water					
GW-36D	0.3	1.2	0.2	0.6	1.3	11	0.6	<0.1	6.8
				Surface Waters					
1	2.6	1.3	3.8	1.0	0.2	2.0	<0.1	<0.1	13
1	7.8	1.6	0.4	80	1.0	110	<0.1	0.1	30
2	4.2	1.0	0.5	2.8	<0.1	1.9	0.3	0.1	7.8
2	9.1	10	0.9	87	17	17	<0.1	<0.1	4800
3	1.3	0.5	1.8	3.0	0.1	0.8	0.3	0.1	18
3	1.2	9.1	1.0	47	12	34	0.1	<0.1	146
4	2.5	0.3	0.2	1.2	0.6	2.0	0.2	<0.1	47
4	6.4	2.3	0.8	45	1.0	21	<0.1	<0.1	14
5	6.8	<0.1	0.9	4.9	6.2	1.6	<0.1	0.4	14
5	11	1.7	0.9	33	8.0	52	<0.1	0.2	38
6	6.9	1.3	0.4	2.0	2.9	3.4	<0.1	0.1	3.9
6	9.5	1.3	0.4	15	<0.1	16	<0.1	<0.1	3.0
7	5.8	1.5	0.8	2.0	2.0	3.0	0.4	0.1	18
7	9.9	3.1	0.7	37	13	28	<0.1	<0.1	38
8	8.1	0.6	0.1	2.8	2.1	4.1	0.3	0.2	17
8	5.2	1.9	0.6	3.0	3.0	22	1.1	<0.1	16

these metals for drinking-water use). An ancillary study of the ground waters in the landfill area indicates that the landfill has contaminated ground waters in the immediate vicinity of the landfill, but has probably not affected the quality of ground waters in the Bottoms area. The main indicator of contamination in ground water at the landfill is the presence of volatile organic chemicals. (See chapter 11 on landfill in this report.)

SURFACE-WATER CHEMISTRY

The quality of surface waters in the pools of the Cheyenne Bottoms ranges from slightly saline to moderately saline depending on the location and the time of sampling (table 3.2). The chemical type of all the pool waters collected was Na-Cl. Waters entering the Bottoms area in Blood and Deception creeks had TDS concentrations much lower than in the pools and were either fresh or just slightly saline. The predominant cation of the creek waters was Ca, while the predominant anion was either HCO_3 or Cl, depending on the sampling period (Table 3.4). The inlet canal samples ranged from fresh to moderately saline, with Na and Cl as the predominant ions.

The variation in the TDS concentrations between the two sampling periods was as large as the range (table 3.2). Dissolved-solids values were much higher in the April 1986 samples than the November 1985 samples. The large variation was due to both substantial differences in rainfall in the Bottoms watershed and to pool management preceding the two collection dates. Rainfall for the Bottoms area was estimated as the average of the observations at Great Bend to the southwest and at Claflin to the northeast of the wetland. The 4 1/2 months preceding the November sampling were relatively wet, with between 14 and 15 inches of rainfall falling over the Bottoms watershed, an amount approximately 3 inches over the normal for that period. About 4.6 inches of the 14-15 inches fell in the month and one-half before the collection date.

This latter precipitation would have been less susceptible to evapotranspiration than earlier precipitation. The five-month interval between the November and April sample dates was comparatively dry, with only about 4-5 inches of precipitation, a departure of 1.5 inches below the normal for that time. Thus, evapotranspiration seems to have been very important in concentrating the dissolved solids during the drier period.

The range in TDS contents for the pool waters at the November sampling (1,810-2,760 mg/L) was much smaller than that for April (4,570-8,690 mg/L). Although Pool 1 had the highest TDS concentration in November, its TDS increased the least during this time (table 3.2) due to larger amounts of water that buffered concentration by evapotranspiration losses. Pool 1 was nearly completely covered by water throughout the period both before and between the two sampling dates, although the water level was at least several inches lower (due to evapotranspiration losses) in April. The dissolved-solids concentration in Pool 2 increased more than in Pool 1, but less than in Pools 3-5. Pools 2 and 5 were full through the summer of 1985, then the level dropped as a result of diversions to other pools. By April, only remnants of Pools 2 and 5 were present as caused by evapotranspiration. The lower TDS concentration of Pool 2 than of Pool 5 may have been due to the greater amount of water that entered Pool 2 from the inlet canal. Pools 3 and 4 were nearly dry until October 1985, when water was diverted to them from Pools 1, 2, and 5. This water then became well concentrated as both were nearly dry at the April collection date.

During the same interval, the TDS contents of the two creeks sampled also changed, although not nearly as great as any of the pool waters. Although the TDS content in Blood Creek decreased from November to April, the Cl content increased (table 3.4). The decreases were primarily in the Ca, Na, HCO_3, and

SO_4 concentrations. In contrast, all of the major dissolved constituents increased in concentration at the Deception Creek sampling site. This suggests differences in the flow and source chemistry for these two creeks. The inlet canal had the greatest change in TDS content of any of the sampling sites. During active inflow, water in the canal was fresh, but became quite saline from evaporative concentration when it was allowed to sit stagnant when inflows were no longer available from the Arkansas River or Walnut Creek.

Five water samples were collected from the aqueduct-canal system carrying water from the Arkansas River to the Cheyenne Bottoms to determine quality changes during water transit. A sixth sample was taken from Walnut Creek approximately 6 miles (channel distance) upstream of the aqueduct inlet to the creek. The samples were all collected on October 8, 1986, in the order listed in table 3.6. In general, the total-dissolved-solids contents (as indicated by the specific-conductance measurements) and the major anion concentrations all decreased from the diversion dam at the Arkansas River to the outlet into the Bottoms pools. This decrease mainly reflected the increasing age of the water in the aqueduct-canal system as related to changes in the Arkansas River water quality with time. Several days before the sample collection, thunderstorms over the Pawnee River valley to the west had produced storm flows that increased the flow of the Arkansas River at the diversion dam south of Dundee. Higher flows in rivers are usually more dilute in major constituent concentrations than low flows. Thus, the water entering the aqueduct-canal system just before the sample collection was from the decreasing-discharge side of storm runoff, during which dissolved-solids concentrations in the discharge would be expected to increase.

The length of the aqueduct-canal system is approximately 23 miles, giving a water-transit time of about 1 1/2 days for an average-estimated flow

Table 3.6-Quality of surface waters collected on October 8, 1986, from the aqueduct-canal system carrying water from the Arkansas River to Cheyenne Bottoms.

Site	Location	Site description	Water temp., deg. C	Sp.C., lab, umho/cm	pH, lab	HCO3, mg/L	SO4, mg/L	Cl, mg/L
C1	18S-12W-31AAAA	Inlet canal in Cheyenne Bottoms at junction of Pools 1,2, and 5	21	436	8.1	155	52	20
C2	18S-13W-33AAAD	Drop structure in canal where it enters the Cheyenne Bottoms basin	20	530	8.1	176	74	27
C3	19S-13W-09ABBB	At Wet Walnut diversion dam just before water enters the canal	20	532	8.1	178	76	28
C4	18S-14W-33DDDD	Wet Walnut Creek six miles upstream of canal inlet	21	245	8.1	125	11	5.7
C5	19S-14W-21BCBB	Dry Walnut Creek just below the canal inlet	21	697	8.2	208	111	42
C6	20S-14W-20DBD	Arkansas River diversion dam just before entering the aquaduct	23	738	8.2	215	119	48

velocity of 2 ft/sec (based on a few flow measurements in the canals). Therefore, water entering the pools was over a day older and reflected more dilute source water in the Arkansas River than the Arkansas River sample listed in table 3.6. Although most of the volume of the canal waters leaving the Walnut Creek diversion dam was derived from the Arkansas River, the small volume of the more dilute waters input from Walnut Creek (represented by site-C4 water in table 3.6) further decreased the dissolved-solids contents. These results indicate that if samples are taken during the summer to determine water-quality changes from evapotranspiration losses along the canals, they must be corrected for changes in water chemistry with flow of the Arkansas River and Walnut Creek sources. This involves either collection at staggered times adjusted for travel in the system starting first at the Arkansas River diversion dam, or collection of a series of samples from the Arkansas River and Walnut Creek sources during the two days preceding the sampling.

Dissolved NO_3 and NH_4 concentrations were generally low (less than 0.3 mg/L as N) in all the surface-water samples except in Pool 1 in November, which had an NH_4-N level of 0.9 mg/L (table 3.4). This water was only about 0.3 mile to the northeast of ground-water site GW-29B and 1.3 miles to the southwest of site GW-20A which also had the highest NH_4 of the ground-water samples. Concentrations of dissolved ortho-PO_4 (less than 0.7 mg/L as P) were generally within the range of typical Kansas river waters. As a whole, the ortho-PO_4 levels decreased from the November to the April sampling. Changes in the NO_4 and NH_4 during this period were not as marked; NO_3 levels increased slightly, while, except for one sample, the variation in NH_4 concentrations was on the order of the analytical error.

Dissolved concentrations of all trace metals except Zn were low in all the surface-water samples (table 3.5). Dissolved Zn was low in all samples

except two, Deception Creek and the inlet canal in April. The Deception Creek sample of April 24, 1986, was obtained from a large pool directly below a galvanized road culvert during a period when Deception Creek had become intermittent. Leaching of Zn from the culvert could explain this high stream value. This side of the culvert was sampled due to difficulties in accessing the other side. In general, concentrations of As, Cd, Cu, Pb, Ni, and Zn increased with the increases in dissolved solids from the November to the April sampling.

A summary of the most current U.S. Environmental Protection Agency criteria for priority metals for the protection of freshwater aquatic life (Federal Register, November 28, 1980, and July 29, 1985) is shown in table 3.7. Many of the criteria depend on hardness concentrations in the water. Table 3.7 includes the appropriate metal criteria for the hardness of each surface-water sample collected from the Bottoms. The Cr criterion listed in this table is for Cr (VI), the most toxic form of Cr. As no criteria exist for total Cr which include all three forms of Cr, the criterion for only Cr (VI) is listed. No total Cr concentrations determined in the water samples exceed the 11 µg/L criterion for hexavalent Cr; thus, the measured values are assumed to be safely within concentrations necessary to protect aquatic life. The expressions relating hardness to the various metals criteria are shown at the bottom of table 3.7. All water-quality criteria in this table for metals other than Cr are total-dissolved concentrations.

A comparison of tables 3.5 and 3.7 indicates that in only one instance does a metal concentration exceed the recognized metal criteria. The Zn value at site 2 (Deception Creek) on April 24, 1986, exceeded the recommended criterion by more than four times. Other than this single, anomalous value, all measured metal concentrations in the surface waters within the Cheyenne

TABLE 3.7.-Total hardness values (mg/L $CaCO_3$) for Cheyenne Bottoms study sites and corresponding water-quality criteria for metals (µg/L) for protection of freshwater aquatic life.

Site	Site #	Date	Total hardness	Metals criteria								
				Arsenic[a]	Cadmium[b] (VI)	Chromium[a]	Copper[b]	Lead[b]	Nickel[b]	Selenium[a]	Silver[b]	Zinc[b]
Blood	1	11-19-85	714	190	5.3	11	63.5	38.8	425	35	119.3	1642
Creek	1	4-24-86	545	"	4.3	"	50.4	27.5	347	"	75.0	1312
Deception	2	11-19-85	170	"	1.7	"	18.6	6.3	143	"	10.1	499
Creek	2	4-24-86	445	"	3.7	"	42.4	21.3	297	"	52.9	1109
Inlet	3	11-19-85	308	"	2.7	"	31.0	13.4	225	"	28.1	817
Canal	3	4-24-86	2962	"	16.2	"	214.4	234.8	1255	"	1379.0	5349
Pool 1	4	11-19-85	714	"	5.3	"	63.5	38.8	426	"	119.3	1642
	4	4-24-86	1165	"	7.8	"	96.6	72.1	618	"	277.0	2465
Pool 2	5	11-19-85	633	"	4.8	"	57.3	33.3	388	"	97.0	1486
	5	4-24-86	1660	"	10.3	"	130.7	112.8	808	"	509.3	3308
Pool 3	6	11-19-85	722	"	5.4	"	64.2	39.3	429	"	121.6	1658
	6	4-24-86	1952	"	11.7	"	150.1	138.5	914	"	673.0	3784
Pool 4	7	11-19-85	631	"	4.8	"	57.2	33.2	388	"	96.5	1482
	7	4-24-86	2456	"	14.0	"	182.7	185.3	1089	"	999.1	4563
Pool 5	8	11-19-85	574	"	4.5	"	52.7	29.4	361	"	82.0	1370
	8	4-24-86	2632	"	14.8	"	193.8	202.2	1148	"	1125.0	4850

[a]Criteria independent of hardness
Arsenic: 4-day average
Chromium (VI): 4-day average
Selenium: 24-hour average

[b]Criteria related to water hardness
Cadmium: exp [0.7852 (ℓn (hardness)) -3.49]; 4-day average
Copper: exp [0.8548 (ℓn (hardness)) -1.465]; 4-day average
Lead: exp [1.266 (ℓn (hardness)) -4.661]; 4-day average
Nickel: exp [0.76 (ℓn (hardness)) +1.06]; 30-day average
Silver: exp [1.72 (ℓn (hardness)) -6.52]; maximum at any time
Zinc: exp [0.83 (ℓn (hardness)) +1.95]; maximum at any time

Bottoms are well within the recommended criteria for the protection of aquatic life.

Although Pb concentrations were too low to be a concern, they seem to vary among pools in a pattern suggesting that spent shotgun shot might be a major source. Hunting is normally allowed at Pools 2, 3, and 4. Pool 1 has been closed to hunting since its formation. Pool 5 is closed to most hunting, but it is sometimes open during teal season. The "firing line" in upland areas on the south side of Pool 5 may contribute some shot to this pool. In November, Pool 2 had by far the highest Pb concentration, and Pool 1 the lowest. Pools 3 and 4 had been kept dry until approximately one month before the November sampling date, then were flooded with water diverted from Pools 1, 2, and 5. The pH and the concentration of HCO_3 are high enough in all samples that the dissolved inorganic Pb would be kept below the criteria by precipitation of Pb carbonate minerals even if there were abundant shot present. However, organic complexes possibly might be able to increase the Pb concentration above the criteria; thus, the presence of the correlation with the expected shot abundance is worth noting.

Ratios of Br/Cl in the pool and inlet canal samples have a comparatively small range given the large range in Cl concentrations (fig. 3.4). As a group, these waters have lower ratios than those for the shallow ground waters in the Bottoms study area. This is evidence additional to the discussion of Br/Cl values for the ground waters that runoff containing oil-field brines has probably not substantially affected the wetland waters. If this was an important contamination source, the Br/Cl ratios would be expected to be higher. The lower ratios in the surface waters than in the shallow ground waters might be due to the influence of the inflow of Arkansas River and

Walnut Creek waters since the start of the management of the Bottoms; the inlet canal waters are in the same range as the pool waters.

SUMMARY AND CONCLUSIONS

The surface water in the pools of Cheyenne Bottoms ranges from slightly to moderately saline, depending on the pool and the amount of water in the pool. Lower salinities are found in the pools with more water and when the water depths in the pools are greater. Loss of water from evapotranspiration greatly concentrates the dissolved-solids concentrations during dry periods.

The salts concentrated in surface waters during dry periods and concentrated in near-surface ground waters by plant transpiration seem to be the main source of salinity in the shallow ground waters rather than a subsurface source. The salinities of the shallow ground waters range from values comparable to the pool waters to a few times those of the pool waters. In general, salinities increase with depth and are higher in the western portion of the Bottoms basin.

Concentrations of metals in the surface waters of the pools are all below criteria for the protection of aquatic-life forms. Lead shot is present in the Bottoms sediments, but the chemistry of the water probably limits the dissolved Pb. Thus, the Cheyenne Bottoms refuge does not have the high-metals problems found in other wetlands in some parts of the United States (such as high Se from irrigation-return flows in the Kesterson Wildlife Refuge of California).

Continued evaporation and concentration of Arkansas River and Walnut Creek waters brought into the Bottoms could slowly increase the salt content of both pool waters and near-surface ground waters underlying the pools. Thus, management of the pools should include flushing of saline water from the pools during exceptionally wet years when there is adequate water available

from the inlet canal to allow appreciable flows out of the Bottoms at the outlet canal.

If sufficient quantities of ground water are available from the dunes area to the east of the pools, they would be a good source for augmenting water supply to the pools, because the dissolved-solids concentrations are low. If the procedure of dredging a pool to increase the water depth is economically viable, the easternmost part of the Bottoms, especially the area of Pool 4, would be the best location because of the lower dissolved solids in the shallow ground waters in comparison to other areas.

CHAPTER 4: ANALYSIS OF SURFACE-WATER AND CLIMATIC DATA FOR CHEYENNE BOTTOMS

Jamshid Sadeghipour and Thomas McClain

PURPOSE AND SCOPE

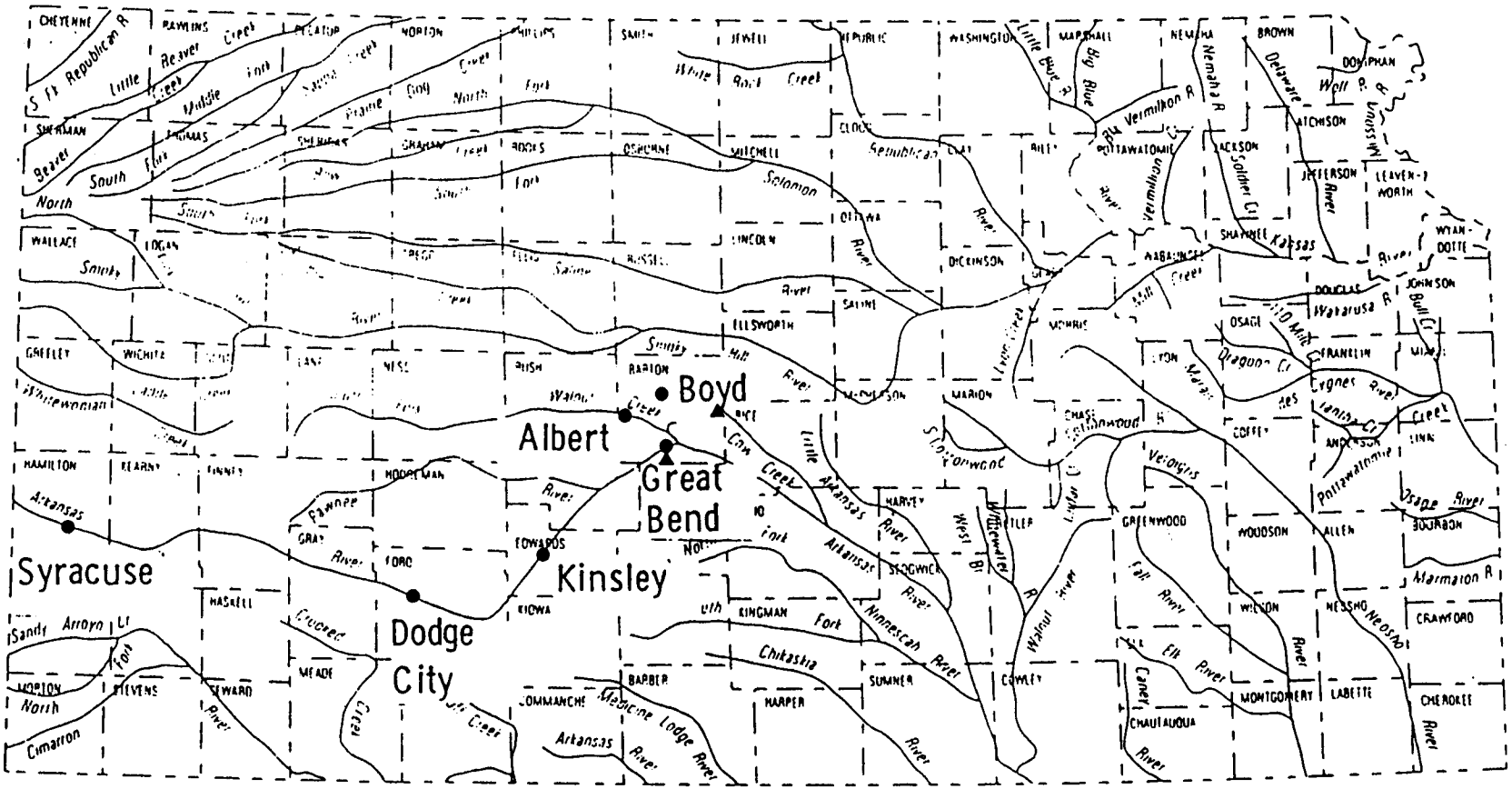
The climatic and streamflow records relevant to the Cheyenne Bottoms will be analyzed to assess the present and future status of water supply in the Bottoms area. Such information is required for the design and implementation of a management plan for control and preservation of water in the Cheyenne Bottoms Wildlife Area.

Our hydrologic analysis involves the appraisal of long-term records of precipitation and streamflow. No attempt was made to analyze the short-term high-flows and low-flows or to estimate the streamflow response to a specific storm event. The report is not meant to be an exhaustive discussion on the hydrology of the area, but a review and summary of generally available data.

SETTING

The Cheyenne Bottoms Wildlife Management Area is located in the Plains Border section of the Great Plains province in Barton County, Kansas (fig. 4.1).

The climate of Cheyenne Bottoms is subhumid continental and is marked by large variations in precipitation and temperature (Latta, 1950). The Bottoms area is generally affected by the moisture-laden air from the Gulf of Mexico and the strong rain-shadow effects of the Rocky Mountains (USCE, 1985). Potential evapotranspiration in the area is determined to be much higher than the average precipitation. The Kansas Water Atlas (KWRB, 1967) shows a mean annual lake-evaporation rate of about 60 inches in the vicinity of the Bottoms.



Blood Creek Near Boyd 07142900
Walnut Creek At Albert 07141900
Arkansas River At Great Bend 07141300
Arkansas River Near Kinsley 07140000
ArKansas River At Dodge City 07139500
Arkansas River At Syracuse 07138000

0 50 100
Scale in miles
0 50 100
Scale in kilometers

● Stream Gaging Station
▲ Precipitation Gaging Station

Figure 4.1 Locations of U.S. Geological Survey Stream Gaging Stations and Precipitation Gages

ARKANSAS RIVER

A stream-gaging station for the Arkansas River at Great Bend (07141300) is located south of town on the downstream side of the bridge on U.S. Highway 291 (fig. 4.1). At this location, the drainage basin of the Arkansas River encompasses approximately 34,356 square miles (88,982 km^2), of which an area of approximatley 6,002 square miles (15,545 km^2) probably does not contribute to streamflow (U.S. Geological Survey, 1984). The water intake to the canal system that transports water to the Bottoms from the Arkansas River is located about 7 miles upstream from this gage.

Records of discharge compiled by the U.S. Geological Survey (USGS) at this station are available for the period September 1940 through September 1984 (see appendix 4.1). Annual discharges are presented in terms of volume of streamflow per water years, i.e. the total flow volume for the period from October of the previous year through September of the water year. The recorded discharges are affected by water diversions for the Bottoms. The average annual-flow volume at the gaging station for 44 complete years of record is 224,000 acre-feet/year. About 54% of this annual flow occurs in the five-month period, April through August (see table 4.1). The maximum annual-flow volume was 1,133,000 acre-feet in 1942, and the minimum annual-flow volume was 4,300 acre-feet in 1984. The maximum monthly flow volume was 371,800 acre-feet and occurred in May 1942. The minimum monthly flow volume was 8 acre-feet and occurred in August 1946. A plot of annual flows versus time for the Arkansas River at Great Bend for the period 1941-1984 is shown in fig. 4.2. Table 4.1 summarizes monthly streamflows as a percent of the annual streamflow in the Arkansas River.

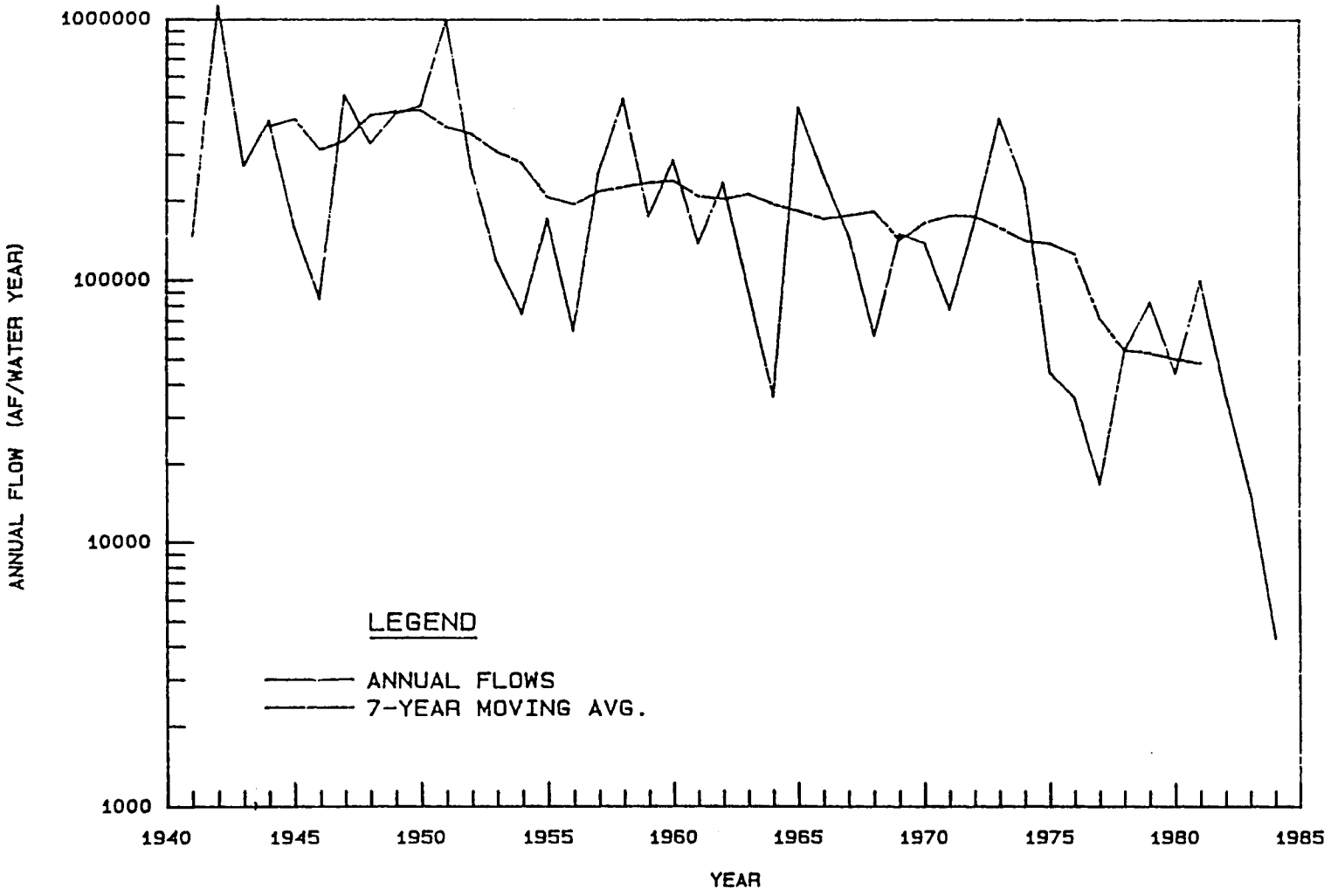


Figure 4.2 Annual Flows for the Arkansas River at Great Bend

Table 4.1-Monthly streamflow as a percent of total annual streamflow-Arkansas River.

Month														Total years of record
O	N	D	J	F	M	A	M	J	J	A	S	Total	
7	6	5	6	6	8	8	10	16	12	8	8	100	44

Because yearly variations make it difficult to see long-term trends in streamflow, a 7-year moving average of streamflow was computed. A moving average was used to "smooth" the annual fluctuations and get a "trend" to determine whether streamflow is increasing, decreasing, or remaining constant. This is shown in fig. 4.2, superimposed on the annual-flow graph. The moving average shows a definite downward trend and ranges from a high of about 445,500 acre-feet to a low of about 48,000 acre-feet.

An examination of streamflow records on the Arkansas River between Kinsley (station 07140000) and Great Bend (station 07141300) shows a gain of streamflow between 5,600 and 558,000 acre-feet per year (see fig. 4.3). Net loss of 8,850, 16,180 and 800 acre-feet per year were indicated in 1964, 1968, and 1984, respectively. The net gain of streamflow in this reach of the Arkansas River is attributed mainly to the inflow from the Pawnee River. This was shown in fig. 4.3 by the close relationship between the annual flows at Pawnee River (station 07141200, near Larned) and the net gain of the Arkansas River along this course. This also indicates the importance of the Pawnee River as a source of water supply for the Cheyenne Bottoms. Any reduction in the streamflow of the Pawnee River will have a considerable effect on the amount of water delivered to the inlet canal and the Cheyenne Bottoms.

Table 4.2 summarizes the mean annual flows of the Arkansas River from stations upstream of the Great Bend station and eastward from the Kansas-

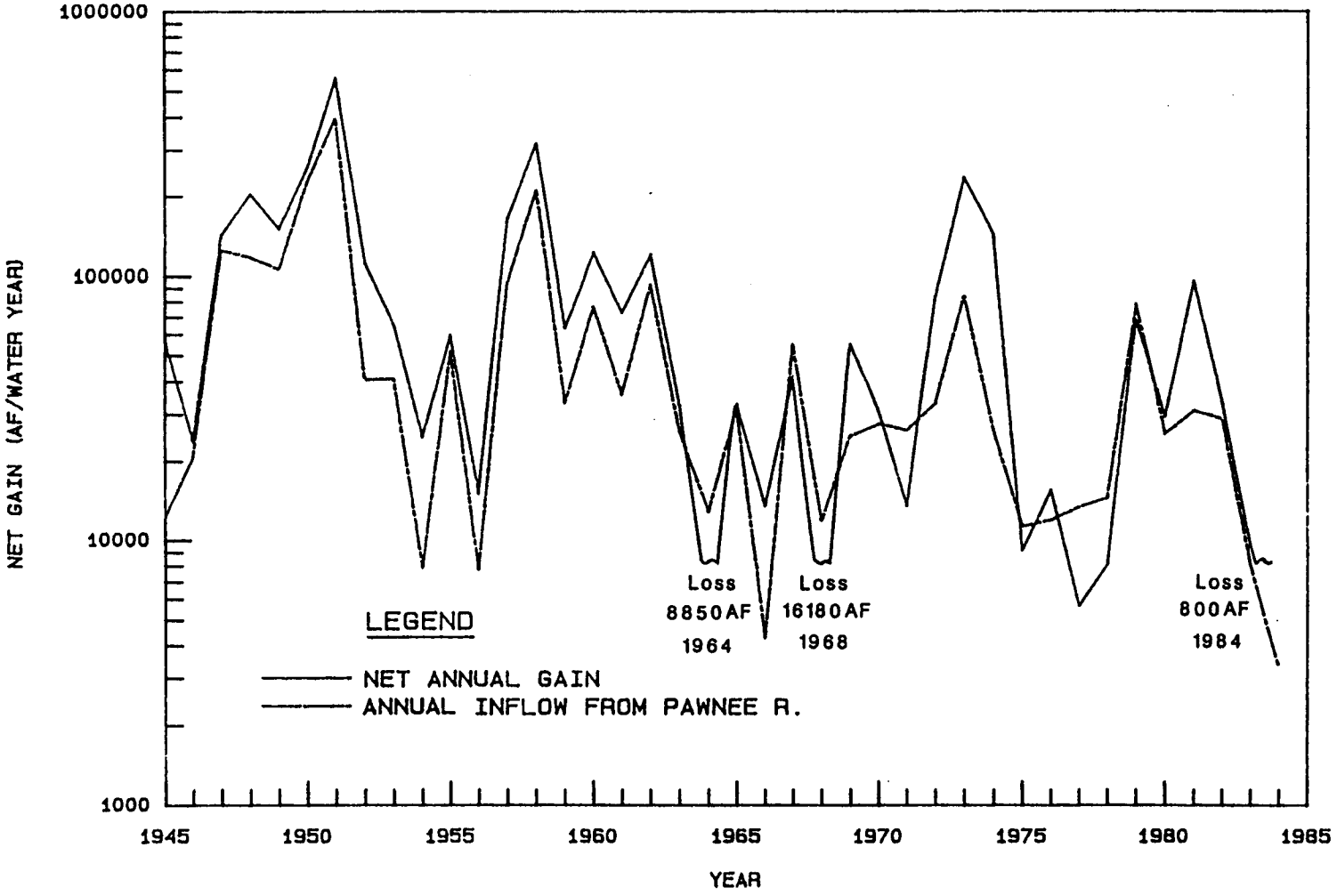


Figure 4.3 Net Gain of Arkansas River Between Kinsley and Great Bend

Colorado border. Mean annual flows were calculated for different time periods to reflect the time variation of the Arkansas River streamflows. As indicated in Table 4.2, flows in the Arkansas River have been reduced considerably over the period of record. However, in the last two decades, the streamflow reduction in the Arkansas River has been massive. At Dodge City (station 07139500), flow in the Arkansas River has almost disappeared in recent years. At Kinsley (station 07140000), the Arkansas River carries less than 5% of what it carried in the 1940's.

The main causes for reduced flows in the Arkansas River are attributed to the increased irrigation along the course of the Arkansas River both in Colorado and Kansas, as well as continuous changes in the land-treatment practices, particularly for agricultural purposes. The effects of irrigation developments are reflected by the increased diversion of water from the river and by lowering the water table in local aquifers, resulting in the drainage of more water from the stream. With regard to the land-use practices, Koelliker and Zovne (1981) have shown that in many river basins in Kansas,

Table 4.2-Mean annual flows for Arkansas River (in AF/year)

	Time period				
Station location	1941-49	1950-59	1960-69	1970-79	1980-84
Syracuse	341,000	157,000	193,000	67,500	105,000
Dodge City	168,000	122,000	130,000	35,500	315
Kinsley	187,000	144,000	138,000	64,000	6,500
Great Bend	385,000	308,000	185,000	126,000	40,000

ground-water withdrawals, watershed dams, and terracing and stubble mulching have reduced precipitation runoff to the streams and resulted in the long-term streamflow decline (see chapter 7 in this report). In such situations, the

restoration of the streamflows to the pre-land-development conditions is practically infeasible.

In order to estimate future streamflow, recurrence intervals and probabilities of given flow values were calculated with the use of the Weibull formula (Linsley et al., 1975). The resulting recurrence intervals were plotted against annual streamflows on a log-probability paper (fig. 4.4). A curve plotted through the data can be used for extrapolation to predict the approximate values of annual flows with different return periods. The annual flows listed in table 4.3 were estimated from the curve-fit in fig. 4.4.

Table 4.3-Recurrence intervals(Tr) for the Arkansas River at Great Bend

Tr	A.F./Year
Mean	224,000
2 years (median)	150,000
5 years	370,000
10 years	550,000
20 years	780,000
50 years	1,300,000

In undeveloped regions, streamflow varies from year to year in response to factors whose variation is random. We have assumed in our analysis that streamflow is a random variable (i.e. to each magnitude of streamflow, a probability may be assigned). Surface-water diversions, changing land-use practices, and ground-water irrigation are undoubtedly lowering the total volume of streamflow that moves past the Great Bend stream gage by introducing nonrandom variations. Therefore, the estimated volumes of flow for different return periods should be viewed with some skepticism if applied in assessing future water availability to Cheyenne Bottoms from the Arkansas River.

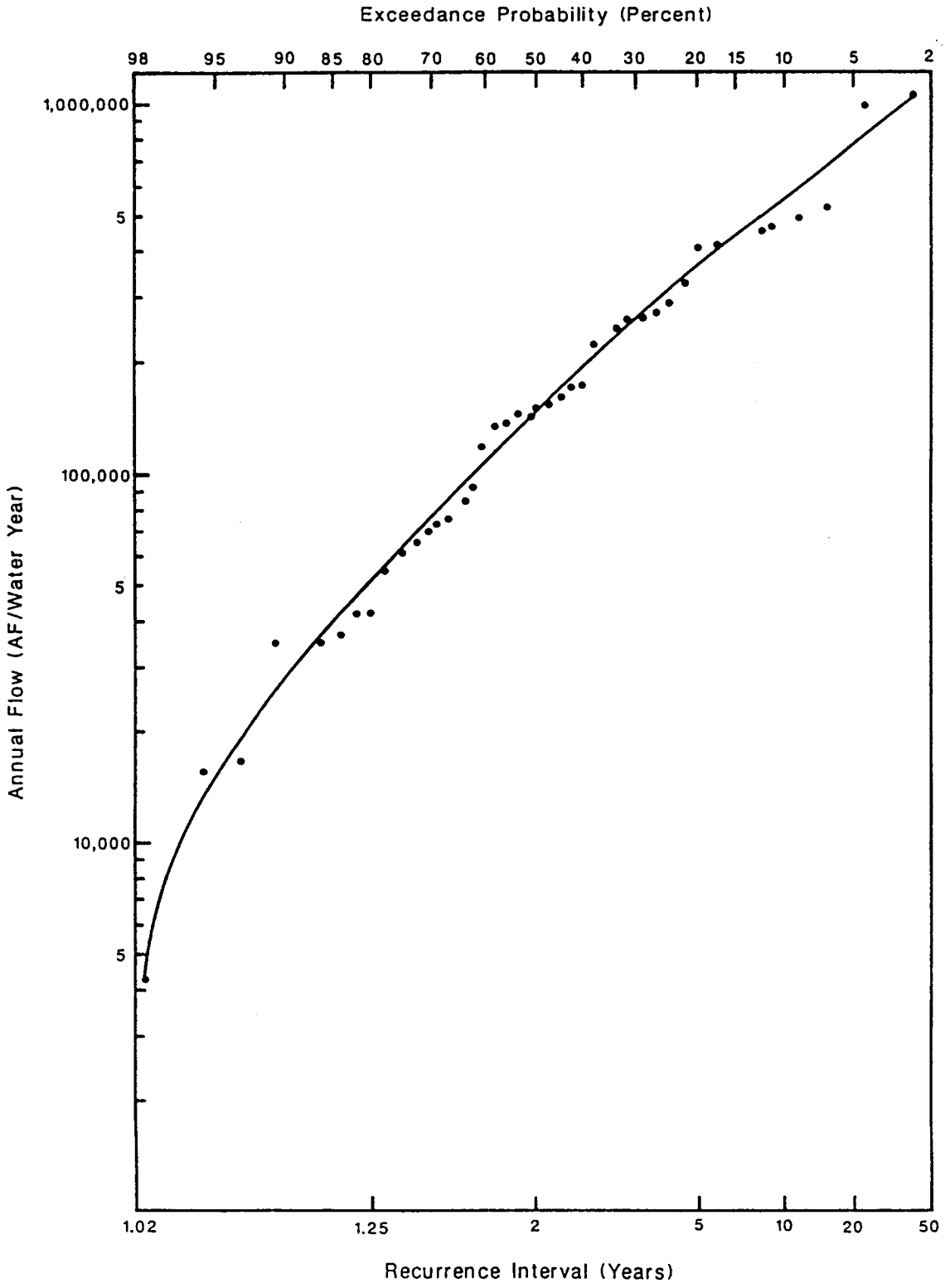


Figure 4.4 Recurrence Interval of Annual Flows for the Arkansas River at Great Bend

WALNUT CREEK

The Walnut Creek valley is an elongated east-west-trending valley that lies west of Great Bend in central Kansas (fig. 4.1). The creek begins in eastern Scott County and flows through Lane, Ness, and Rush counties before emptying into the Arkansas River near Great Bend in Barton County. The total watershed area of Walnut Creek is approximately 1,600 square miles.

A stream-gaging station for Walnut Creek at Albert (station 07141900), 14 miles northwest of Great Bend, is located on the downstream side of the highway bridge 0.2 mile north of Albert (fig. 4.1). This gaging station is approximately 10 miles upstream from the junction of the inlet canal and Walnut Creek. The average annual-flow volume at this station for 24 complete years of record is 38,000 acre-feet. The maximum annual-flow volume was 113,300 acre-feet in 1960. The minimum annual-flow volume of 2,790 acre-feet occurred in 1977 (see appendix 4.1). Table 4.4 summarizes monthly streamflows as a percent of the average annual streamflow in Walnut Creek. A plot of annual flow volume for Walnut Creek at Albert for the period 1959-1982 is shown in fig. 4.5. Fig. 4.5 also shows the 7-year moving average of streamflow at the Albert gage. During the 1960's, the trend of the moving average seems to show an increase during wet periods and a decrease during dry periods, which is what normally would be expected. In the second part of the 1970's there seems to be a distinct downward trend in the moving-average streamflow, indicating an overall decline of flow in Walnut Creek in recent years. The flow probabilities and recurrence intervals for Walnut Creek were calculated using the previously discussed techniques. The flows listed below in table 4.5 are interpolated from fig. 4.6. The expected annual-flow volume with the 50-years recurrence interval was not interpolated because of the lack of data for extremely high flows.

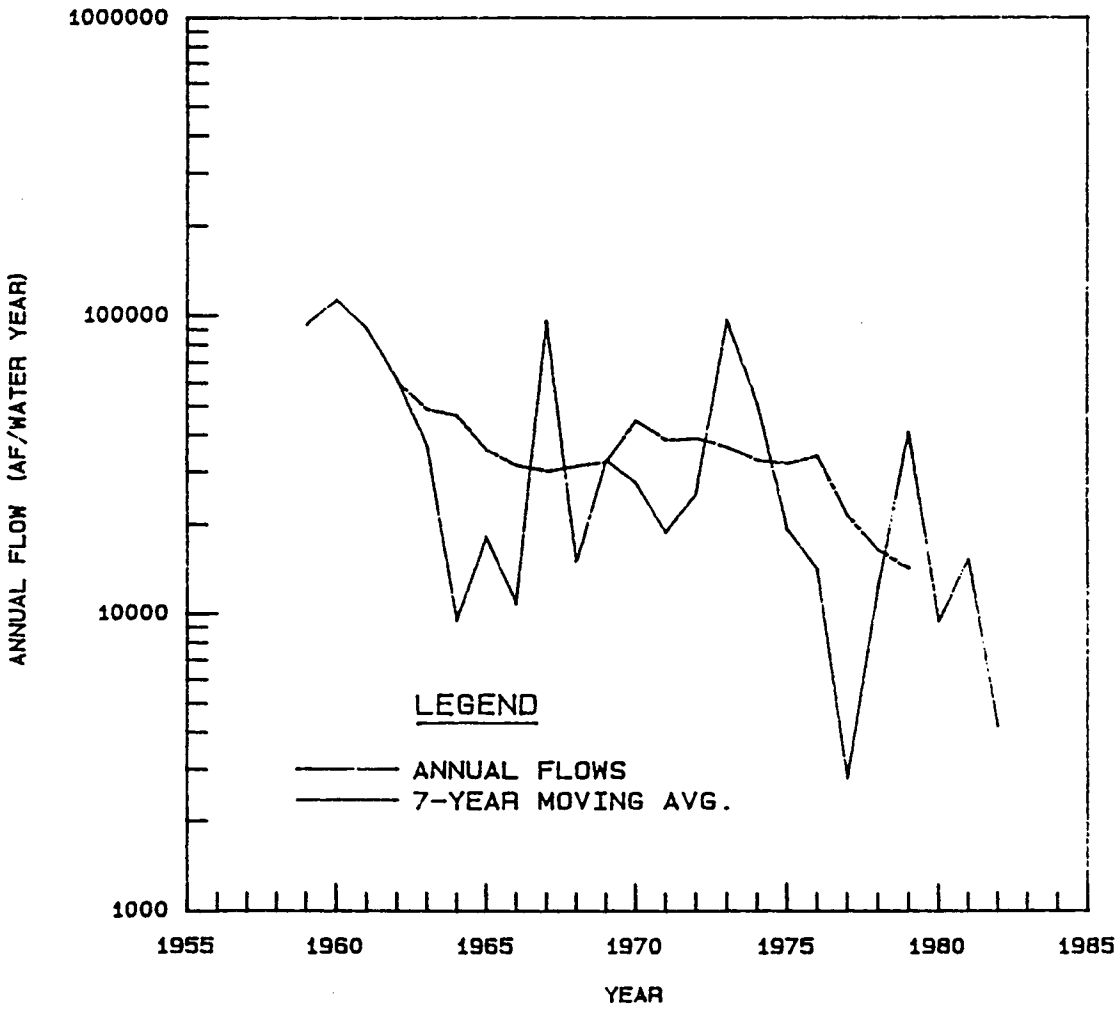


Figure 4.5 Annual Flows for Walnut Creek at Albert

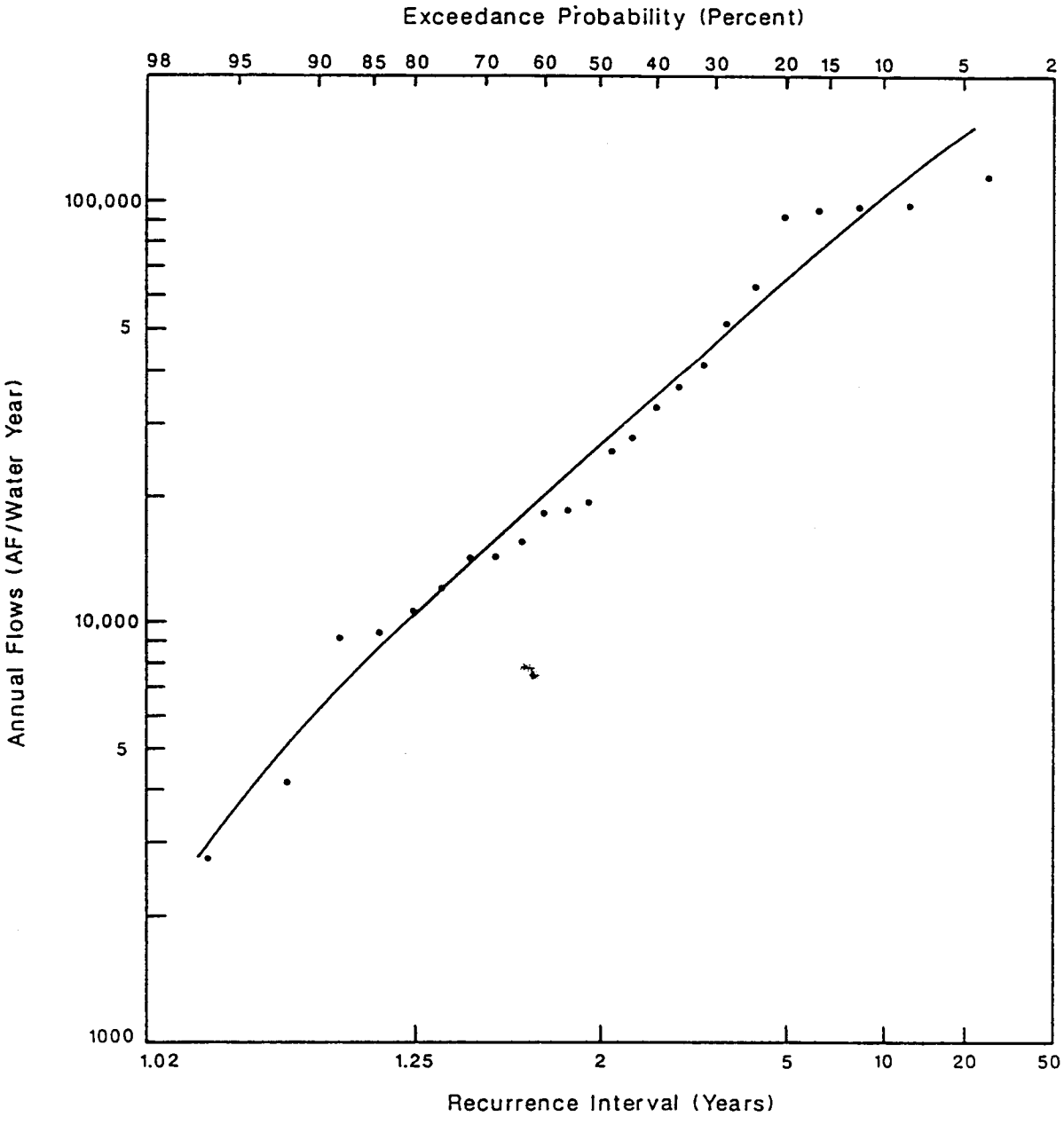


Figure 4.6 Recurrence Interval of Annual Flows for Walnut Creek at Albert

Table 4.4-Monthly streamflow as a percent of total streamflow--Walnut Creek.

Month													Total years of record
O	N	D	J	F	M	A	M	J	J	A	S	Total	
10	3	1	2	2	7	6	8	22	16	8	15	100	24

Table 4.5-Recurrence intervals (Tr) for Walnut Creek at Albert.

Tr	A.F./Year
Mean	38,000
2 years (median)	27,000
5 years	66,000
10 years	105,000
20 years	145,000
50 years	-------

BLOOD CREEK

A stream-gaging station for Blood Creek near Boyd (station 07142900) is located on the downstream side of the bridge on State Highway 4, approximately 1.3 miles northwest of Boyd (fig. 4.1) and 11.9 miles upstream from Cheyenne Bottoms. Blood Creek flows directly into Cheyenne Bottoms. The average annual flow at that station for 18 complete years of record (1963-1980) is 5,130 acre-feet. The continuous-record gage at this station was dropped in favor of a crest-stage indicator gage in 1981. This type of gage records only peaks of flows. The maximum annual-flow volume of 17,430 acre-feet was recorded in 1974, and the minimum annual-flow volume was 1,210 acre-feet in 1963. The maximum discharge of 3,860 ft^3/sec occurred June 29, 1967; the minimum is zero flow at times during most years (see appendix 4.1).

Fig. 4.7 shows the plot of annual-streamflow volumes for the Blood Creek gaging station. Superimposed on the annual-steamflow graph is a 7-year moving average of the streamflows. The plot of the moving average shows a distinctive upward trend for Blood Creek before 1972, followed by the constant decline of

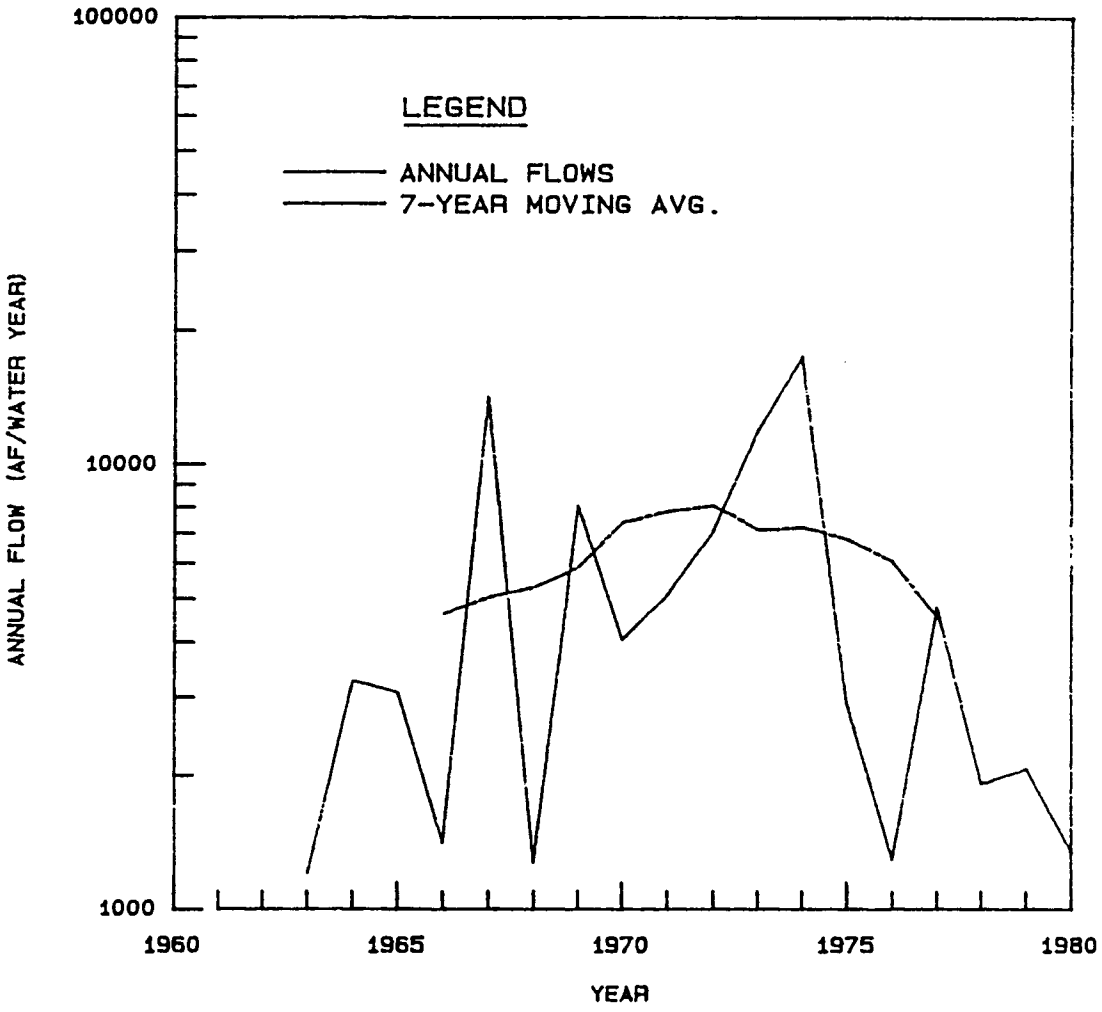


Figure 4.7 Annual Flows for Blood Creek Near Boyd

streamflow in the most recent years. The drainage area of the Blood Creek(upstream of the gage) is so small (61 square miles) that runoff will vary closely with precipitation. Table 4.6 summarizes monthly streamflows as a percent of the average annual streamflow in Blood Creek.

Table 4.6-Monthly streamflow as a percent of total streamflow--Blood Creek.

Month													Total years of
O	N	D	J	F	M	A	M	J	J	A	S	Total	record
4	5	2	2	4	8	9	16	21	17	6	6	100	18

Fig. 4.8 shows a graph of flow versus recurrence interval for Blood Creek. Table 4.7 lists recurrence intervals estimated from fig. 4.8. The expected annual-flow volume with the recurrence interval of 50 years was not estimated due to the lack of data for extremely high flows.

Table 4.7-Recurrence intervals (Tr) for Blood Creek near Boyd.

Tr	A.F./Year
Mean	5,130
2 years (median)	3,100
5 years	8,500
10 years	14,000
20 years	22,000
50 years	----

DECEPTION CREEK

The Deception Creek drainage basin is on the north side of Cheyenne Bottoms and flows unregulated into Cheyenne Bottoms (fig. 4.1). The drainage area is approximately 44 square miles and is ungaged. Since it is ungaged, no flow records exist to determine high- and low-flow frequencies. Therefore, the volume and frequency of mean annual flow must be estimated. One way to do this is to use streamflow records from other comparable streams in the area. The streams used in this case are shown in table 4.8.

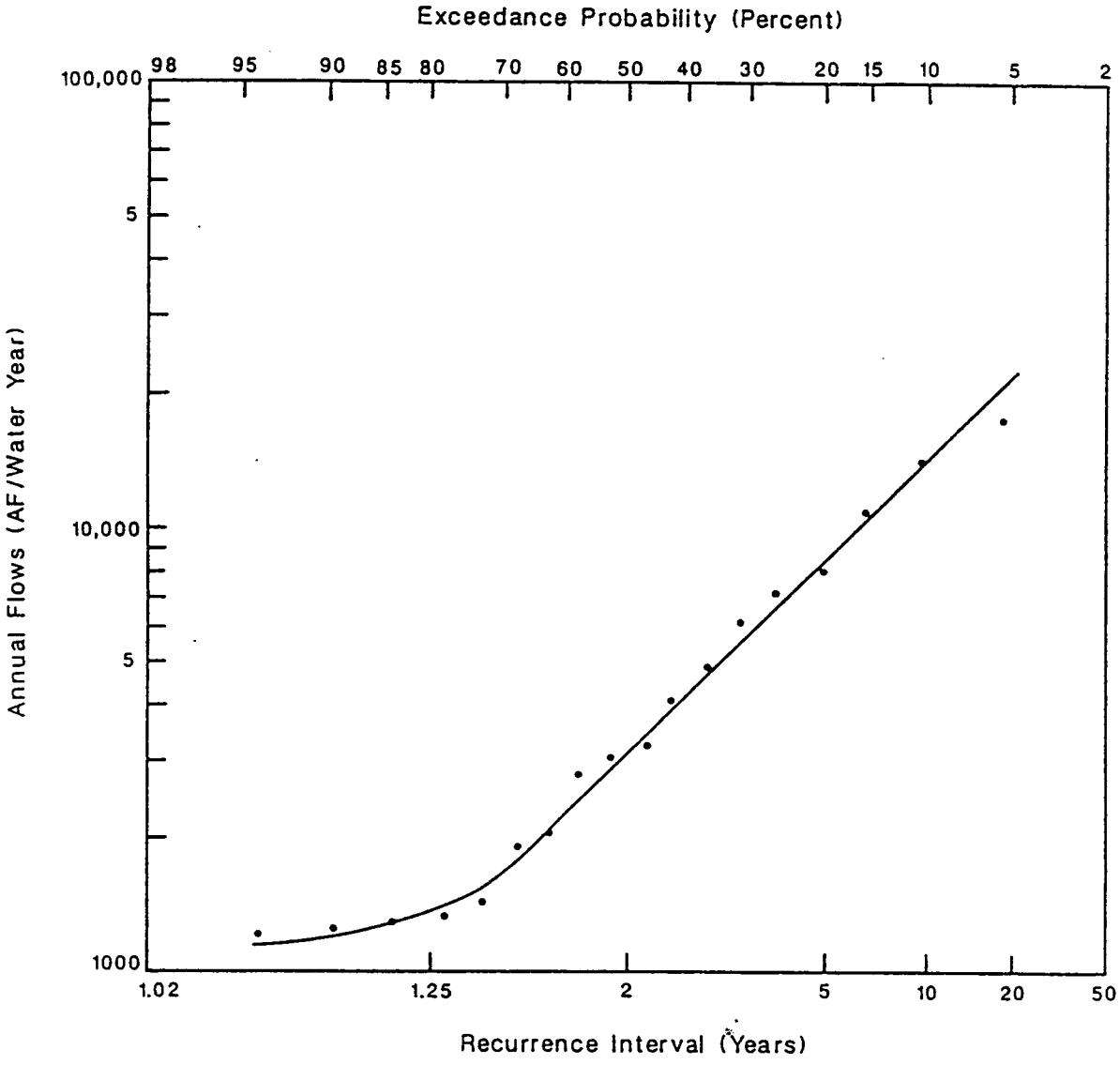


Figure 4.8 Recurrence Interval of Annual Flows for Blood Creek Near Boyd

Table 4.8-Drainage area and mean annual discharge for streams in central Kansas.

		Drainage area (mi^2)	Mean annual discharge (AF/Yr)
1.	Pawnee River near Larned (07141200)	2,148	53,180
2.	Guzzlers Gulch near Ness City (07140700)	58	1,540
3.	Walnut Creek near Rush Center (07141780)	1,256	18,400
4.	Walnut Creek at Albert (07141900)	1,410	38,000
5.	Cow Creek near Claflin (07142860)	43	5,220
6.	Blood Creek near Boyd (07142900)	61	5,310
7.	Big Creek near Hays (06863500)	594	27,970
8.	North Fork, Big Creek, near Victoria (06863900)	54	2,930

Drainage areas and mean annual discharges were plotted on a log-log paper and a curve showing the relationship between drainage area and mean annual flow was plotted (fig. 4.9). Based on a drainage area of 44 square miles, Deception Creek should have a mean annual discharge of approximately 3.5 ft^3/sec (2,500 acre-feet/year).

As a check on the calculations by Hazen's method (Hazen, 1930), annual streamflow was calculated by estimating the runoff from the basin. The Kansas Water Resources Board (1967) estimated annual runoff from the general area of Deception Creek to be approximately one inch. Since the basin area is 44 square miles (28,160 acres) and the average annual precipitation is about 26 inches, total precipitation falling on the basin would be:

Total precip. = 26" x 28160 A = 732160 acre-inches/12 inches per foot

= 61,013 acre-feet/year.

Runoff = 1 inch/26 inches = .038 or 3.8%.

Therefore,

.038 x 61,013 acre-feet/year = 2,318 acre-feet/year

2,318 acre-feet compares well with 2,500 acre-feet/year from the graph.

Since Deception Creek has no historical gaging record, determining flood probabilities and recurrence intervals in the same manner as the Arkansas

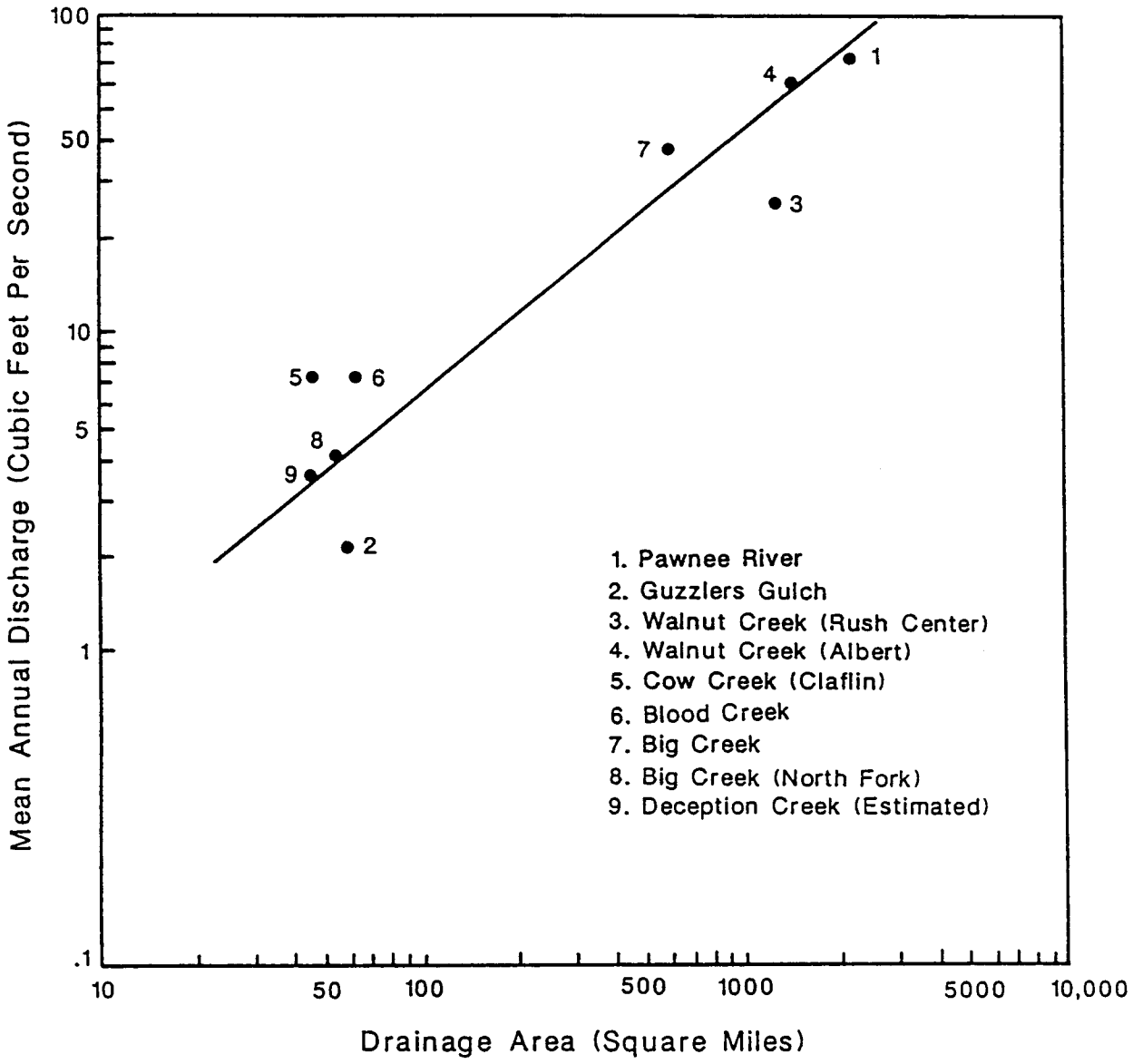


Figure 4.9 Mean Annual Discharge vs. Drainage Area of Selected Streams in Central Kansas

River, Walnut Creek, and Blood Creek is not possible. The annual-flow probabilities and recurrence intervals must be estimated. A commonly accepted method is that of Hazen (1930). Briefly, Hazen calculates hydrologic characteristics of nearby, similarly gaged basins and applies those characteristics to the ungaged basins. The results of the calculations are shown in fig. 4.10 and summarized in table 4.9.

Table 4.9-Recurrence intervals (Tr) for Deception Creek.

Tr	A.F./Year
Mean	2,500
2 years (median)	2,000
5 years	4,000
10 years	5,400
20 years	6,500
50 years	-----

CLIMATOLOGY

The climatic factors of precipitation, temperature, sunshine, humidity, and wind all affect streamflow runoff to some extent but only precipitation and temperature account for major changes in the runoff regime of a particular basin. In general, the transformation of precipitation into streamflow is extremely complicated because of insufficient knowledge of many basin characterisitics affecting streamflow. Nevertheless, an analysis of records of precipitation and temperature can explain qualitatively the existence of long-term streamflow patterns of a particular basin.

GREAT BEND STATION

The Great Bend station (#3218) is one of the two stations in Barton County with monthly records of total precipitation. The station is located at latitude 38°21' N. and longitude 98°46'W. along the Arkansas River south of the Cheyenne Bottoms Wildlife Area.

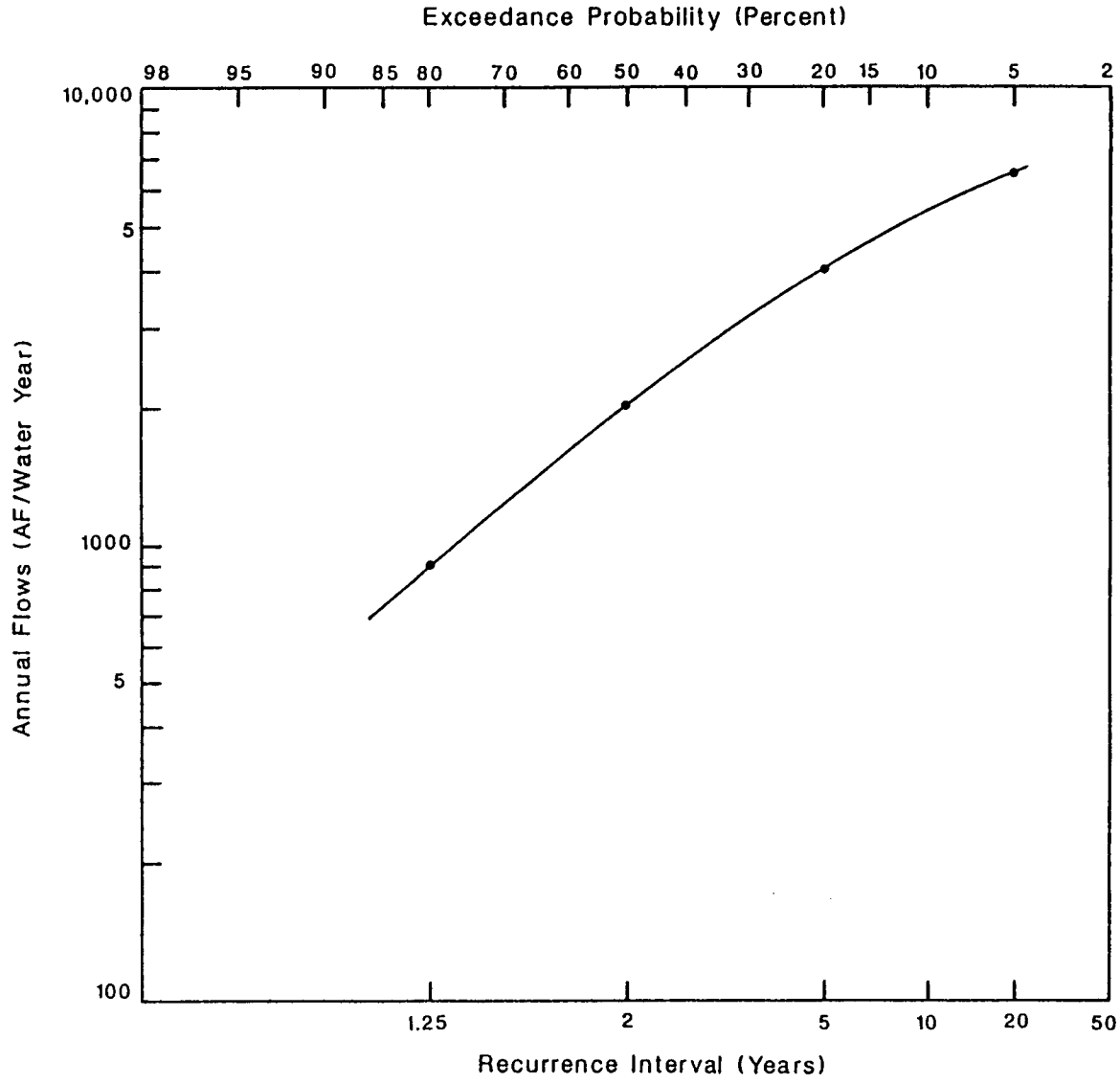


Figure 4.10 Calculated Recurrence Interval of Mean Annual Flow in Deception Creek

The Great Bend station precipitation record from 1931 to 1982 was studied. The monthly and annual precipitation for this station are contained in appendix 4.2. The average annual precipitation for the 52 years of record is 24.7 inches, of which 73% occurs during the months of April through September. Table 4.10 summarizes the monthly precipitation as a percent of the average annual precipitation at Great Bend. The recorded annual precipitation ranges from a low of 14.2 inches in 1956 to a high of 43.6 inches in 1973.

Fig. 4.11 shows the time variation of the annual precipitation at the Great Bend station. Also shown in fig. 4.11 is the five-year moving average of annual precipitation. The five-year averaging is known to be sufficient for damping out most of the random components, leaving the effects of long-term wet and dry cycles in the record. As can be seen in fig. 4.11, during a wet period, the five-year moving-average line always is above the long-term mean while during the drought period, the moving-average line stays below the mean annual precipitation. An analysis of the moving-average line in fig. 4.11 indicates that the Great Bend area has been in a state of long-term above-normal or wet period since 1958. This points out the fact that the lack of precipitation is not the cause of long-term streamflow decline in local streams. Note, however, that the short-term below-normal precipitation in this area resulted in drought periods of one to three years in the last three decades but did not have any long-term effect.

Further analysis of the precipitation records involves determining the recurrence intervals or the exceedance probabilities associated with the annual precipitation. Recurrence intervals were calculated with Weibull's formula (Linsley et al., 1975). The annual precipitation and the corresponding recurrence intervals were plotted on probability paper and a

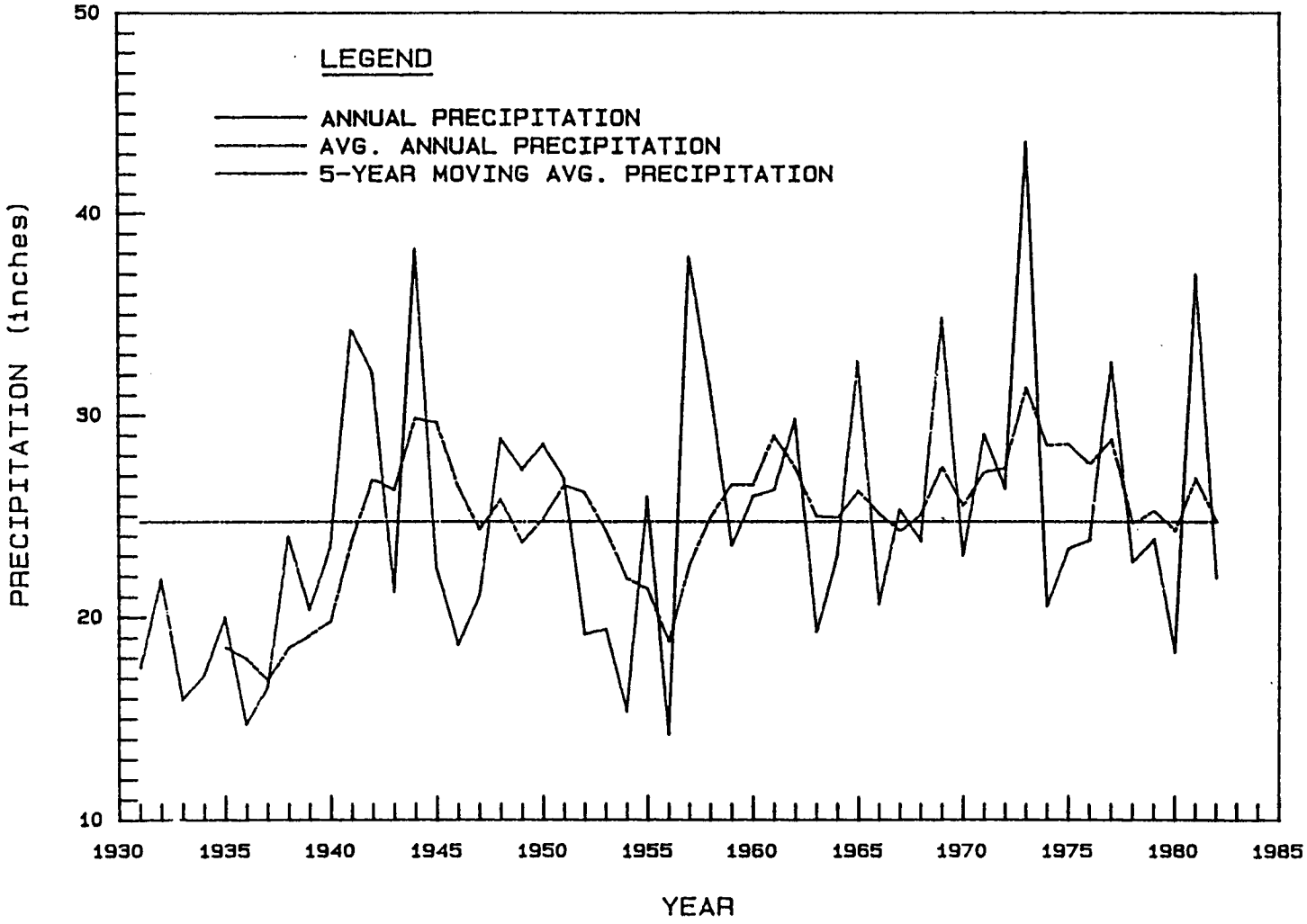


Figure 4.11 Annual Precipitation at the Great Bend Station

curve was drawn through the data points (fig. 4.12). Subsequently, the estimates of annual precipitation were obtained from this graph for the desired recurrence intervals. Table 4.11 summarizes the results of this analysis.

Table 4.10-Monthly precipitation as a percent of annual precipitation, Great Bend.

Month													Total years of
J	F	M	A	M	J	J	A	S	O	N	D	Total	record
3	4	6	8	14	17	13	12	9	7	4	3	100	52

Table 4.11-Recurrence intervals(Tr) for annual precipitation, Great Bend.

Tr	Inches
Mean	24.7
2 years (median)	23.5
5 years	30.0
10 years	34.5
20 years	38.0
50 years	43.0

In addition to the precipitation data, maximum and minimum monthly temperatures also are recorded at the Great Bend station for the period 1948-1982. Table 4.12 presents a summary of these data.

Table 4.12-Maximum and minimum monthly temperatures(°F) at the Great Bend station.

	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Maximum temperature	50	61	67	75	87	97	103	99	91	81	65	53
Minimum temperature	3	14	23	37	47	56	61	60	51	37	25	17

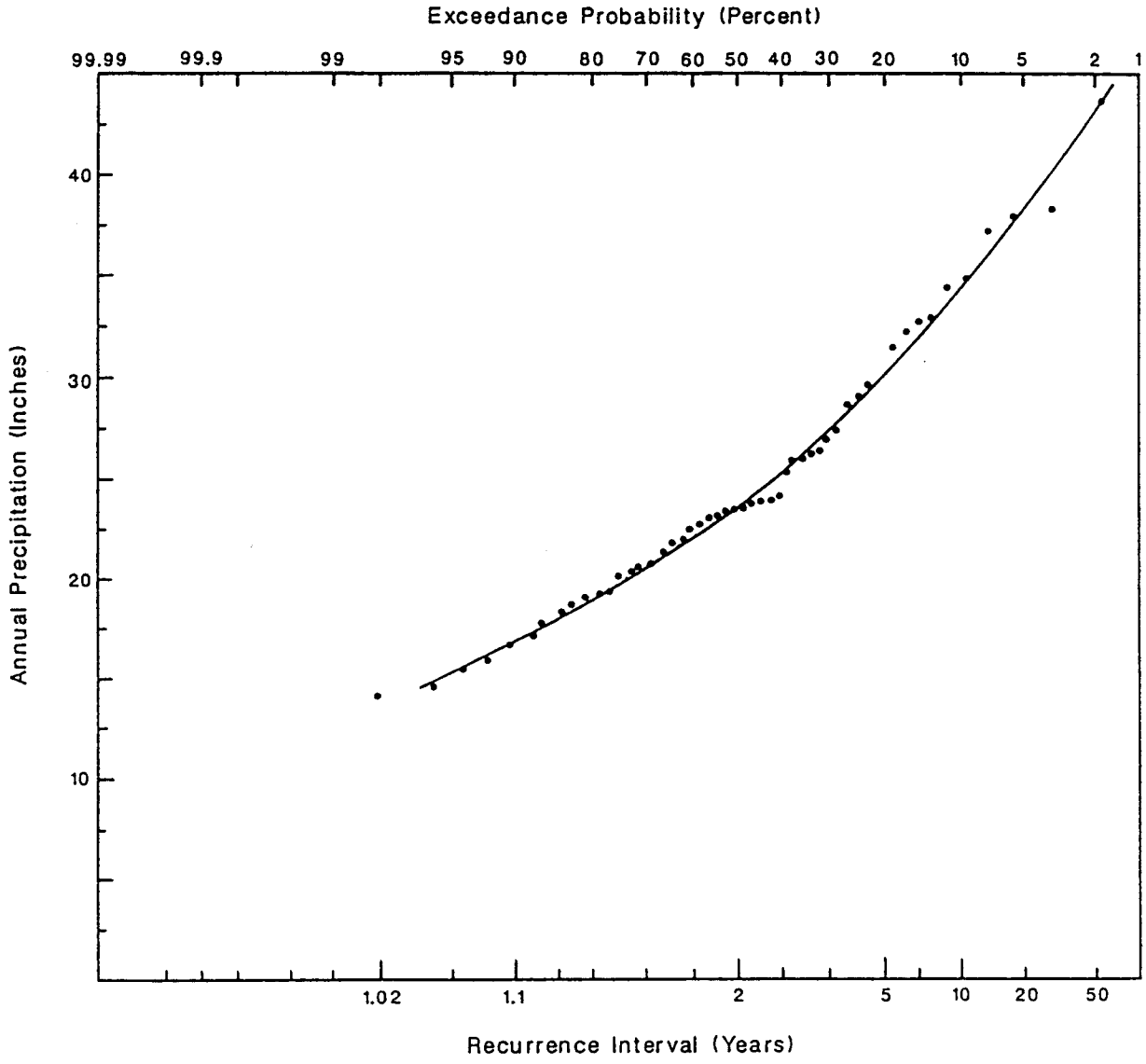


Figure 4.12 Recurrence Interval of Annual Precipitation at Great Bend

The large variations in temperature seen in table 4.12 are typically characteristic of the subhumid continental climate. Changes in the temperature influence the basin runoff in two ways: (1) high temperature increases evapotranspiration and thus reduces the amount of runoff from precipitation, and (2) low freezing temperature changes the timing of runoff by delaying the response of runoff to precipitation.

CLAFLIN STATION

The Claflin station (#1536) is located at latitude 38°31'N and longitude 98°32'W., approximately 7 miles northeast of the Cheyenne Bottoms. Records of monthly precipitation are available for this station for the period 1931-1982 (see appendix 4.3). Monthly temperatures were not recorded at this station.

The mean annual precipitation at Claflin was calculated to be 24.5 inches. A list of monthly percentages of the annual precipitation is provided in table 4.13. Of the total annual precipitation, approximately 75% occurs during the months of April through September. The lowest precipitation in the record is 12.3 inches that occurred in 1956, and the highest precipitation of 41.8 inches occurred in 1973.

The time-series representation of the annual precipitation is shown in fig. 4.13. Time variations of precipitation at Claflin station are very similar to the ones from the Great Bend station. This is not surprising in view of the proximity of the two stations. The five-year moving-average precipitation was depicted in fig. 4.13 to reflect the long-term cycles of wet and dry periods. Except for the occurrence of a recent two-year drought of relatively low severity, the moving average exhibits a general pattern of long-term above-normal precipitation in the last two decades (see fig. 4.13).

The series of annual precipitation were plotted against their recurrence intervals on a probability paper (fig. 4.14). The magnitudes of precipitation

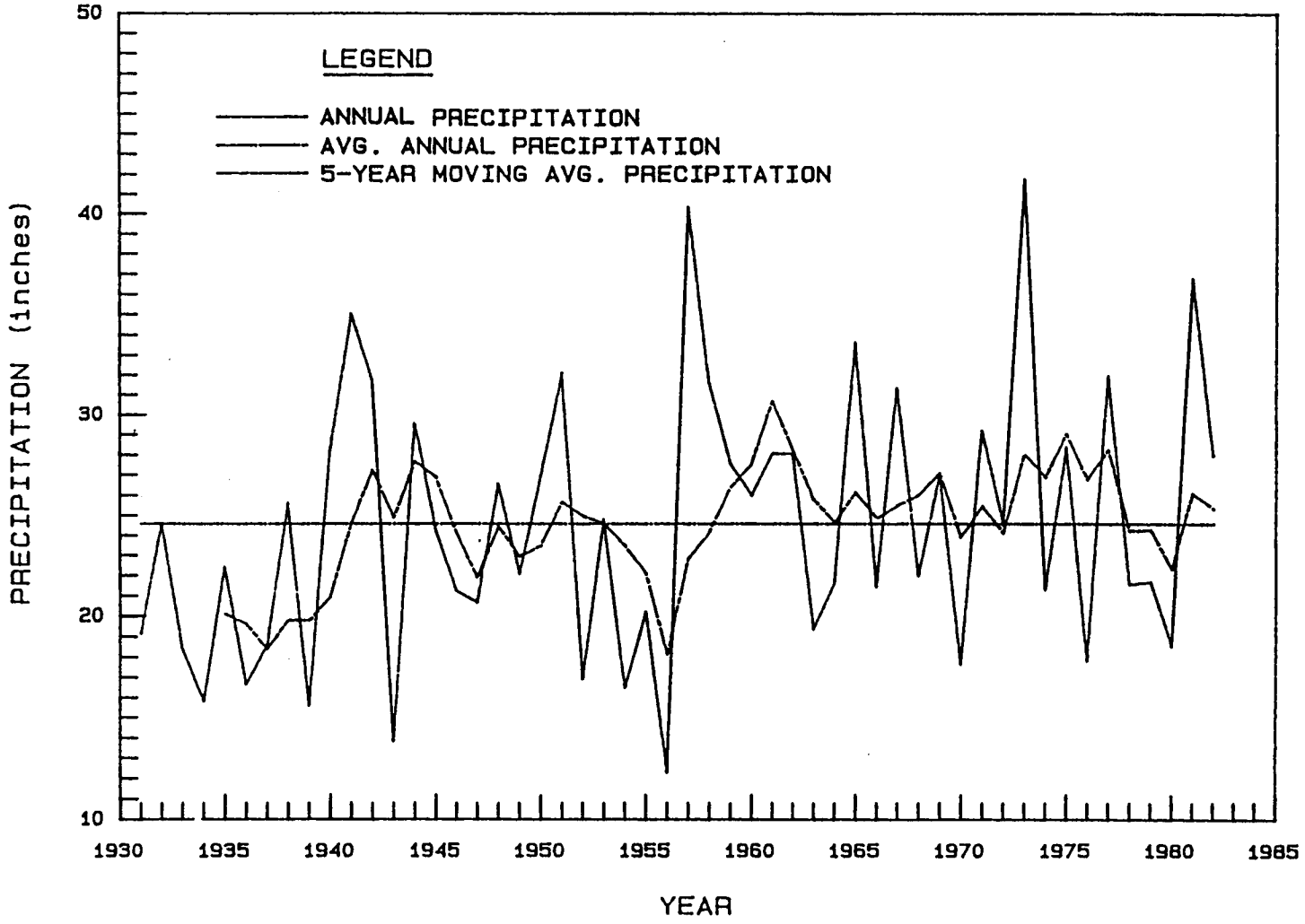


Figure 4.13 Annual Precipitation at the Claflin Station

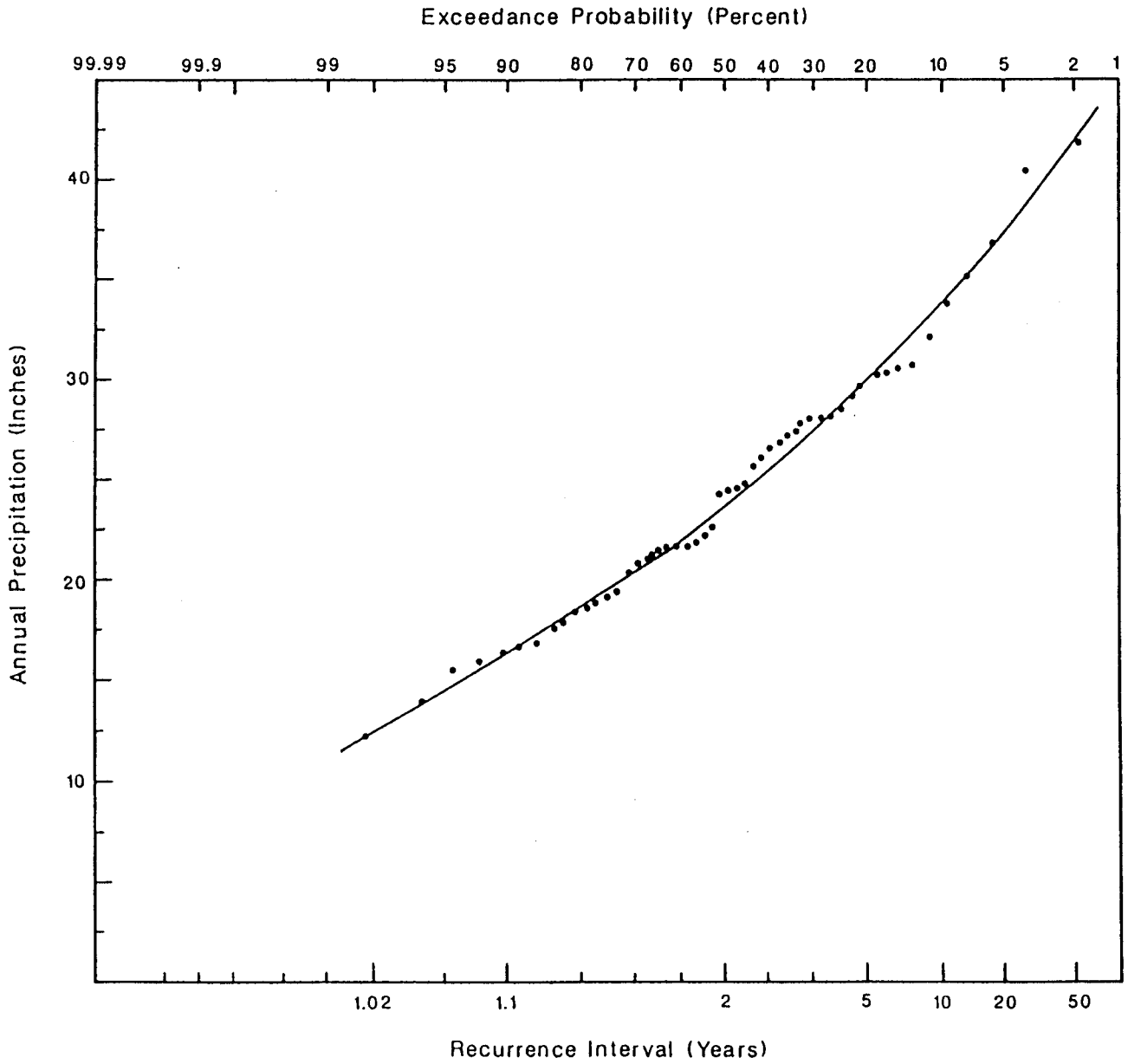


Figure 4.14 Recurrence Interval of Annual Precipitation at Claflin

were obtained from a curve fitted to the data points in fig. 4.14. Table 4.14 presents a list of recurrence intervals and the associated annual precipitations. The information on table 4.14 can be used for prediction of future occurrence of different magnitudes of annual precipitations in this area.

Table 4.13-Monthly precipitation as a pecent of annual precipitation, Claflin.

Month													Total years of
J	F	M	A	M	J	J	A	S	O	N	D	Total	record
2	3	6	8	15	16	14	12	10	7	4	3	100	52

Table 4.14-Recurrence intervals(Tr) for annual precipitation, Claflin.

Tr	Inches
Mean	24.5
2 years (median)	23.5
5 years	30.0
10 years	33.5
20 years	37.0
50 years	42.0

SUMMARY AND CONCLUSIONS

Efficient management of Cheyenne Bottoms wildlife area is dependent upon the long-term availability of water supply. The Cheyenne Bottoms marshland area is supplied by two streams, Blood Creek and Deception Creek, flowing directly into the marsh from the northwest while water from Walnut Creek and the Arkansas River is conveyed to the Bottoms by means of an unlined canal about 23 miles long. Lake evaporation in the area is approximately 60 inches per year, which causes a rapid decline in any water that flows in from the streams feeding the Bottoms.

The Arkansas River gage at Great Bend has an average annual flow of 224,000 acre-feet, 54% of which occurs between April and August. The trend of the long-term average flow at this gage is downward, ranging from a high of 445,500 acre-feet/year to a low of 48,000 acre-feet/year. However, in the reach between Kinsley and Great Bend, the river generally shows a gain in streamflow. The streamflow gain is primarily a result of the inflow from the Pawnee River. The flow recurrence intervals for the Arkansas River at Great Bend are summarized in table 4.15 below.

Walnut Creek has an average annual flow of 38,000 acre-feet/year; 38% of the annual flow occurs in June and July and 25% in September and October. The period of record for Walnut Creek is only 24 years, so long-term trends are not as obvious as on the Arkansas River. What record there is shows an increase in streamflow during wet periods and a decline during dry periods. Recurrence intervals for Walnut Creek also are summarized in table 4.15.

Table 4.15-Summary of recurrence intervals for streams in the Cheyenne Bottoms Vicinity.

	Streamflow summaries (Acre-Feet)			
	Arkansas River	Walnut Creek	Blood Creek	Deception Creek
Mean	224,000	38,000	5,130	2,500
2 years (median)	150,000	27,000	3,100	2,000
5 years	370,000	66,000	8,500	4,000
10 years	550,000	105,000	14,000	5,400
20 years	780,000	145,000	22,000	6,500
50 years	1,300,000	-------	------	-----

Blood Creek flows directly into Cheyenne Bottoms from the northwest. The average annual flow at the gaging station near Boyd is 5,130 acre-feet per year. This station has 18 years of record and the long-term moving average of annual discharge shows a trend that fluctuates closely with precipitation; 63% of the flow comes during April through July. Recurrence intervals for Blood Creek are summarized in table 4.15.

Deception Creek also flows directly into Cheyenne Bottoms from the northwest. Its drainage area is 44 square miles and it is ungaged. The average-annual flow volume was estimated by Hazen's method and found to be approximately 2,500 acre-feet/year. A second method of estimation using estimated runoff from the soil types in the area gives an annual average of about 2,300 acre-feet. Recurrence intervals are summarized in table 4.15.

In addition to the surface-water anaysis, an evaluation was made of the long-term precipitation and temperature variations in this area. The average annual precipitation calculated from the two stations in the close proximity of the Cheyenne Bottoms is 24.6 inches. More than 70% of annual precipitation normally occurs during the months of April through September. The average annual precipitation from the two stations ranged from a low of 13.2 inches to a high of 42.7 inches. The five-year moving-average precipitation shows the cyclic change of wet and dry periods but also indicates that the area has been in a state of long-term above-normal precipitation in the last two decades. Obviously, lack of precipitation is not the cause of long-term streamflow decline in this area. The monthly temperature at Great Bend is widely varied, which is a typical characteristic of the subhumid climate in this area. Temperature, in conjunction with sunshine and wind, determines the evaporation losses.

In summary, the long-term surface-water supply for Cheyenne Bottoms will continue to decline, basically because streamflow is being lost to irrigation, small dams, and various agricultural practices that reduce runoff.

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Appendix 4.1. Hydrologic data for selected stream-gaging stations.

	Flow in AF/Water Year				
	Arkansas River near Kinsley	Arkansas River at Great Bend	Pawnee River at Larned	Walnut Creek at Albert	Blood Creek near Boyd
1941		146,100	24,490		
1942		1,113,300	24,670		
1043		270,300	34,810		
1944		405,600	93,850		
1945	100,900	157,700	12,290		
1946	60,650	84,470	20,680		
1947	368,800	511,500	125,300		
1948	123,900	328,900	117,600		
1949	281,300	431,400	106,100		
1950	207,800	465,200	228,600		
1951	440,300	998,000	397,700		
1952	153,500	265,500	40,490		
1953	52,470	117,900	40,960		
1954	49,630	74,250	7,860		
1955	111,400	171,000	51,890		
1956	48,990	63,940	7,730		
1957	90,390	255,500	95,200		
1958	174,200	493,200	210,600		
1959	110,700	173,800	33,120	94,360	
1960	163,600	286,500	76,750	113,300	
1961	64,880	137,300	35,550	90,540	
1962	113,800	234,200	93,260	61,370	
1963	58,840	91,030	25,710	36,760	1,210
1964	44,540	35,690	12,800	9,480	3,280
1965	424,100	456,800	32,100	18,170	3,070
1966	235,700	249,100	4,280	10,790	1,410
1967	105,100	146,600	55,060	96,660	14,190
1968	77,280	61,100	11,760	14,900	1,270
1969	94,680	149,800	24,920	32,870	8,070
1970	106,700	137,700	27,650	27,440	4,040
1971	63,950	77,400	26,050	18,730	5,120
1972	82,160	166,200	33,000	25,350	7,100
1973	180,000	416,400	84,320	97,570	11,900
1974	83,180	225,600	26,120	51,200	17,430
1975	35,190	44,260	11,230	19,340	2,870
1976	20,080	35,520	11,900	14,070	1,290
1977	11,090	16,720	13,350	2,790	4,800
1978	46,180	54,310	14,470	12,330	1,910
1979	14,710	82,810	78,660	41,110	2,080
1980	14,850	44,070	25,260	9,360	1,340
1981	3,910	100,200	30,900	15,350	
1982	2,760	36,050	28,680	4,190	
1983	5,900	15,420	8,000		
1984	5,100	4,300	3,280		

Appendix 4.2. Monthly distribution of total precipitation (in hundreth of inch) at Great Bend station.

	Monthly total precipitation												
Year	J	F	M	A	M	J	J	A	S	O	N	D	Year total
1931	8	14	377	276	218	134	101	173	93	66	250	46	1756
1932	121	38	77	97	455	797	202	155	143	72	8	22	2187
1933	0	21	16	136	234	64	165	657	95	50	56	100	1594
1934	45	130	8	64	333	326	92	283	251	63	122	0	1717
1935	0	69	58	27	717	494	58	158	154	64	188	15	2002
1936	62	8	0	57	416	138	38	62	453	131	0	107	1472
1937	80	72	74	15	412	170	424	154	68	138	35	17	1659
1938	0	128	218	239	806	494	102	170	220	2	24	0	2403
1939	119	151	103	63	119	646	99	509	29	48	78	73	2037
1940	80	104	93	325	381	58	311	362	221	64	221	128	2348
1941	130	103	78	221	420	634	409	459	238	588	69	76	3425
1942	19	81	141	411	294	765	153	568	291	333	26	126	3208
1943	12	42	129	123	180	179	496	250	215	323	10	162	2121
1944	102	123	285	619	413	407	642	616	178	164	101	176	3826
1945	102	137	96	429	192	354	335	186	189	171	0	45	2236
1946	39	50	142	140	212	168	106	127	190	451	240	0	1865
1947	17	65	202	259	430	399	199	158	21	24	121	213	2108
1948	73	301	157	54	189	907	594	179	78	79	240	36	2887
1949	315	64	136	153	560	871	295	104	38	65	0	127	2728
1950	8	7	71	76	341	2441	101	653	237	90	19	12	2859
1951	60	100	133	329	546	577	217	309	207	141	53	13	2685
1952	20	26	365	438	215	0	352	234	35	0	137	95	1917
1953	12	36	170	70	131	387	180	180	220	67	340	150	1943
1954	2	56	38	215	333	149	143	289	163	133	0	14	1535
1955	117	140	16	197	261	619	447	117	572	110	0	0	2596
1956	118	57	10	227	227	55	338	79	0	281	22	6	1420
1957	12	34	528	346	588	879	200	182	578	314	116	11	3788
1958	44	204	290	93	487	202	893	243	545	11	74	46	3132
1959	74	85	182	71	514	378	194	142	200	418	10	79	2347
1960	197	276	151	200	258	293	185	338	239	243	81	138	2599
1961	8	51	226	183	393	377	333	493	90	202	211	67	2634
1962	109	71	131	105	135	735	909	390	221	50	90	35	2981
1963	34	0	152	48	362	286	521	143	155	151	24	51	1927
1964	0	29	89	148	338	483	199	285	187	22	359	170	2309
1965	113	130	22	110	367	1139	382	269	364	138	2	236	3272
1966	40	223	6	108	28	387	570	460	103	17	2	120	2064
1967	49	0	8	338	344	770	562	37	242	49	49	88	2536
1968	16	20	0	169	225	236	673	148	89	518	176	103	2373
1969	19	179	165	161	541	259	442	1047	336	300	7	29	3485
1970	24	4	318	259	168	678	42	122	423	219	32	14	2303
1971	171	347	95	174	433	338	223	123	126	456	338	85	2909
1972	44	25	32	224	374	395	271	501	278	159	243	90	2636
1973	48	90	956	237	198	146	658	342	980	247	157	301	4360
1974	33	11	126	317	248	236	20	426	70	450	58	57	2052
1975	83	164	128	134	430	430	150	357	174	0	218	71	2339

1976	15	70	111	608	440	213	279	30	390	218	10	0	2385
1977	84	2	181	241	674	642	151	707	138	199	188	58	3265
1978	40	132	75	118	302	475	57	250	529	15	171	105	2269
1979	174	10	336	129	162	177	680	45	18	457	75	123	2386
1980	91	113	291	114	198	50	159	472	122	98	0	118	1826
1981	4	16	259	213	822	833	538	176	266	264	296	17	3704
1982	30	100	103	60	514	320	252	227	180	252	53	104	2195

Appendix 4.3. Monthly distribution of total precipitation (in hundreth of inch) at Claflin station.

Year	Monthly total precipitation												Year
	J	F	M	A	M	J	J	A	S	O	N	D	Total
1931	0	17	266	404	196	109	204	107	77	345	345	33	1915
1932	111	39	74	131	429	916	156	329	206	39	0	32	2462
1933	0	19	32	28	229	74	277	946	52	7	58	118	1840
1934	39	107	0	25	260	389	109	220	261	58	113	0	1581
1935	6	69	58	46	726	368	177	317	220	60	193	5	2245
1936	107	2	0	71	415	98	47	164	517	123	0	121	1665
1937	124	80	75	29	432	301	241	226	145	129	61	19	1862
1938	0	145	165	256	643	485	402	240	204	0	23	0	2563
1939	67	103	95	56	45	478	266	244	7	41	86	70	1558
1940	61	62	42	340	321	150	551	350	487	138	244	83	2829
1941	118	105	57	185	468	689	107	225	677	745	62	65	3503
1942	24	99	166	399	157	808	87	437	467	349	51	124	3168
1944	79	135	270	592	369	258	528	607	179	145	104	167	2960
1945	69	90	92	526	254	458	284	113	356	139	0	40	2421
1946	27	48	181	251	267	121	97	149	313	396	271	1	2122
1947	25	26	183	273	517	355	267	110	6	38	90	173	2063
1948	21	246	232	57	207	487	815	160	100	75	228	27	2655
1949	147	25	143	153	488	566	261	85	194	98	0	48	2208
1950	10	8	64	65	302	188	1011	706	194	104	19	26	2697
1951	50	110	99	282	579	639	562	300	400	155	27	8	3211
1952	12	20	215	477	284	14	200	200	19	0	165	86	1692
1953	15	38	143	116	191	428	473	354	224	71	258	170	2481
1954	0	48	36	151	309	314	105	355	134	160	0	35	1647
1955	115	95	23	228	327	270	325	54	482	92	9	2	2022
1956	81	50	8	175	175	85	226	163	0	223	36	6	1228
1957	17	47	425	345	770	1021	154	224	419	413	153	48	4036
1958	44	170	400	171	359	381	912	325	274	32	72	15	3155
1959	58	75	160	46	573	262	337	134	620	417	0	71	2753
1960	166	261	108	159	259	462	217	326	238	214	51	135	2596
1961	4	39	220	189	429	549	256	608	155	159	158	41	2807
1962	113	68	167	101	128	671	642	519	240	63	81	12	2805
1963	30	4	213	53	284	285	494	129	249	144	14	37	1936
1964	8	28	150	68	297	397	226	306	188	9	344	145	2166
1965	107	116	20	84	335	1424	290	130	507	129	0	224	3366
1966	16	214	7	89	1	529	619	434	123	24	0	86	2142
1967	13	0	50	447	207	838	741	183	441	86	52	80	3138
1968	0	5	0	171	213	195	616	100	91	575	202	28	2196
1969	13	136	149	198	406	489	295	565	135	299	0	24	2709
1970	27	11	136	107	154	314	134	265	365	221	14	15	1763
1971	20	157	39	217	556	344	402	99	122	564	379	25	2924
1972	6	8	58	271	537	227	148	299	224	219	307	145	2449
1973	31	95	887	255	328	147	537	260	900	325	174	240	4179
1974	5	0	119	348	390	226	43	278	51	529	62	76	2127
1975	70	126	155	116	578	547	49	785	171	0	191	57	2845
1976	2	21	128	697	334	32	87	61	179	234	4	0	1779
1977	70	0	295	266	571	440	241	808	123	136	200	48	3198

1978	38	196	176	116	417	310	159	135	354	23	203	26	2153
1979	171	26	351	80	225	177	324	60	22	489	115	131	2171
1980	90	142	335	150	293	24	125	449	22	93	0	130	1854
1981	0	11	291	195	936	875	406	259	186	230	289	6	3684
1982	46	59	195	49	612	206	995	275	0	210	44	105	2796

CHAPTER 5: GROUND WATER HYDROLOGY

Lynn Vogler and Thomas McClain

The ground water hydrology of Cheyenne Bottoms is a unique system compared to surrounding areas. Since the Bottoms is essentially a closed basin topographically, surface runoff flows in from all directions except the southeast side. This includes water from Blood, Deception, and Walnut Creeks and the Arkansas River. The surface water then recharges the ground water system. The ground water flows slowly toward the southeast, and leaves the basin through a narrow subsurface gap (Latta, 1950).

Water level recorders, observation wells, and meteorological equipment installed at the Bottoms are beginning to provide the information necessary to better analyze the hydrologic system, although the length of record is not presently enough to provide good answers. One significant piece of data that has been analyzed are recent ground water levels. These indicate that the water table in the Bottoms is essentially at the same level as that measured by Latta in 1942. This can be seen in the following two examples of Latta's wells and observation wells installed in 1985. In 1942 Latta recorded a water level elevation of 1792 feet for well 18-12-16 bbb; well 18-12-9 cbb, one half mile away, installed in early 1985 had a water level levation of 1791.7 feet. In 1942 well 18-12-35ccc had a water level elevation of 1793 feet, while 18-12-34 dba, 1.5 miles away, had a 1985 water level elevation of 1791.8 feet.

The significance of this is that although surface water supplies are declining ground water levels are not. Since the ground water system is an integral component of the hydrologic system at the marsh, a decline in the water table beneath the pools would probably cause more rapid surface water infiltration which would shorten the residence time of the water in the pools.

CHAPTER 6: WATER BALANCE OF CHEYENNE BOTTOMS, KANSAS

Marios Sophocleous and Robert Shapiro

INTRODUCTION

Wetlands are dynamic ecosystems with fluctuating boundaries. They can be characterized in terms of hydrology, vegetation, and soils. The three components interact with each other and with geology and topography to give a wetland its distinctive characteristics. Water entering, stored in, and leaving a wetland can be expressed in terms of a water budget. According to Carter et al. (1978), all natural wetland functions are a result of, or are closely related to, wetland hydrology. Most nutrients, whether dissolved or in particulate form, move through the wetland in or with water. Therefore a basic understanding of the hydrology of the wetland is needed in order to determine overall nutrient budgets.

In order to establish the value of wetlands, we must identify and quantify the hydrologic and biologic functions the wetlands perform. Because hydrology is the dominant influence on all wetland functions, we need to provide an accurate definition of the hydrologic characteristics of wetlands.

WATER BUDGET

Water budgets are often used in hydrologic analysis of wetlands. The water-budget method allows the planner to compute a continuous record of soil moisture, actual evapotranspiration, ground-water recharge, and surface runoff from a meteorological record and some observations on the soil and vegetation. The power of such a technique in planning is obvious. The water balance has been used for computing soil-moisture stress under which natural vegetation can survive, the prediction of streamflow and water-table elevations, the flux of water to lakes, and variations of water level and

salinity. The most obvious use of the water balance is in a basic description of the hydrology of a place or region. The water balance also is useful in predicting some of the human impacts on the hydrologic cycle. The hydrologic effects of changes in weather or changes in vegetation cover can be estimated quickly at a very early stage in planning.

VERSATILE SOIL-MOISTURE BUDGET (VB)

Most water-budgeting techniques make use of the well-known concept of potential evapotranspiration as an indicator of the possible maximum loss of water from the soil under conditions where soil-water supply is not limiting. Budgeting methods for estimating soil moisture and actual evapotranspiration from vegetated soil, when water supply is at times limited, are comparatively more complicated, since they account for various soil and plant characteristics that modulate or alter the potential rate. In this report a meteorological soil-moisture budget called "Versatile Budget" (Baier et al., 1979), which is a multigeneration evolution of the Holmes and Robertson (1959) modulated budget, is employed.

The Versatile Soil Moisture Budget (VB) requires as minimum input only daily-observed data on precipitation and estimates of potential evapotranspiration (PE) or the total sky and solar radiation at the top of the atmosphere (which is available from standard tables as a function of latitude), and daily minimum and maximum temperatures if daily PE values are not available, as in the present case. The VB computerized procedure simulates variations in daily soil-moisture content by making use of physical and biological concepts of water movement in the soil and water uptake by plant roots. The VB output contains daily estimates of actual evapotranspiration (AE) soil-moisture content in several "zones" or layers in the soil profile, and water losses due to runoff and drainage. Because the

data from climatological stations are usually considered to be representative of the surrounding area, we can assume that the estimates of the various hydrologic components based on such data also are representative of this same area and of the soil for which the water characteristics are specified in the particular computer run.

The basic structure of the budget can be described by the flow chart presented by Baier et al. (1979), shown in figure 6.1. Model components can be split into evaporation functions, including all vegetation cover and soil-water extraction characteristics, and recharge functions including infiltration, drainage, runoff, and snowpack submodels.

The validity of the estimates from the VB has been extensively verified by comparison with measured data and by evaluating the efficiency of such estimates in explaining variations of observed crop yields. For further details on the VB and verification, the reader is referred to Baier et al. (1979) and Sophocleous and McAllister (1986).

WATER-BUDGET IMPLEMENTATION

a) Climatic zones: The Cheyenne Bottoms watershed was subdived into three climatic zones in order to model the water budget for the entire basin, based on the distribution of available National Oceanic and Atmospheric Administration (NOAA) climatological stations covering the basin (figure 6.2). The three climatological stations recording daily maximum and minimum temperature and precipitation are the Claflin station, covering mainly the northeastern portion of the basin; the Great Bend station, covering the southwestern portion; and the Bison station, covering the northwestern portion of the basin (figure 6.2).

b) Soils: Four dominant soil associations (Dodge et al., 1981) composed mainly of 9 different soil series, are found within the basin (figure 6.3).

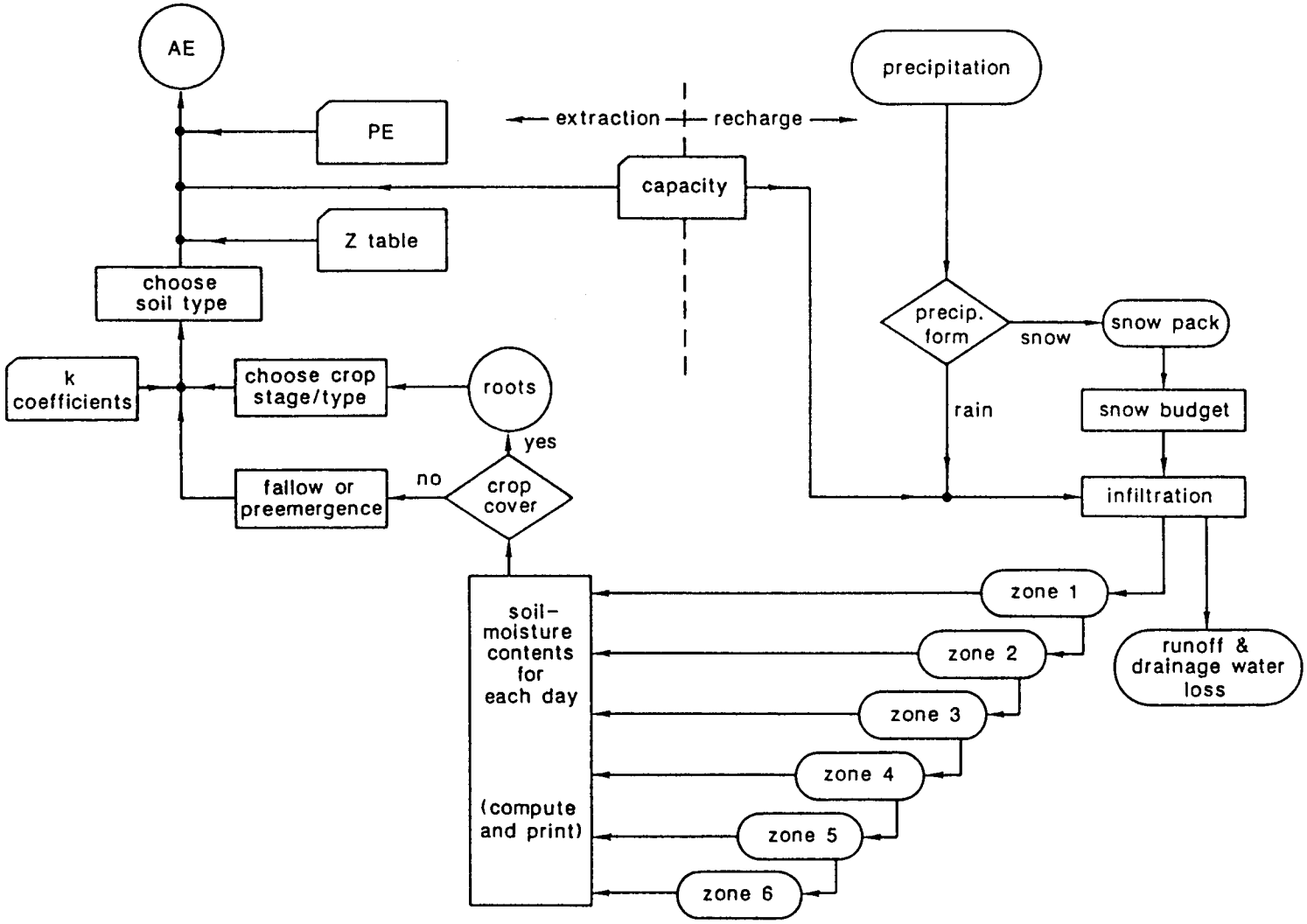

Figure 6.1 Soil-Root-Atmosphere Pathways for Water in the Versatile Budget

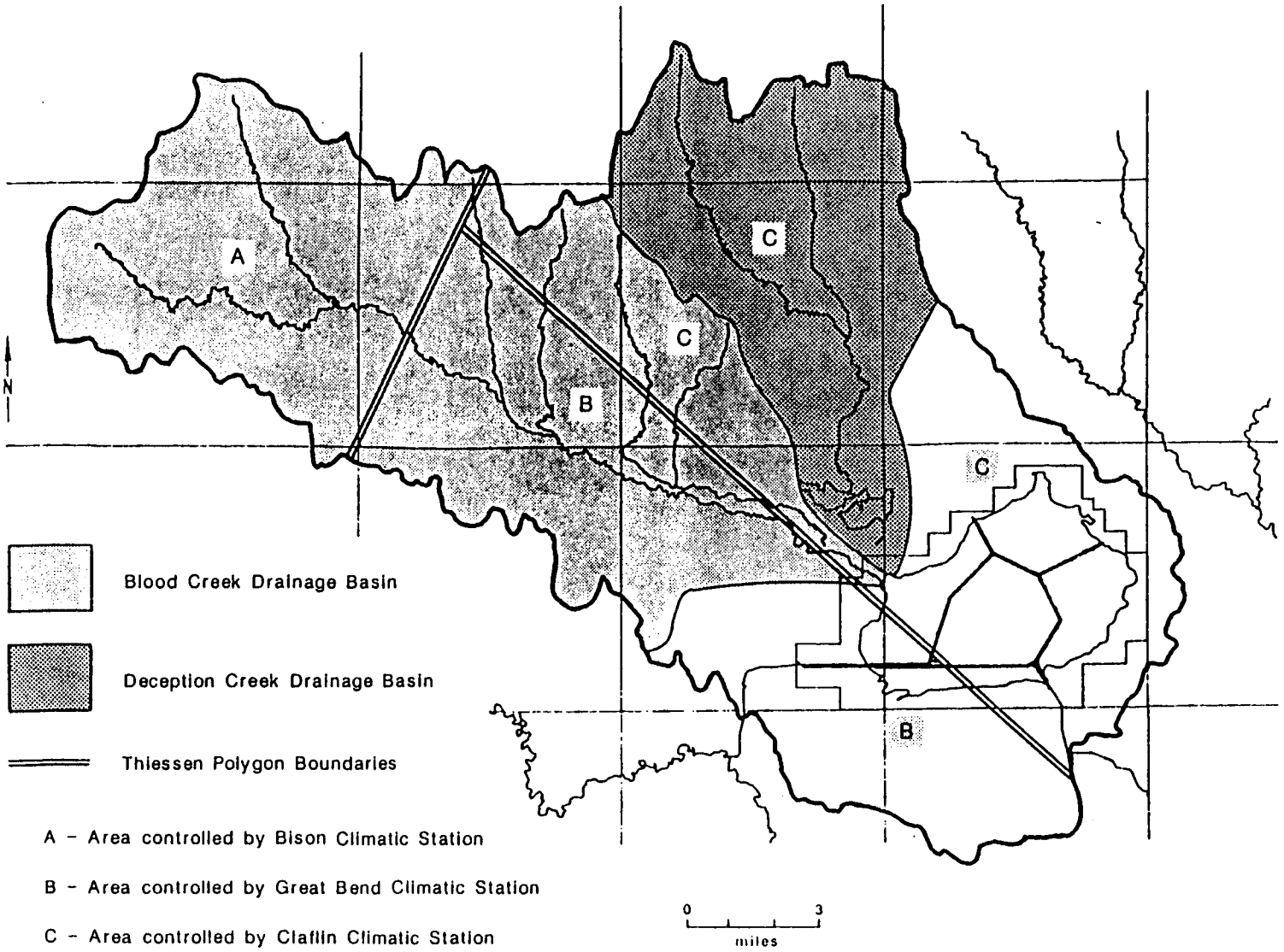

Figure 6.2 Blood and Deception Creek Drainage Basins and Associated Climatic Regions

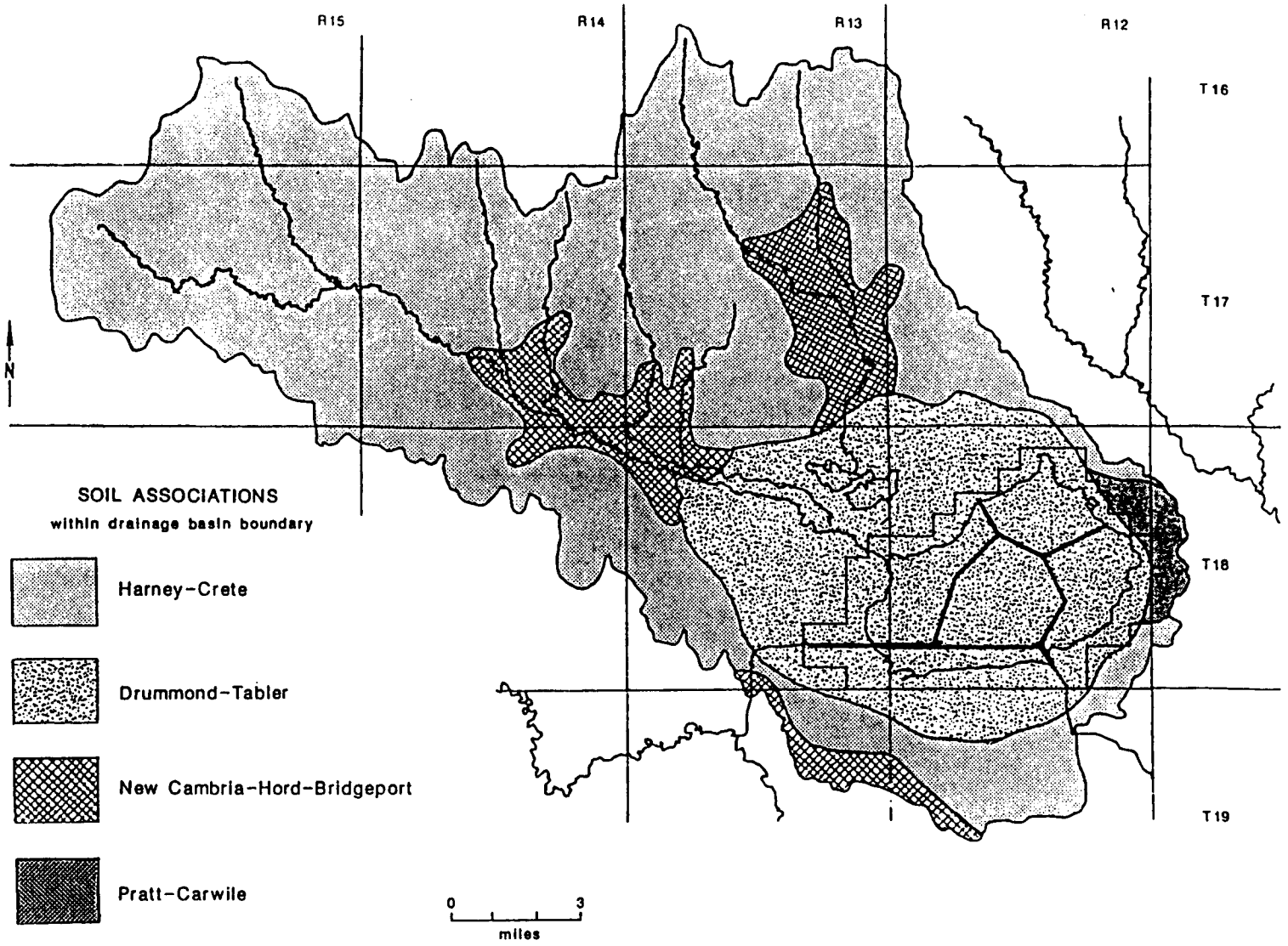

Figure 6.3 Soil Associations of the Cheyenne Bottoms Drainage Basin

For each soil series the available water capacity was determined from the Barton County Soil Conservation Service (SCS) soil survey (Dodge et al., 1981) to depths of 1, 3 and 5 feet. The 1-foot soil depth was used to model the available soil moisture for cattails, since they have a rooting depth of up to 1-foot; the 3-foot soil depth was used to model the available soil moisture for winter wheat and other small grains, since they have a rooting depth of approximately 3 feet. The 5-foot depth, which is generally the depth limit of the SCS soil surveys, was used for all other vegetation covers in the basin, since the highest root density of most crops and grasses is in the upper 5 feet. Soil associations, soil compositions, and available water capacities for each soil are tabulated in table 6.1.

c) Vegetation: In the Cheyenne Bottoms basin, the dominant vegetation types are dryland winter wheat and native grasses (grassland, pasture); in addition, in the Cheyenne Bottoms proper, cattails are prevalent. The vegetation parameters are represented in the versatile budget by crop coefficients. There is a coefficient for each "standard" soil zone and a different set of coefficients for each stage of crop growth. At different plant-growth stages the roots can utilize the moisture in the soil profile at different depths and rates. Crop coefficients for winter wheat (and small grains) were modified from Baier et al. (1979) and Vanderlip and Brown (1974).

Table 6.1-Soil characteristics-Cheyenne Bottoms drainage basin.

Soil association (area)	Soil percentage composition	Total available water capacity for upper 5 feet (inches)
Pratt-Carwile ($4.00\ mi^2$)	Pratt - 55% Pratt - Tivoli - 11% Narum - 15% Tabler - Drummund - 10%	6.89
New Cambria-Hord-Bridgeport ($24.15\ mi^2$)	Hord - 50% New Cambria - 23% Harney - 22%	10.82
Drummond-Tabler ($59.88\ mi^2$)	Drummond - 35% Tabler - Drummond - 20% Tabler - 5% Hard - 4% Naron - 3% (water-covered area - 25%)	8.89
Harney-Crete ($149.87\ mi^2$)	Harney - 60% Crete - 15% Nibson - Wakeen - 8% Wakeen - 8%	10.17

Crop coefficients for natural growth (simulated as brome grass) and alfalfa are those presented in Baier et al. (1979). With regard to cattails we had difficulties obtaining crop coefficients. A literature search resulted in very few relevant publications, the most useful of which was the study by Krolikowska (1978). Analysis of actual and potential evapotranspiration data from that publication in conjunction with field observations at the Cheyenne Bottoms resulted in the crop coefficients used in this study. The various crop-growth stages and corresponding dates, as well as the crop coefficients adopted in this report, are shown in table 6.2.

The components of the water balance resulting from the versatile-budget procedure were added by a specially written program to check for input errors and to determine the range of error within the calculations. The utility program calculated the hydrologic-balance equation error as

$$PCP + SD - ET - DR - RO = error$$

where PCP = precipitation (in)

SD = soil-moisture deficit (in)

ET = evapotranspiration (in)

DR = deep drainage (in)

RO = surface runoff (in)

Large errors were considered to be input errors and were traced to their cause and corrected. Small errors, generally less than 1% of total precipitation, were considered to be due to cumulative rounding errors.

Table 6.2-Crop-growth stages and crop coefficients for Cheyenne Bottoms vegetation.

Crop	Growth Stage Dates	Growth Stages	Crop Coefficients					
	9/20-10/17	Fallow	.40	.15	.12	.10	.02	.01
Wheat-Fallow	10/18-11/30	Planting to emergence	.40	.15	.12	.10	.02	.01
	12/1-3/1	Dormancy	.40	.15	.12	.10	.02	.01
(Small Grains)	3/2-5/1	Spring growth to heading	.17	.13	.10	.07	.09	.02
	5/2-5/20	Heading to soft dough	.33	.15	.14	.12	.01	.05
	5/21-6/15	Soft dough to ripening and harvest	.22	.13	.12	.10	.06	.04
	6/16-10/10	Fallow	.40	.15	.12	.10	.02	.01
Brome Grass (grass-land, pasture)	9/20-3/15	Dormancy	.50	.20	.10	.04	.02	.01
	3/16-10/10	Growth	.55	.19	.17	.08	.03	.01
Cat-tails	9/20-3/15	Dormancy	1.97	.75	.39	.16	.08	.04
	3/16-10/10	Growth	2.16	.79	.67	.31	.12	.04
Alfalfa	9/20-11/20	Full cover	.50	.25	.25	.20	.18	.12
	11/21-4/1	Dormancy	.50	.20	.10	.04	.02	.01
	4/2-4/9	Spring growth to full cover	.50	.20	.15	.12	.08	.05
	4/10-5/20	Full cover to first cut	.50	.25	.23	.22	.15	.10
	5/21-6/10	First cut to full cover	.50	.22	.18	.15	.15	.10
	6/11-7/10	Full cover to second cut	.50	.25	.25	.20	.18	.12
	7/11-8/1	Second cut to full cover	.45	.25	.20	.20	.20	.15

8/2-9/5	Full cover to third cut	.50	.25	.25	.20	.18	.12
9/6-10/10	Third cut to full cover	.45	.25	.20	.20	.20	.15

RESULTS AND DISCUSSION

Table 6.3 summarizes the results of the water budget for the nonwater-covered area (more than 86% of total area) of the Drummond-Tabler soil association which encompasses the Cheyenne Bottoms (figure 6.3). This budget was run for the last two water years for which data were available at the time (October 1, 1982, to September 30, 1984), and the results for the area not covered by open water were averaged for a water-year period (table 6.3).

Table 6.3-Two consecutive water-year budget (1983 and 1984)
for the Drummond-Tabler soil association
(Units in inches, except those in parentheses which are in acre-feet);
total area equals 59.88 square miles (38,323 acres).

PCP	AE	SD	RO	DR	AREA WEIGHT*	VEG.COVER
21.76	19.11	1.99	0.71	3.65	.44	Small
(59,869)*	(52,578)	(5475)	(1953)	(10,042)		grains
21.76	23.21	3.09	0.48	1.00	.40	Grasses
(59,869)	(63,858)	(8502)	(1321)	(2751)		
21.76	21.53	0.17	0.25	0.02	.12	Cattails
(59,869)	(59,236)	(468)	(688)	(55)		
21.76	24.17	2.92	0.51	0.00	.04	Alfalfa
(59,869)	(66,500)	(8034)	(1403)	(0)		

AREA-WEIGHTED AVERAGES:

21.76	21.24	2.25	0.55	2.01

CANAL INFLOW: 1.39
CANAL OUTFLOW: 0.00

*Excluding water areas (approx. 5,307 acres)

PCP -- precipitation
AE -- actual evapotranspiration
SD -- soil-moisture deficit
RO -- surface runoff
DR -- deep drainage

Using native grasses as an example, actual evapotranspiration from the grasses (23.21 inches) was higher than the precipitation in the area (21.76 inches), resulting in a soil-moisture deficit of 3.09 inches. Runoff from grassland during the accounting period amounted to 0.48 inches, while deep drainage was 1 inch (table 6.3).

Natural precipitation is seen to be the dominant water source in the area, while actual evapotranspiration is the predominant water-"loss" term. Soil-moisture deficit, which is the next (second in magnitude) water-"loss" term, indicates that climatic, vegetation, and animal water-use consumption exceeds the combined sum of precipitation, canal-water import, and moisture of the soil profile. It should also be noted that final soil-moisture deficit values are not monotonically cumulative, like values of precipitation, evapotranspiration, drainage, and runoff, but are a running algebraic total (with positive and negative values). Because the final soil deficit indicated in the tables of this report is responsive mainly to the weather conditions of the previous few weeks, the reader is referred to the time distribution of water-balance components shown in figs. 6.7-6.9 (to be discussed in greater detail later).

Alflafa, prairie grasses, and cattails consumed on an area-weighted average 34.5% more water than small grains, such as wheat and millet, during the water-budget accounting period. The largest contributor to deep drainage losses, however, was the small-grains group, mainly because of its shallower root system compared to the prairie-grasses group and its lower transpiration activity. In comparing the values of the water-balance components from this and other following tables, the different depths of the root zone for various vegetation covers should be kept in mind. Thus, for the Drummond-Tabler soil association, the available water capacity, which is a measure of the maximum-

possible soil-water deficit, is 1.9 inches for cattails, 5.3 inches for small grains, and 8.8 inches for grasses and alfalfa over the soil thickness of the root zone.

It is worthwhile noting (refer to figure 6.4) that during the two-water-year budget-accounting period an average of only 4,429 acre-feet/year were imported in the Bottoms through the inlet canal and none was released at the outlet, compared to 10,000-20,000 acre-feet/year, on the average, imported during the 1960's and 1970's (figure 6.4). Streamflow data from Blood Creek are not available since 1980. If the average streamflow data during the water years 1978 and 1979 were taken as representative of recent conditions, then less than 2,000 acre-feet/year would have entered the Drummond-Tabler soil association, which amounts to approximately 0.6 inches of water over the Drummond-Tabler area. Contributions from the Deception Creek subbasin, which were never measured, are expected to be less than half of those from the Blood Creek subbasin due to the smaller size of the Deception Creek subbasin (figure 6.2). These amounts of water were probably consumed in the Bottoms-general area since canal outflow during the 1983 and 1984 water years was zero. It is interesting to note that the total water imports to Cheyenne Bottoms from Blood and Deception creeks and the inlet canal from the Arkansas River are much less than the amount of water contributed to the Bottoms from natural precipitation. For example, during 1980, the last year for which streamflows in Blood Creek are gaged, the total water imports to the Bottoms was less than 20% of natural precipitation at the Bottoms area.

Blood and Deception Subbasins

A water balance-simulation also was run for the entire Blood (approximately 112.5 square mile) and Deception (approximately 46.6 square mile) creeks subwatersheds (figure 6.2) to assess the various hydrologic

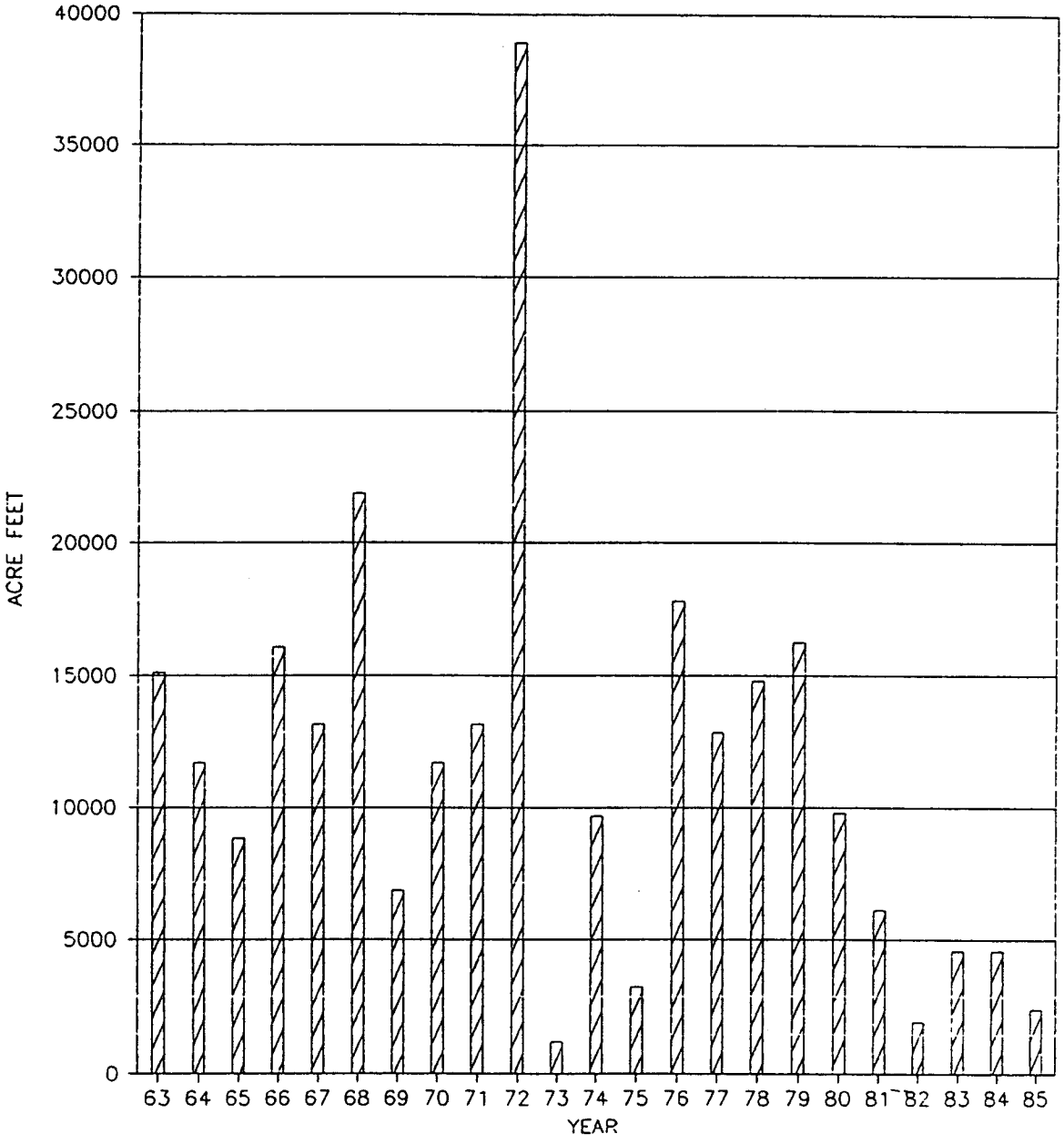

Figure 6.4 Water Received at Cheyenne Bottoms

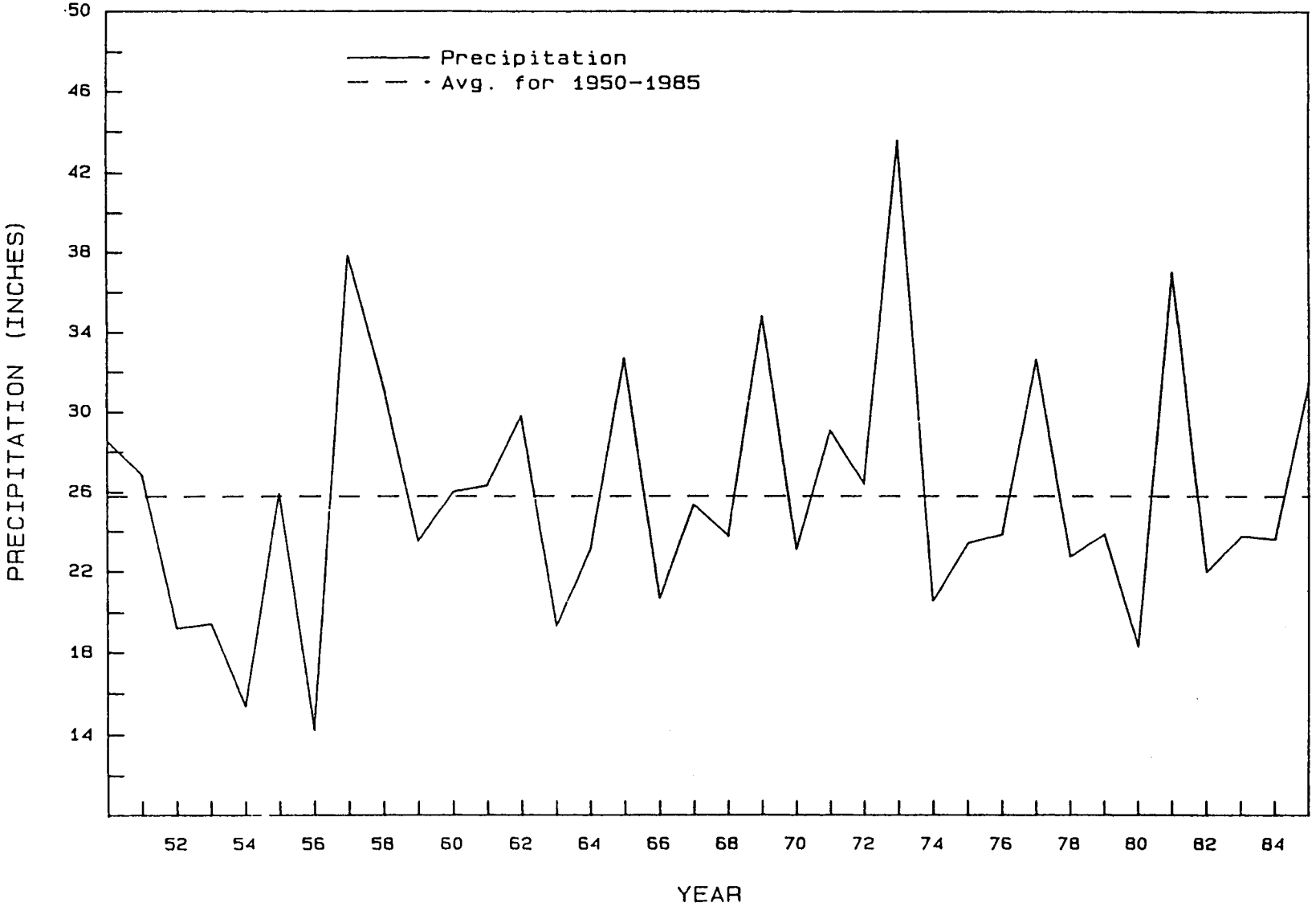

Figure 6.5 Annual Precipitation at Great Bend, 1950-1985

Table 6.4-Water budget for the Blood Creek subbasin
area equals 71,972 acres
(units in inches, except those in parentheses which are in acre-feet).

Water Year	Type	PCP	AE	DR	RO	SD	Crop
1956	Dry	11.92 (71,492)	16.87 (101,180)	.45 (2699)	.49 (2939)	5.71 (34,247)	WH
1984	Normal	24.01 (144,004)	19.09 (114,495)	6.94 (41,624)	1.27 (7617)	3.70 (22,191)	WH
1957	Wet	35.20 (211,118)	26.78 (160,618)	6.78 (40,664)	1.98 (11,875)	0.39 (2339)	WH
1956	Dry	11.92 (71,492)	18.88 (113,236)	.32 (1919)	.44 (2639)	8.21 (49,241)	GR
1984	Normal	24.01 (144,004)	24.33 (145,923)	4.06 (24,351)	.82 (4918)	5.44 (32,627)	GR
1957	Wet	35.20 (211,118)	35.25 (211,418)	1.89 (11,336)	1.82 (10,916)	3.85 (23,091)	GR

WH = small grains
GR = native grasses

Table 6.5-Water budget for Deception Creek subbasin
area equals 29,841 acres
(units in inches, except those in parentheses which are in acrefeet).

Water Year	TYPE	PCP	AE	DR	RO	SD	Crop
1956	Dry	10.80 (26,857)	15.98 (39,738)	0.94 (2338)	0.08 (199)	5.81 (14,448)	WH
1984	Normal	23.90 (59,433)	18.38 (45,706)	8.02 (19,944)	0.89 (2213)	3.51 (8728)	WH
1957	Wet	36.86 (91,662)	25.67 (63,835)	10.68 (26,558)	1.12 (2785)	0.75 (1865)	WH
1956	Dry	10.80 (26,857)	18.23 (45,333)	0.29 (721)	0.08 (199)	8.14 (20,242)	GR
1984	Normal	23.90 (59,433)	23.44 (58,289)	4.61 (11,464)	0.84 (2089)	5.09 (12,658)	GR
1957	Wet	36.86 (91,662)	34.54 (85,892)	4.56 (11,340)	1.18 (2934)	3.57 (8878)	GR

WH = small grains
GR = native grasses

The effect of native grasses as contrasted to small grains on the components of the water balance is apparent from tables 6.4 and 6.5. Thus, actual evapotranspiration (AE) and soil-moisture deficit (SD) are higher, and deep drainage (DR) and surface runoff (RO) are lower in grasslands compared to small-grain lands.

A compilation of surface-runoff estimates from several daily water-budget simulations of the area with varying precipitation inputs (including the ones in tables 6.4 and 6.5) resulted in the rainfall-runoff relationship shown in figure 6.6. Such a relationship is essential for development and engineering works at the Cheyenne Bottoms since the expected surface-runoff amounts could be predicted using this relationship for various amounts of yearly rainfalls. Unfortunately, stream-gaging records at Blood Creek near the Boyd gage, during the chosen average, below- and above-average years are not available for comparison of simulated and observed runoff values. However, a simulation run during the 1965 water year, for which streamflow data at the above-mentioned station are available, resulted in a Versatile Budget estimate of 1.01 inches for small grains. Precipitation during that water year was 23.59 inches, which amounts to 3,113.5 acre-feet (drainage area up to the streamflow-gaging station is 36,992 acres). This compares well with the measured streamflow of 3,070 acre-feet during that water year.

Time patterns of hydrologic variables

The time distribution of maximum and minimum daily air temperature, precipitation, soil-moisture deficit of the root zone, deep drainage, and runoff, as well as cumulative values of actual evapotranspiration and precipitation are shown in figs. 6.7, 6.8, and 6.9 for three plant covers (cattails, native grasses, and small grains) for the Drummond-Tabler soil association encompassing the Cheyenne Bottoms. Note the minimal amounts of

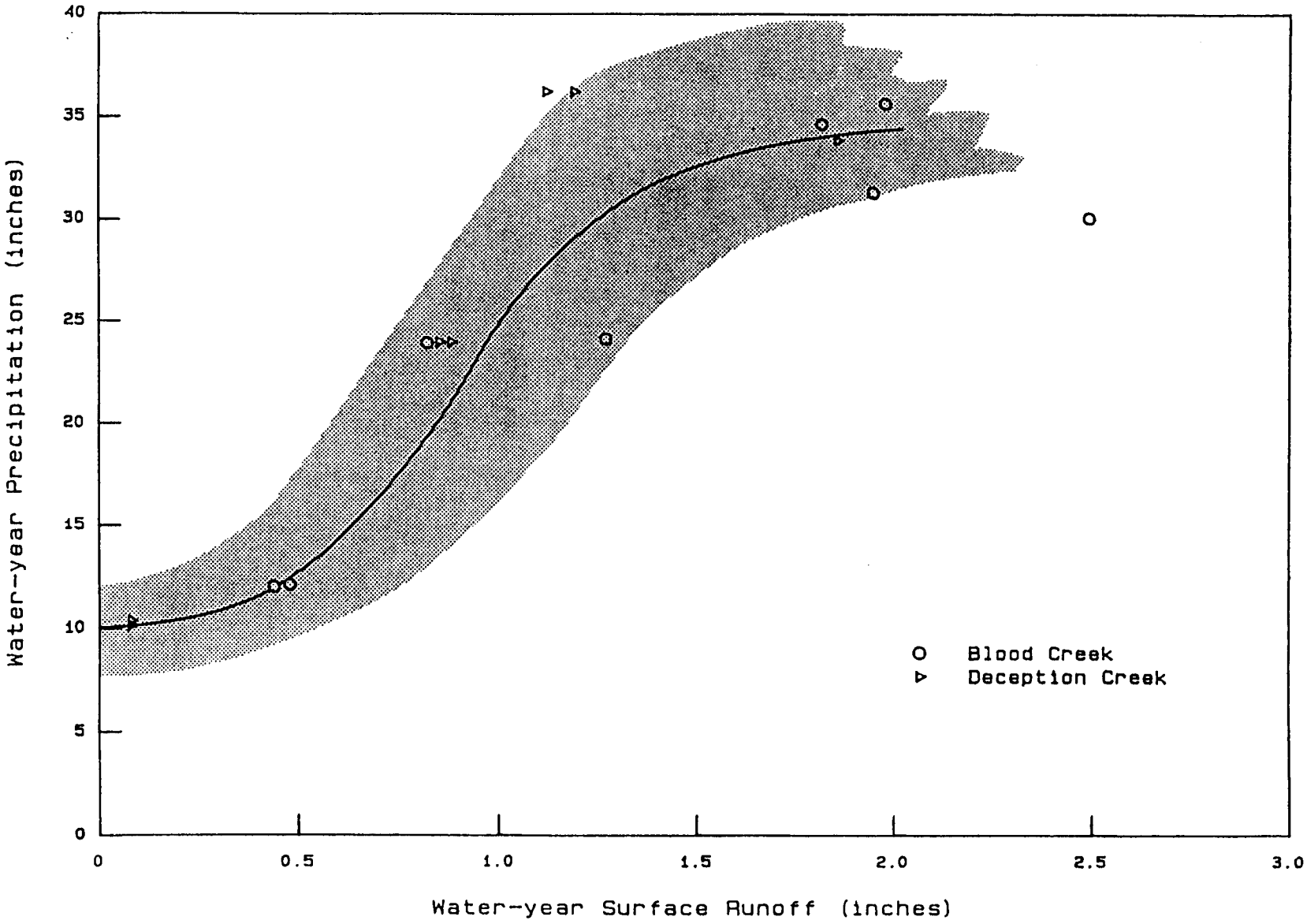

Figure 6.6 Average Rainfall-Runoff Relationship in the Cheyenne Bottoms Watershed

deep drainage and runoff from areas covered by cattails (figure 6.7), as compared to areas covered by small grains (such as wheat, figure 6.9); areas covered with prairie grasses (figure 6.8) exhibit intermediate deep drainage and runoff values, but create higher soil deficits because of deeper root systems and longer growing seasons. Note the relatively constant water demand of cattails which results in a relatively constant water deficit over time as shown in figure 6.7. This water demand is so high that the entire precipitation amount over time is consumed--note the cumulative precipitation (PCP) and actual evapotranspiration (AE) for cattails compared to small grains and grasses.

SUMMARY

All natural wetland functions are closely related to wetland hydrology. Water entering, stored in, and leaving a wetland can be expressed in terms of a water budget. In this study, a meteorological water budget called "Versatile Budget" is employed to estimate daily values of actual evapotranspiration, soil-moisture content in several zones, or layers in the soil profile (and hence soil-moisture deficits or surpluses), and water losses due to surface runoff and deep drainage.

In order to employ this water-budgeting technique, the Cheyenne Bottoms watershed was subdivided into three climatic zones and four dominant soil associations. Predominant vegetation covers were small grains and native grasses. Results from this water-budgeting procedure demonstrate that precipitation is the principal water supply of the Cheyenne Bottoms (much larger than the combined flows of the Blood and Deception creeks, and the inlet-canal water inports), while actual evapotranspiration is the major water-depletion process and of comparable magnitude to precipitation.

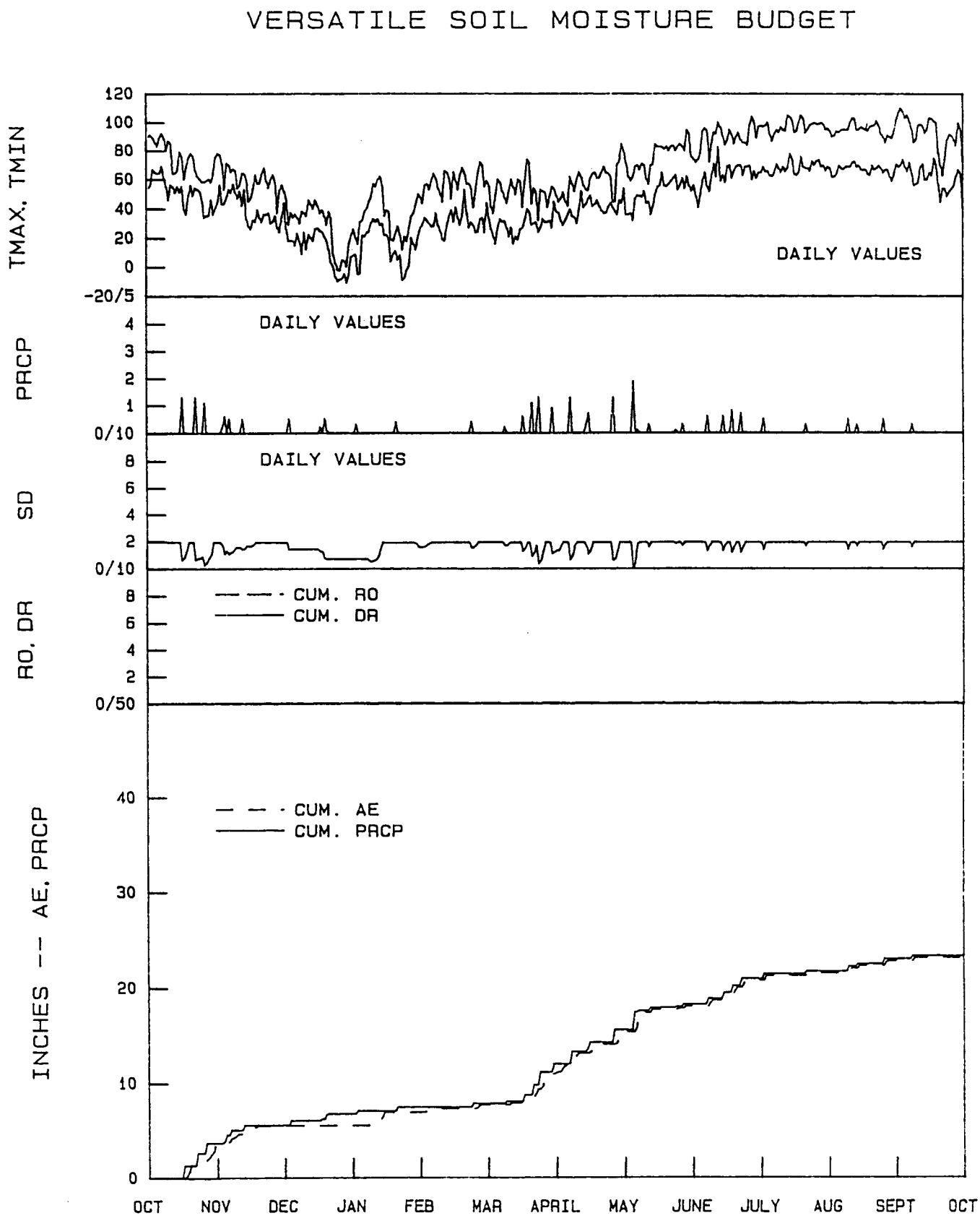

Figure 6.7 VB Results for Cattails in the Drummond-Tabler Association, Claflin Climate Region, Water Year 1984

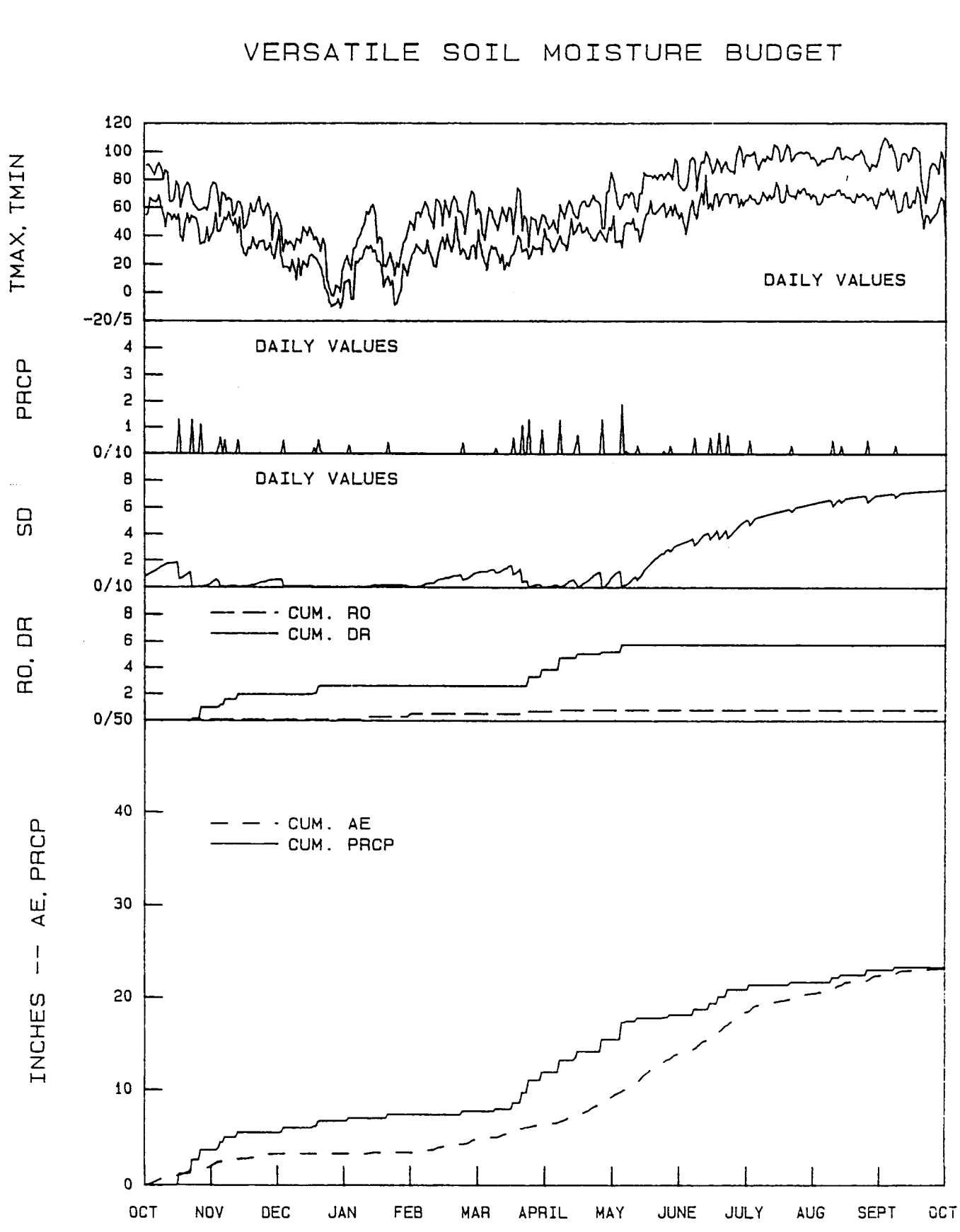

Figure 6.8 VB Results for Grasses in the Drummond-Tabler Association, Claflin Climate Region, Water Year 1984

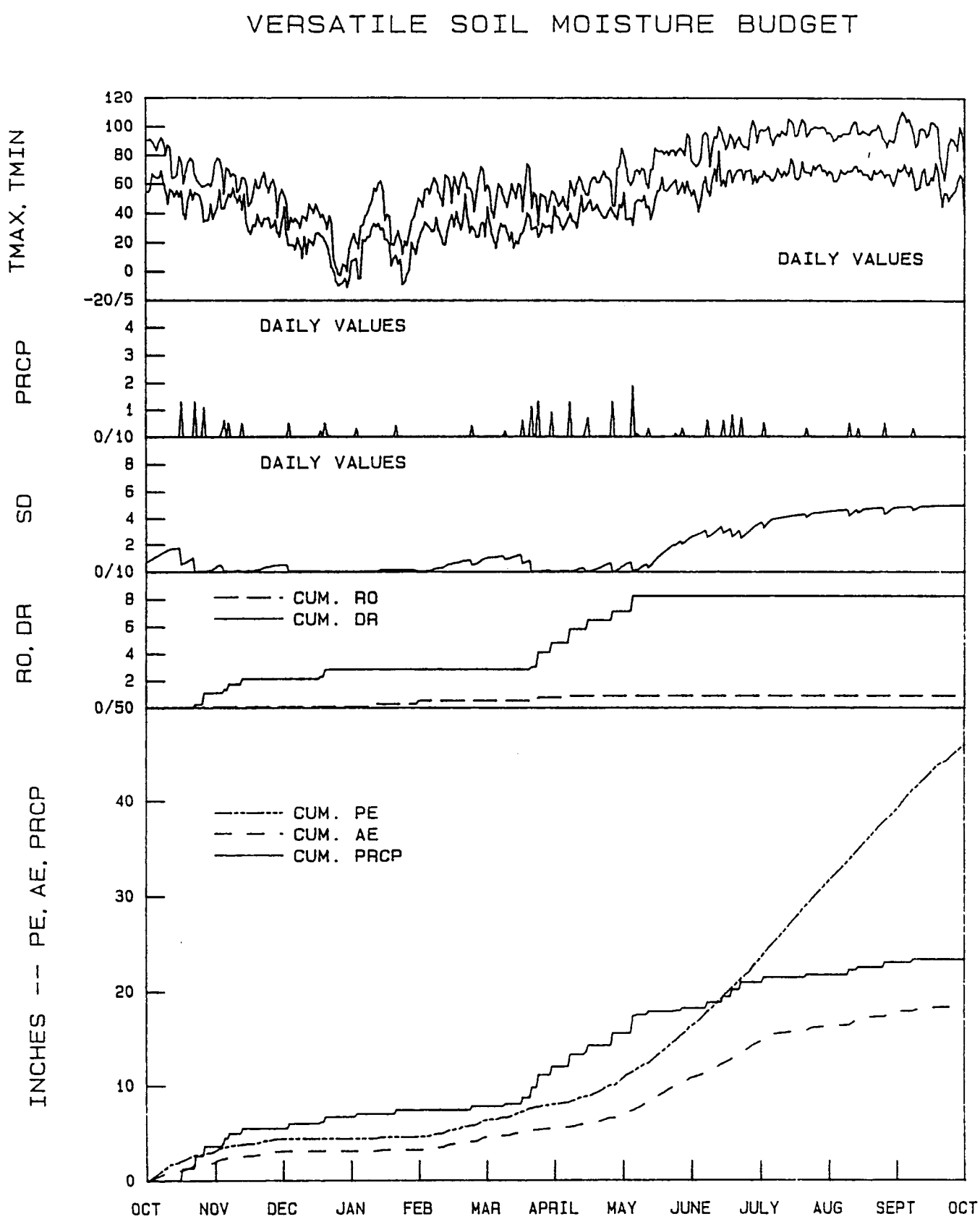

Figure 6.9 VB Results for Small Grains in the Drummond-Tabler Association, Claflin Climate Region, Water Year 1984

Water resources of the basin were also demonstrated to not be sufficient to meet the natural water demands, resulting in appreciable soil-moisture deficits. The effects of vegetation on water use are significant, with prairie grasses, cattails, and alfalfa transpiring higher amounts of water and creating larger soil-moisture deficits compared to small grains. However, deep drainage from small grains is larger compared to the other vegetation types considered in this report.

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CHAPTER 7: THE EFFECT OF LAND USE ON RUNOFF IN THE CHEYENNE BOTTOMS WATERSHED

Gary Welker

INTRODUCTION

This study focuses on the surface hydrology of a marsh, the Cheyenne Bottoms, and its relationship to the land use conditions in the watershed of the wetland. The assessment of land use practices in the watershed involves identifying changes in land use over time. Land use conditions under investigation in this research project were land cover conditions (cropping practices) and soil and water conservation practices.

The hydrologic cycle of a wetland can be viewed as a closed system, in which numerous variables exist that influence the volume of water stored in a wetland at a certain point in time. These variables include precipitaion, surface flow (inflow and outflow), ground water (inflow and outflow), and evapotranspiration. In this study the precipitation and surface water segments of the hydrological regime were investigated, particularly the relationship between surface water and land use.

SURFACE FLOW

When a wetland, such as the Cheyenne Bottoms, is lower than its surrounding watershed, surface water may flow into the marsh via two pathways. Overland flow (runoff) is nonchannelized sheetflow of water occurring where soil infiltration rates are exceeded by precipitation rates. Overland flow occurs immediately after excess rainfall or snow/ice melt. The general sequence of events are as follows: 1) A thin layer of water forms on the surface, and downslope surface flow begins. 2) Flowing water accumulates in surface depressions. 3) The surface depressions fill, then overflow. 4) Overland flow enters micro-channels, these micro-channels unite to form

rills, the rills form rivulets which discharge into small gullies, and the gullies empty into channels. 5) Along each channel, lateral inflow from the land surface takes place (Cook, 1946).

The second pathway for surface water flow into a wetland is through channelized streamflow. Streamflow sources can be from overland flow, ground water and/or direct precipitation. Surface flow into a marsh such as Cheyenne Bottoms generally occurs in times of excess precipitation which usually leads to flooding.

A very important element of surface flow is rainfall intensity. High intensity precipitation generally occurs for a short time and over a small area. Storms which cover large areas tend to be of low intensity but may last for periods of days. Flooding normally occurs when high intensity rainfall lasts unusually long.

LAND USE

Land use conditions can have profound effects on overland flow and in turn can affect streamflow in a watershed. The difference between water yield from pastured land and land with row crops is significant. Land treatments, such as soil and water conservation practices, serve to further influence the volume of overland flow. Land use in the Cheyenne Bottoms watershed is almost exclusively agricultural. Census data for 1939 and 1982 for Barton County reveal that agricultural land use comprised 98.8% and 97.6% of the county, respectively (USDC, 1942, 1982). Urban or built-up land uses (transportation, residential, commercial, industrial, etc.) along with sparse riparian forest along Blood and Deception creeks constitute the remaining few percentages of land use in the Cheyenne Bottoms watershed.

Cropping Practices

Cropping practices (soil-cover complexes) in the Cheyenne Bottoms watershed were categorized as row crops, small grains, fallow, and pasture. Cropping practices can significantly affect the volume of surface flow in a watershed. For example, grassed watersheds will yield less runoff annually than row cropped watersheds of the same size. Furthermore, soil and water conservation methods on the various cropping practices can also affect surface flow volumes. The conservation practice of mulching (conservation tillage) increases infiltration and reduces runoff. The soil and water conservation practices of concern in this study were terracing, water impoundments, and conservation tillage. The type and moisture content of a soil form the basis of land use/runoff assessment. Soils are categorized by their infiltration properties, which can be directly related to runoff potential. The amount of moisture present in soil is known to have significant effects on runoff rates and volume (McCuen, 1982).

Terraces

Terraces can be placed into two main categories, broad based or bench. Bench terraces are primarily constructed for the reduction of land slope. Broad based terraces, the terrace type under investigation in this study, remove or retain water on sloping land for the purpose of soil erosion control. These terraces can be constructed, depending upon the type of broad based terrace, using excavated soil from the uphill or downhill side of the terrace ridge. The alignment of terraces will be either parallel or nonparallel depending upon topography, machinery operations, and cropping practices.

Broad based terraces can be segregated into graded and level terraces. The level terraces' primary function is moisture conservation with erosion

control a secondary benefit. In low to moderate rainfall climates, level terraces restrain runoff so that the moisture may percolate into the soil.

Graded terraces were most prevalent in the Cheyenne Bottoms watershed. The primary purpose of graded terraces is to control soil erosion by reducing slope length and diverting runoff to outlets at nonerosive velocities (Schwab et al., 1981). Beasley et al. (1984) concur that graded terraces are mainly for erosion control but point out that they also conserve moisture. Graded terraces are constructed by cutting a shallow channel uphill of the terrace ridge. The excavated material is used to form the terrace ridge and the resultant channel or depression may be used to hold runoff or to divert runoff to an outlet system.

Outlet Systems

Outlet systems commonly associated with terraces can be grouped into three categories; internal drainage (infiltration), underground outlets and grass waterways. Grass waterways transport water more economically than underground outlets and were prevalent in the Cheyenne Bottoms watershed. In this study grass waterways were placed into the pasture land use category.

Water Impoundments

Water impoundments generally can be categorized as either excavated ponds or embankment ponds. Excavated ponds are constructed below orignal ground surface, and usually on flat terrain where diversion dams are not feasible. Water for excavated ponds is supplied by overland flow (runoff) and/or ground water where the water table is intersected by the excavation.

Embankment ponds are formed by earthen structures (dams) across gullies or natural depressions. These ponds are generally built above ground on fair to moderate slopes. Water is generally supplied by surface water runoff, as

opposed to groundwater inflow (Beasley et al., 1984). Water loss from water impoundments results from evaporation and seepage. Seepage varies widely according to soil types and construction techniques. Smith (1955) estimates 1 inch per month for good construction techniques and 2 inches per month for fair construction practices or permeable soils.

Conservation Tillage (mulching)

Conservation tillage, as defined by Crosson (1982) is the presence of crop residue on the soil surface, which reduces soil and wind erosion, and in the Great Plains increases soil moisture. The amount of crop residue left on the ground can vary but to be defined as conservation tillage, enough residue must remain to significantly reduce soil erosion, when compared to conventional tillage. Conventional tillage uses a millboard plow to bury or remove residue. Conservation tillage does not disturb or invert the soil as much as conventional tillage but does rely more on the use of herbicides.

PURPOSE OF STUDY

The purpose of this study was to ascertain if land use practices in the Cheyenne Bottoms watershed have affected surface flow into Cheyenne Bottoms. Future and presettlement surface water conditions in the watershed will be predicted from projections of future land use patterns.

METHODS

An initial survey confirmed the presence of soil and water conservation practices including gradient terraces and water impoundments in the Cheyenne Bottoms watershed. A watershed map (figure 7.1) and 7 1/2 minute topographical maps of the Cheyenne Bottoms watershed were obtained from the Kansas Geological Survey. The watershed map was 1 inch to a mile in scale and detailed the main creeks in the Cheyenne Bottoms watershed along with an

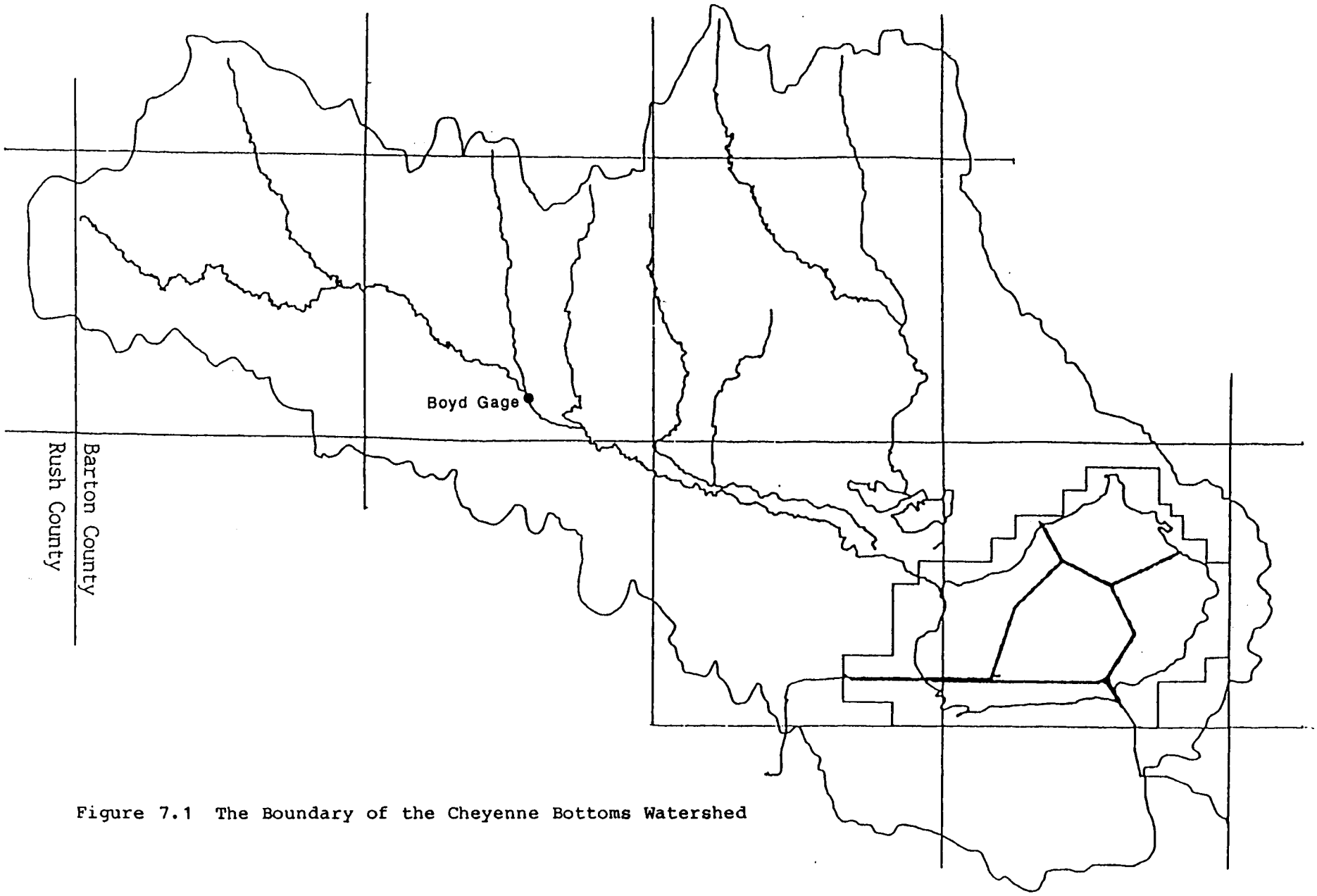

Figure 7.1 The Boundary of the Cheyenne Bottoms Watershed

outline of the watershed itself. Thirteen topographic maps were needed to cover the Cheyenne Bottoms watershed area. The watershed boundary was inscribed on the topographic maps, and then the maps were cut and taped together to form a topographic mosiac of the watershed.

The impact of land use practices on overland flow in the Cheyenne Bottoms watershed was assessed for five time periods. These were presettlement (1850), pre-terrace construction (1938), the mid-point of terrace construction (1965), present-day conditions (1984), and future conditions (year 2000). In conversations with the Barton County Soil Conservation Service (SCS) and the Barton County Agricultural Stabilization and Conservation Service (ASCS), it was determined that the period before 1940 could be considered pre-terrace construction. The midpoint of terrace construction in Barton County was considered to fall in the mid-1960's (figure 7.2). A set of 1938 black and white aerial photographs were located in storage at the Barton County SCS office and were studied there. Black and white 1965 aerial photographs were obtained from the ASCS Aerial Photography Field Office (2222 West 23rd South, P.O. Box 30010, Salt Lake City, Utah 84125). Present-day photography was obtained from the Barton County ASCS office in Great Bend, Kansas. The 1984 aerial photographs were 35mm color slides used by the ASCS county office to obtain crop information. Terraces and water impoundments in the Cheyenne Bottoms watershed were traced on tracing paper. Tracing the 1984 color slides involved projecting the image onto a white, heavy grade paper and outlining the targeted features. The mosaic of topographic maps was compared to the aerial photography to determine the affected area of land behind each terrace. The affected area was defined as the area between the lowest terrace on a slope and the ridge of that same slope. Each northeast quarter section was measured and the results multiplied by four. All water impoundments were

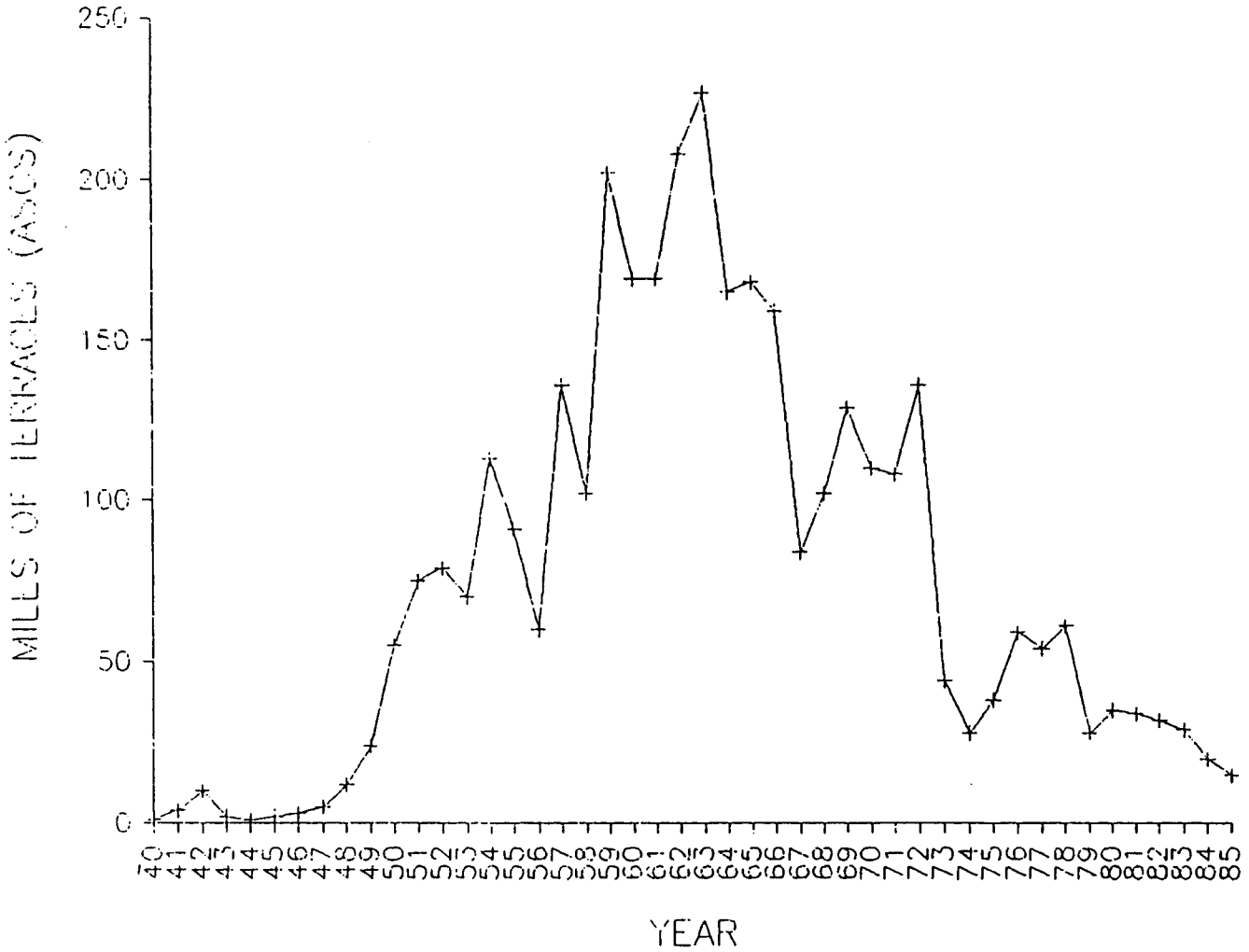

Figure 7.2 This graph represents the number of terraces constructed in Barton County, Kansas, per year, with federal assistance (ASCS)

visually identified and then traced. Each water impoundment boundary was traced according to bank capacity, not the water area at the time the photographs were taken. Scale factors for each of the three sets of photographs were calculated by measuring three distances in the field, then comparing them to the measurements taken from the three sets of photographs for the same points of reference. Once the tracings had been completed, the surface areas of terraces and water impoundments were measured with a Lasico, model #L30, compensating polar planimeter. In conjunction with the land use measurements, the watershed map land-area coverage was measured using the polar planimeter.

The soil survey of Barton County, provided by the Barton County SCS, was used to determine the number and area of the different soil types in the Cheyenne Bottoms watershed. The soil survey contains numerous aerial photographs of Barton County with soil boundaries inscribed on the photos. These photos were measured with the same planimeter used on the land use assessment. Each northeast quarter section was measured and the overall results were multiplied by a factor of four. The final results of soil types and amounts were placed into the four SCS hydrologic soil groups, to estimate the runoff potential from precipitation.

General precipitation records were obtained from the 67th Annual Report and Farm Facts book published by the Crop and Livestock Reporting Service of Kansas (Kansas State Board of Agriculture, 1984). The precipitation average used for Barton County, 25.57 inches per year, is an overall average covering the years 1951-1980.

Agricultural cropping practices play a major role in impeding or facilitating overland flow in a watershed. Cropping practices were grouped into four categories: pasture, small grains, row crops, and fallowed land.

Land use information for the whole of Barton County was obtained from the Annual Report and Farm Facts books for the years 1938, 1965 and 1984 (Kansas State Board of Agriculture, 1938, 1965, 1984) and U.S. Bureau of Census records (1939). This information was used to estimate the crop acreage in the watershed in 1938, 1965, and 1984. The Manhattan, Kansas, ASCS office provided data on agricultural terraces and water impoundments that were constructed in Barton County with federal monetary assistance. The water impoundment figures are from 1940 to 1983 and are the number of impoundments constructed per year (figure 7.3). The terrace data are from 1940 to 1985 and illustrate the linear distance of terrace construction per year (figure 7.2).

Land use figures were estimated for the presettlement (1850) period in discussions with Dr. James Koelliker, professor of Agricultural Engineering, Kansas State University. The year 2000 land use values were estimated after discussions with Dr. Koelliker and the Barton County SCS staff and after assessing land use trends. The "Water Yield Analysis" model used in this study was developed by Dr. Koelliker. Water Yield Analysis computes the affects of upland soil and water conservation practices on various cropping practices and estimates the water yield for a given watershed. The model was run on a Zenith 158 microcomputer after consultation with Dr. Koelliker.

The Cheyenne Bottoms watershed is drained predominantly by two creeks, Blood and Deception. A stream flow gage was in operation on Blood Creek from March 1962 to September 1980, located near Boyd, Kansas (lat 38° 32' 10", long 98° 51' 35", in NE NW sec. 34, T. 17S., R. 14 W., Barton County, at the downstream side of the bridge on State Highway 4). The availability of stream flow data on Blood Creek led to the modeling of the Blood Creek watershed to estimate the runoff characteristics of the entire Cheyenne Bottoms watershed. The water yield data of the Blood Creek watershed (which lies

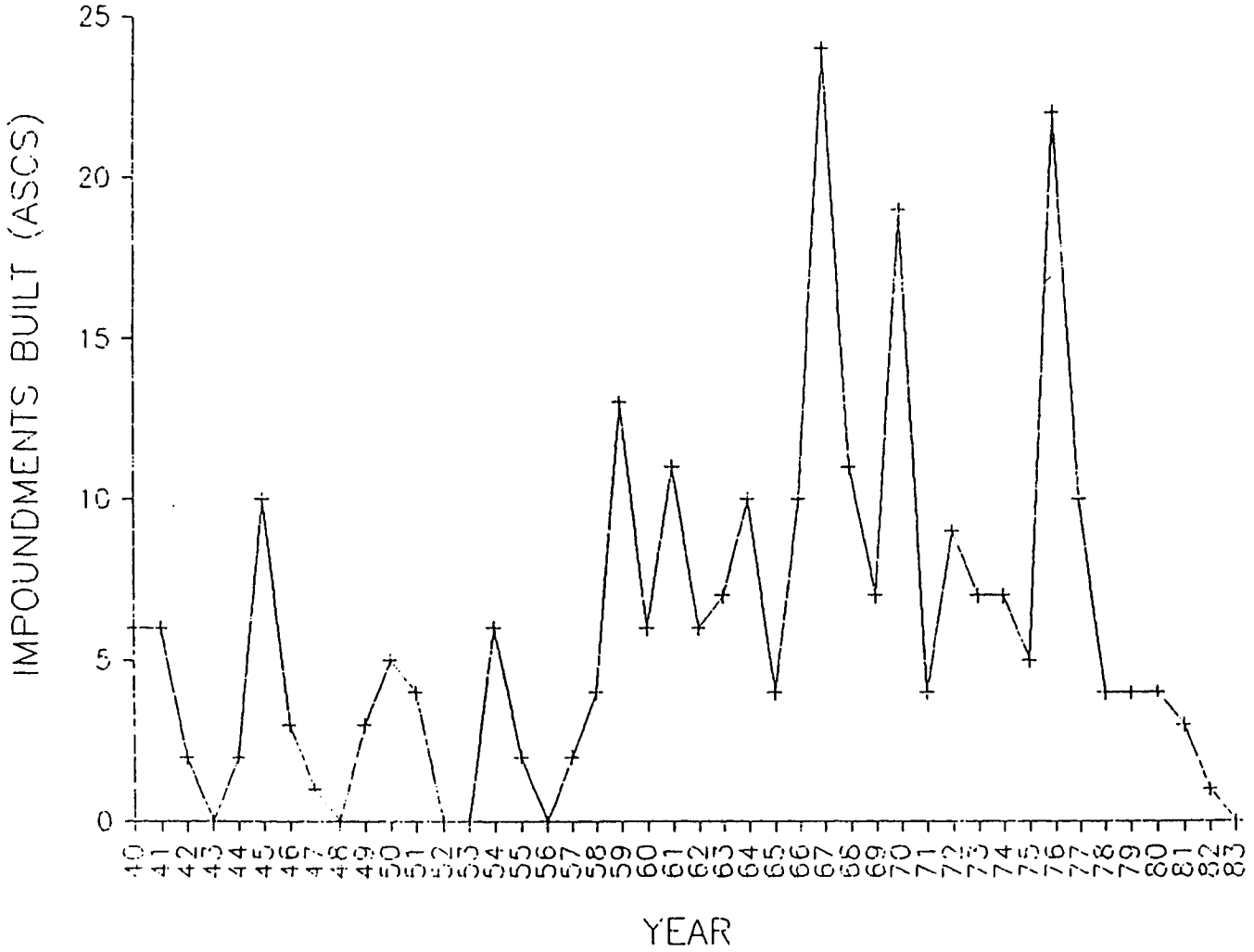

Figure 7.3 This graph represents the number of federally assisted water impoundments constructed in Barton County, Kansas from 1940 to 1983 (ASCS).

entirely in the southwest Cheyenne Bottoms watershed) were used to estimate the water yield over the entire Cheyenne Bottoms watershed. In the model three of the four land use categories (row crops, small grains and fallowed land uses) were further sub-divided by soil and water conservation techniques used: mulch (conservation tillage), terracing (predominantly graded terraces), mulch and terracing (combined conservation practices), and straight or straight row (no conservation practices). Pasture was subdivided into pasture on cropland and uncultivated pasture (rangeland, prairie).

Runoff-curve numbers assigned to each specific land use were developed using U.S. Soil Conservation Service runoff-curve numbers (soil moisture condition II) in conjunction with soil data results (figure 7.4). Row crops, small grains, and fallow were considered B/C group soils with pasture falling into group C soils.

Runoff yields for each specific land use were generated using runoff yields developed in two separate water yield studies conducted in proximity to the Cheyenne Bottoms (Koelliker, 1983; Koelliker, unpub.). Runoff yield per cropping practice was compared between studies and evaluated by the respective moisture deficit of the area in which the study was conducted. The moisture deficit is the difference between mean annual precipitation and evaporation rate of the area in question. The development of runoff yield values and the generation of runoff curve numbers (land use/hydrologic soilgroup relationship), from established curve numbers (U.S.D.A., 1972) culminates into a runoff curve for each cropping practice in the Cheyenne Bottoms watershed (figure 7.5). This figure illustrates the relationship of the SCS hydrologic soil groups, land use, and runoff yields.

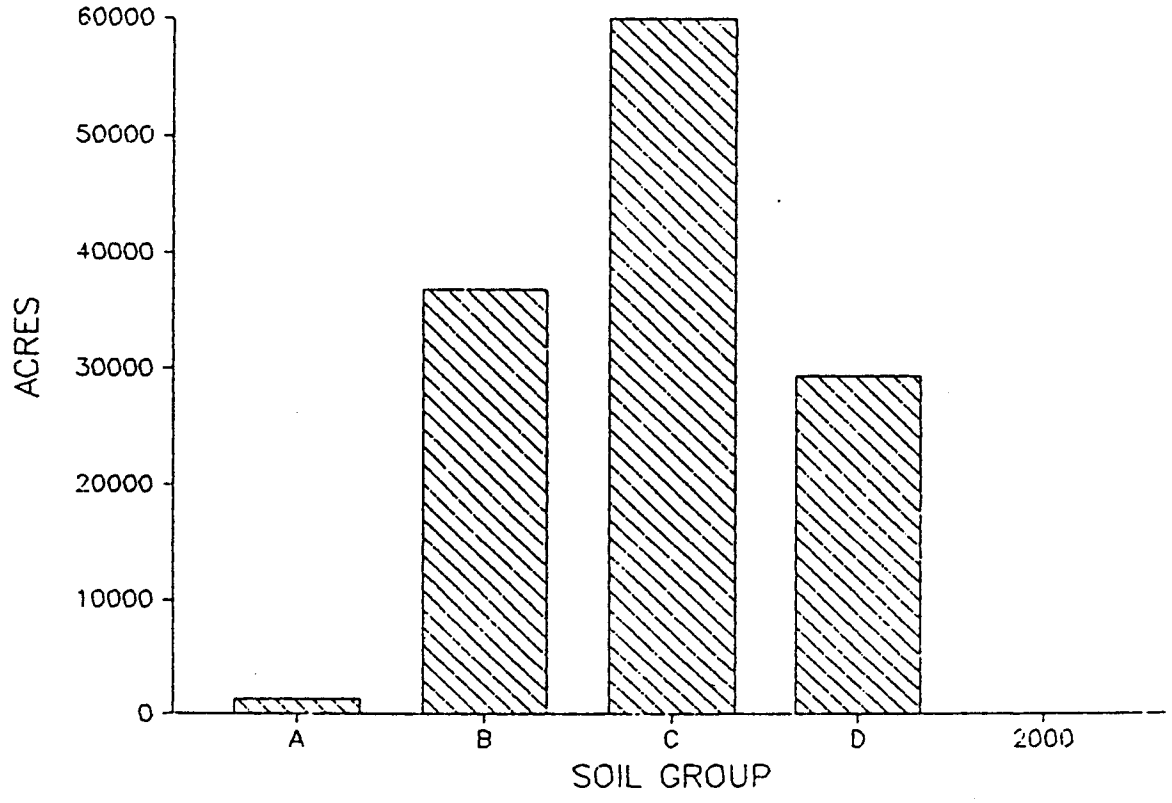

Figure 7.4 - This graph illustrates the acreage of the SCS hydrologic soil groups found in the Cheyenne Bottoms watershed.

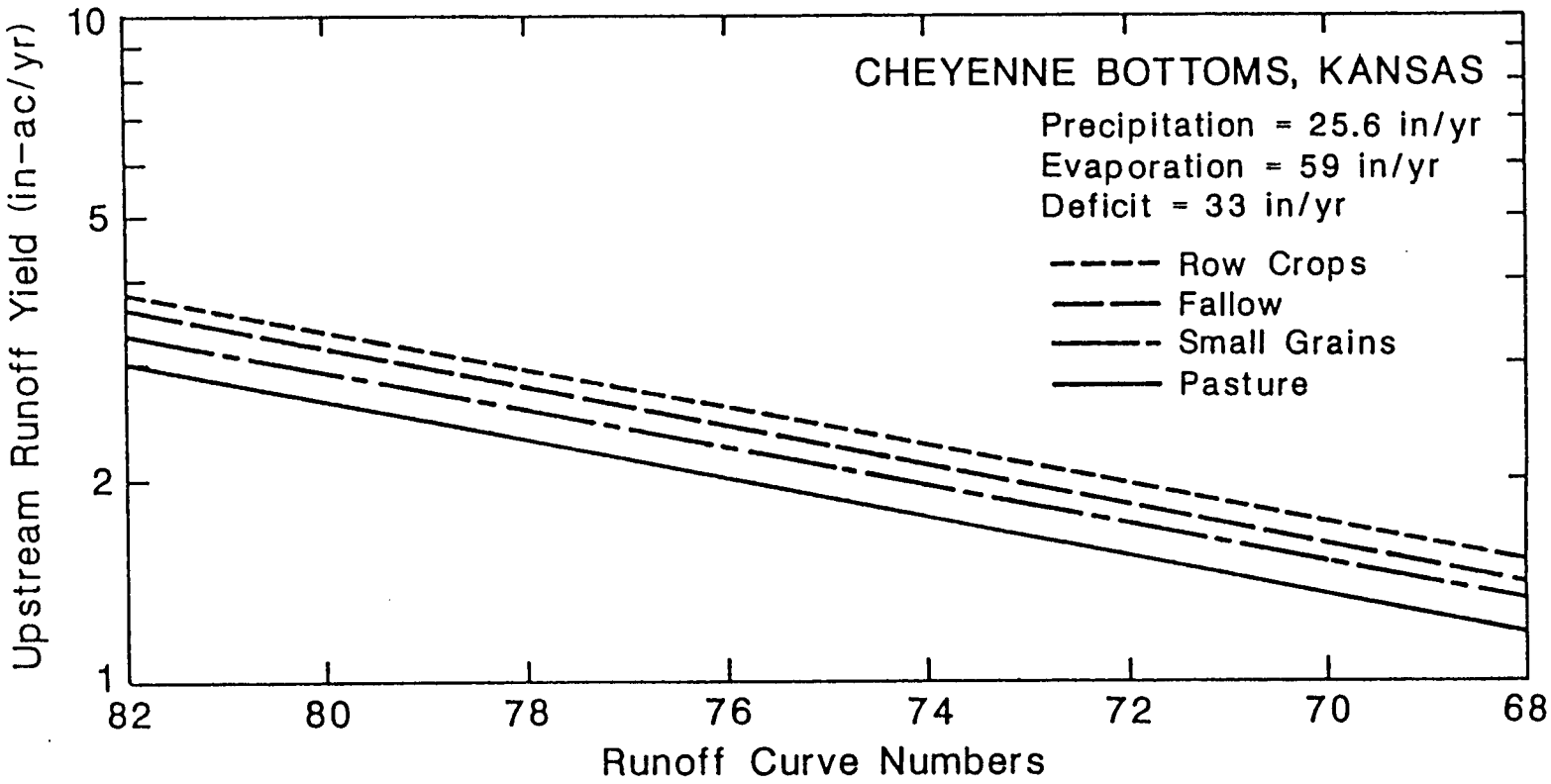

Figure 7.5 - Runoff curves for each of the four cropping practices in the Cheyenne Bottoms watershed.

Reduction in water yield by means of water impoundments is another land use variable of "Water Yield Analysis." The average surface area of a water impoundment, average drainage area above a typical pond, percolation rate of ponds in the watershed, and the estimated percentage reduction in runoff are variables used to calculate the effect of water impoundments on runoff.

The loss of water in transit from field to creek and upstream to downstream is termed transmission loss. Evaporation and infiltration from field to creek and evaporation and percolation from upstream to the downstream destination are processes which result in transmission losses.

The resultant value obtained by the determination of runoff yield from various land use practices, minus transmission losses and reduction incurred by water impoundments, is the overall water yield values.

RESULTS AND DISCUSSION

The Cheyenne Bottoms watershed covers approximately 154,203 acres (241 square miles) or 27% of Barton County's land area. The watershed acreage figure used in the models was 142,913 acres. This adjusted watershed value is the Bottoms wetland area (12,290 acre marsh) subtracted from the total watershed land area.

The Cheyenne Bottoms watershed contains 23 different soil types. The most predominant soil in the watershed, by far, is Harvey silt loam. Figure 7.4 illustrates the proportion of the SCS hydrological groupings in the watershed. Group C soils are the most common, followed by group B soils.

Water impoundment and terrace construction trends in Barton County that were built with Federal monetary assistance are illustrated in figure 7.3. The remote sensing results are as follows: 1938--34 impoundments, 1965--144 impoundments, and 1984--223 impoundments. A value of zero was used for the presettlement model. The model run for the year 2000 used the 1984 water

impoundment number. The average water surface area held by an impoundment was estimated at 2 acres and 160 acres was the value used for the average drainage area behind a water impoundment. The percentage reduction in runoff due to water impoundments was estimated as 0% for 1850, 30% for 1938, 31% for 1965, 32% for 1984, and 34% for the year 2000. The acres of land behind terraces and the percentage of terraced land in the watershed was: 1) 1938--6 acres, 0%; 2) 1965--14,239 acres, 10%; and 3) 1984--20,739 acres, 15%. The presettlement terrace figure was zero. The year-2000 estimated terrace figure was 23,850 acres, or 17%, which reflects a suggested 15% increase (SCS, 1986). Mulching was approximated as roughly 5% for 1965, 25% for 1984, and 40% for the year 2000 (SCS, 1986).

No data are published for transmission losses in the Cheyenne Bottoms watershed. After consultation with Kansas Geological Survey personnel, a value of 25% was established.

The end product of the "Water Yield Analysis" model is the overall water yield value. This value represents the combined effects of cropping practices, soil and water conservation techniques and transmission losses. The overall water yield for pre-settlement, 1938, 1965, 1984, and 2000 is 1.01 acre-inches/year, 1.85 acre-inches/year, 1.67 acre-inches/year, 1.60 acre-inches/year and 1.49 acre-inches/year, respectively (table 7.1). Figure 7.6 graphically depicts the runoff trends in the watershed throughout the years.

The percentage of the watershed in each of the 4 cropping practices are presented in tabular form in table 7.2. The largest shift in land use, of course, occured from the presettlement period to the 1938 test year. In this transition period land use went from pasture conditions to a majority of small grains land use (figures 7.7a,b). Since 1938 pastureland use has slowly

OVERALL WATER YIELDS PER TEST PERIOD					
Year	1850	1938	1965	1984	2000
Overall Water Yield (Acre/Inches/Year)	1.01	1.85	1.67	1.60	1.49

Table 7.1 - This table represents the overall water yield per test period in the Cheyenne Bottoms watershed.

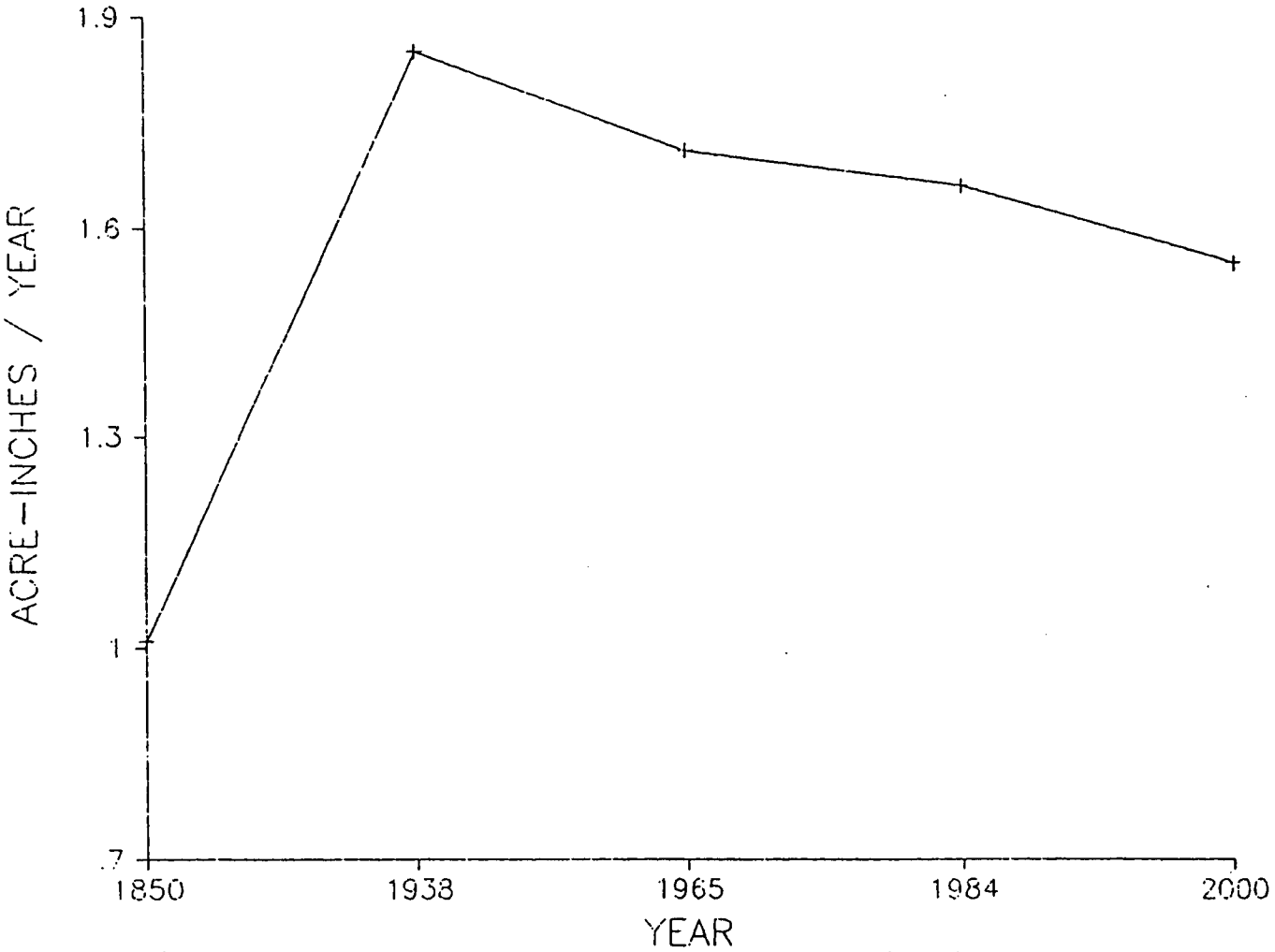

Figure 7.6 This graph represents the overall water yields (in/yr) for each of the five test periods.

Year	PERCENTAGE OF WATERSHED BY CROPPING PRACTICE			
	Pasture	Small Grains	Row Crops	Fallow
1850	100	–	–	–
1938	27	53	5	15
1965	31	43	8	18
1984	28	40	16	16
2000	33	30	17	20

Table 7.2 - The percentage of the Cheyenne Bottoms watershed by cropping practice per time period.

Figure 7.7a - The percentage coverage of the Cheyenne Bottoms watershed by pasture per time period.

Figure 7.7b - The percentage coverage of the Cheyenne Bottoms watershed by small grains per time period.

increased and small grains have steadily decreased. The estimated water yields for pasture are significantly less than the estimated water yields for small grains. The shift from pasture to predominantly small grains (1850-1938) increased water yield significantly (figures 7.7a,b; 7.8a,b). Row crops had the highest estimated water yield values, followed by the fallow water yield values. With only a small portion of the watershed in fallow and row crops (20%), the increased estimated water yield coefficients were recognized as contributing factors in the overall increase in water yield. Row crops increased in acreage through 1984 and were assumed to increase slightly in overall percentage of watershed area coverage in the future (year 2000). The steady increase in row crops was echoed by an increase in water yield. It is interesting to note that the percentage of row crops in the 1984 period was less than the year 2000 value (figure 7.7d) but had a larger accumulated water yield value in the 1984 test period (figure 7.8d). This was attributed to the estimated increases in terracing and conservation tillage for the year 2000.

The amount of fallow land increased slightly from 1938 to 1984 (15%-16%) (figure 7.7c) but the estimated water yield decreased (.47 inches/year to .42 inches/year; figure 7.8c). Again soil and water conservation practices reduced the water yield, thus offsetting the increase expected when fallowed acreage were expanded.

The increase in the number of water impoundments coincides with the reduction in water yield values (figures 7.9a,b,c). A decrease in water yield from land use practices was compounded by a larger percentage reduction in yield even if the number of water impoundments remains the same, as in the cases of 1984 and year 2000. The 1938-1965 and 1965-1984 reductions in yields (figure 7.9c) were influenced by increasing numbers of water impoundments and increased reduction in yield values.

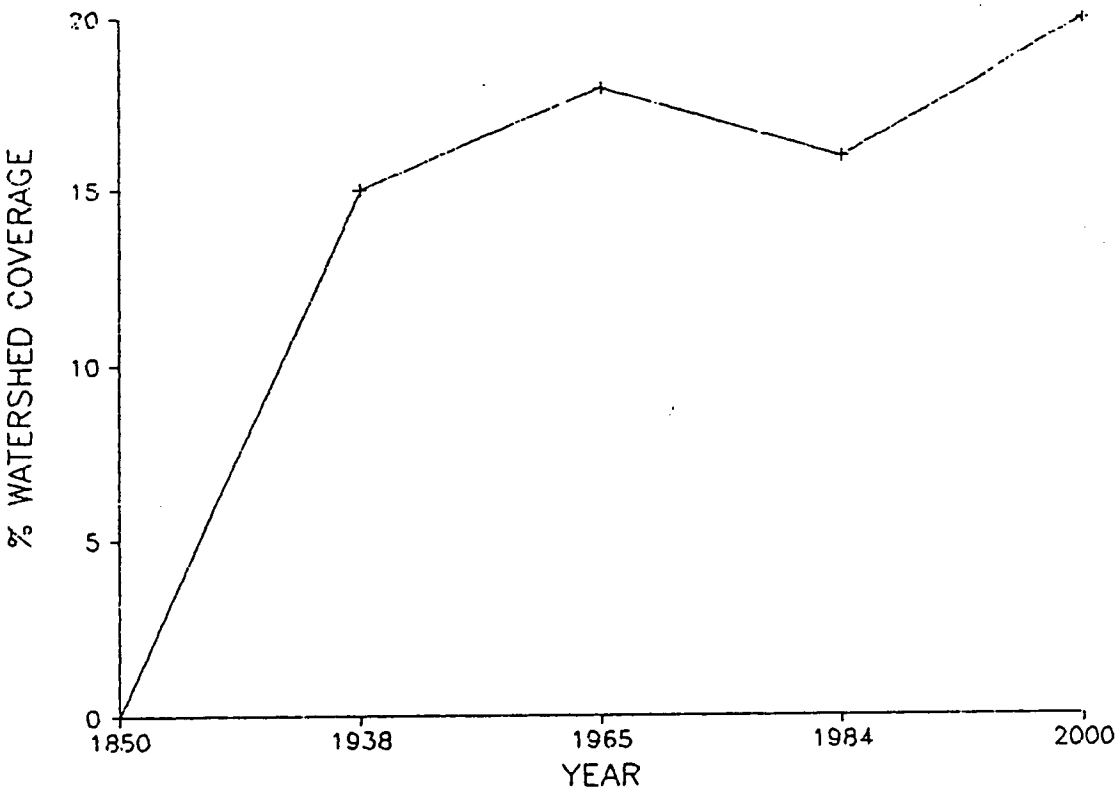

Figure 7.7c - The percentage coverage of the Cheyenne Bottoms watershed by fallowed land per time period.

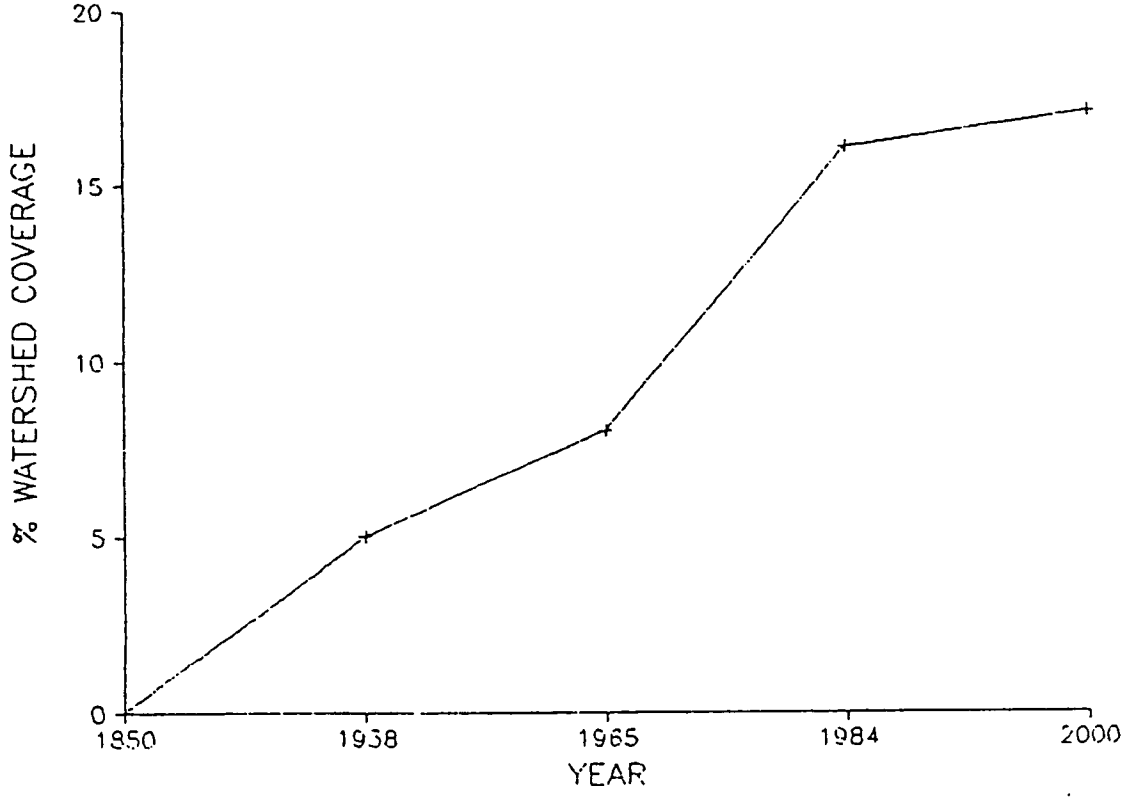

Figure 7.7d - The percentage coverage of the Cheyenne Bottoms watershed by row crops per time period.

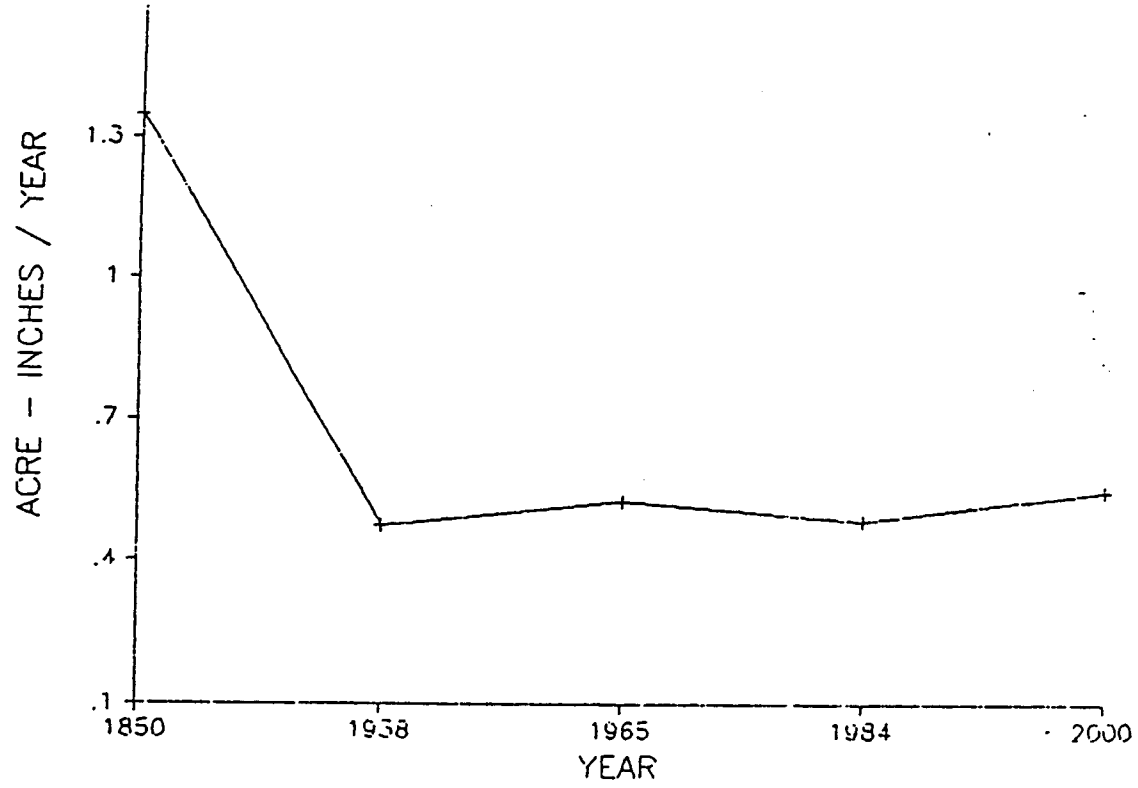

Figure 7.8a - The water yield for pasture per time period in the Cheyenne Bottoms watershed.

Figure 7.8b - The water yield for small grains per time period in the Cheyenne Bottoms watershed.

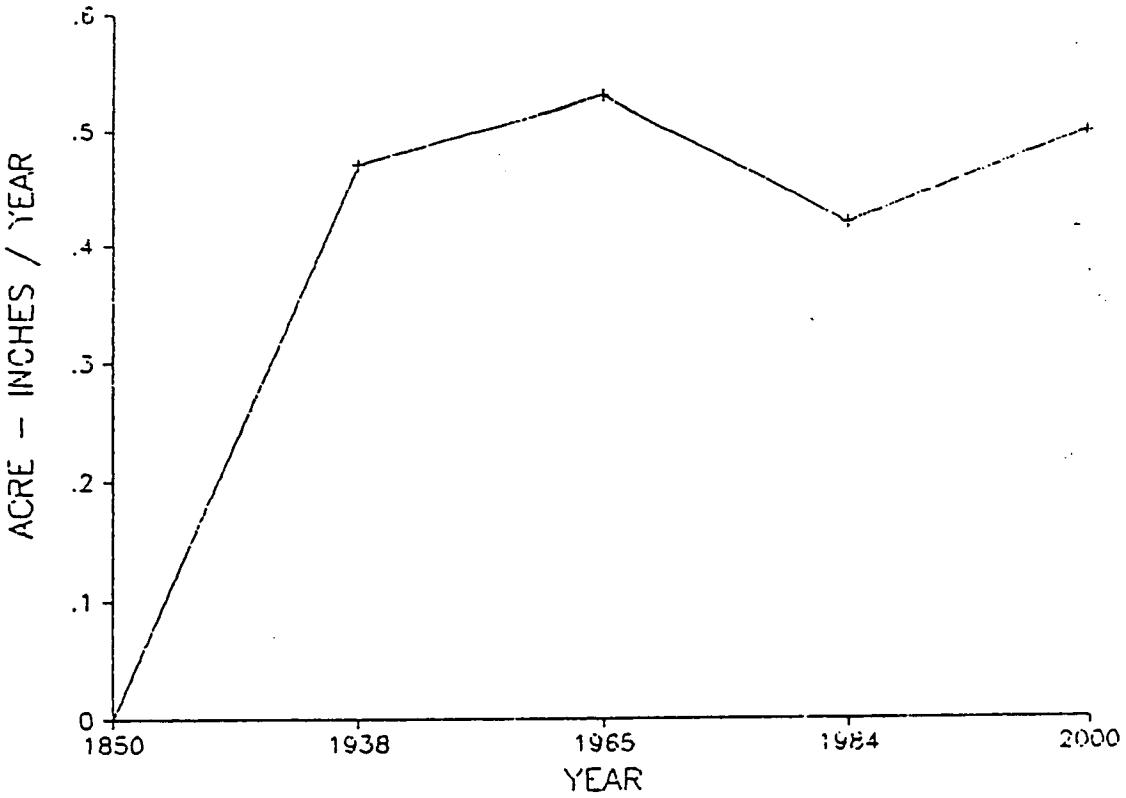

Figure 7.8c - The water yield for fallowed land per time period in the Cheyenne Bottoms watershed.

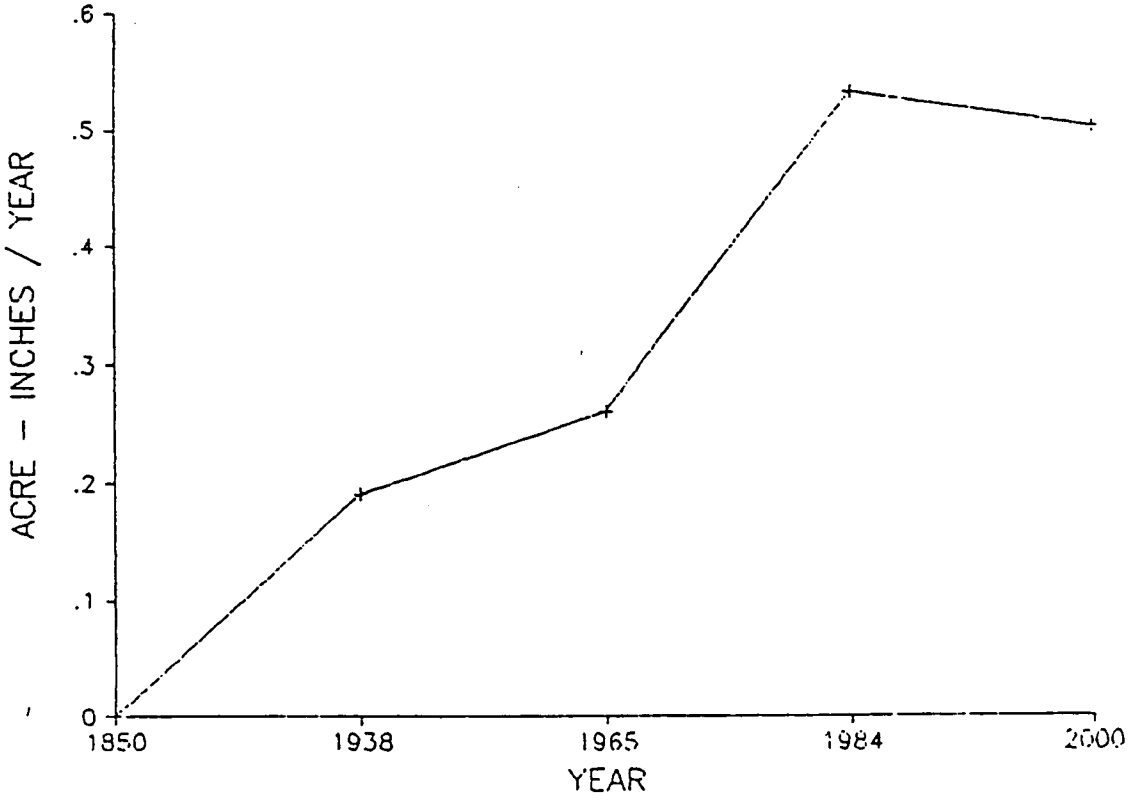

Figure 7.8d - The water yield for row crops per time period in the Cheyenne Bottoms watershed.

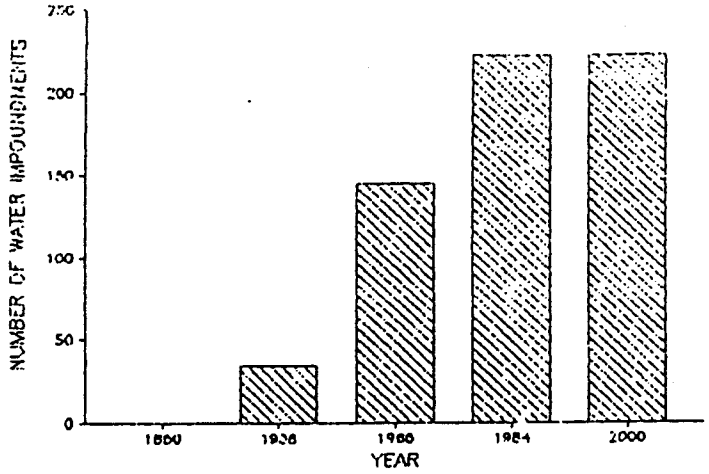

Figure 7.9a - The accumulative number of water impoundments in the Cheyenne Bottoms watershed, as detected by aerial photography, per time period.

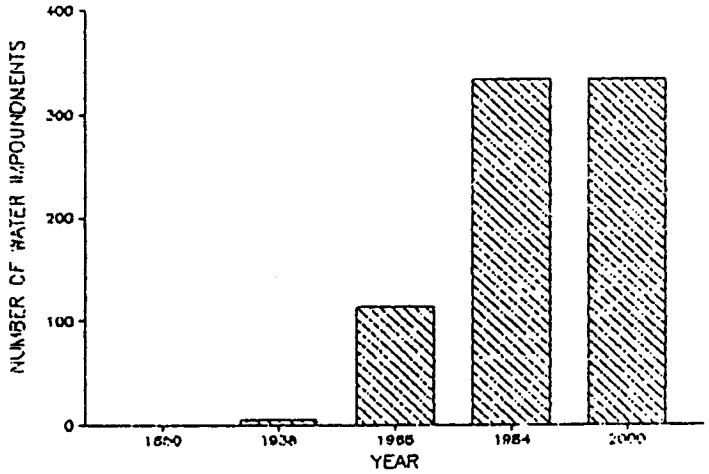

Figure 7.9b - The accumulative number of water impoundments constructed in Barton County, Kansas with federal assistance, per time period.

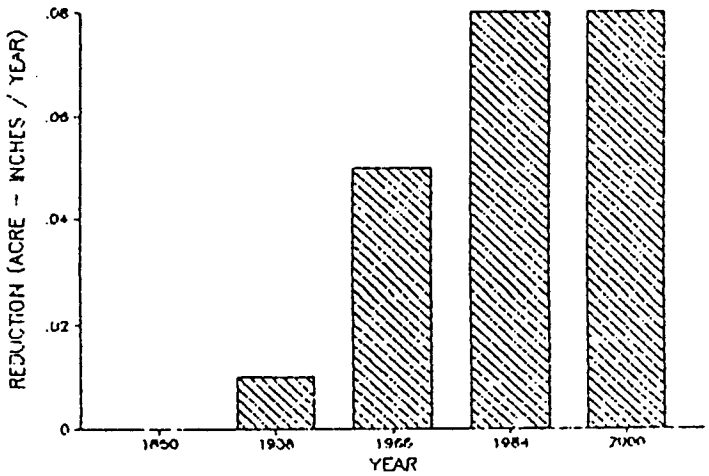

Figure 7.9c - The reduction in water yield per time period due to water impoundments.

The amount and intensity of precipitation is believed to determine whether the Cheyenne Bottoms marsh will receive appreciable amounts of water from runoff in the watershed. Precipitation records for 1950 to 1986 reveal that 12.07 (inch/year) in 1956 and 35.20 (inch/year) in 1957 are the low and high rainfall values (chapter 6, 1986; years=hydrologic years). In low precipitation years, no stream flow in the watershed will reach the wetland area. In years of average precipitation (25.6 in/year, 1951-1980, Kansas Board of Agriculture, Barton County average), most stream flow from Blood Creek and/or Deception Creek will accumulate in the wetland areas located just northwest of the Cheyenne Bottoms Wildlife Management Area and will not be transported to the Bottoms pools. In high precipitation years, enough streamflow in Blood Creek and Deception Creek would be generated by overland flow to transport water through the area northwest of the management area and enter the Bottoms. Likewise, a localized storm of high intensity and moderate to long duration could produce conditions where streamflow would reach the Cheyenne Bottoms wetland.

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CHAPTER 8: STREAMFLOW DIVERSIONS AND INLET CANAL PERFORMANCE

Lynn Vogler, Marios Sophocleous and Thomas McClain

WATER RIGHTS

The purpose of this section is to examine the delivery system of water into the Bottoms; in particular, the inlet canal between the Arkansas River diversion near Dundee and the drop structure at Cheyenne Bottoms.

Water loss along the inlet canal is and has been a significant problem. The inlet canal is a 22.7-mile-long conveyance system consisting of various sections of concrete culvert, constructed ditch, and stream channel. Water loss along the canal is estimated from Fish and Game records to range from as little as 25% to as much as 84%. Water loss occurs due to seepage out of the canal and to evapotranspiration. Loss in this instance is a relative term applied to surface water that should be received at Cheyenne Bottoms but never reaches there. Water "lost" to seepage from the canal has likely supplied thousands of acre feet of recharge to local ground water users. Recharge has been documented in observation wells near the Wet Walnut diversion dam.

The initial step in addressing the water-loss problem is to determine the amount of water being lost and where those losses are taking place.

Presently, water losses can only be estimated in one of two ways: 1) comparison of Arkansas River diversion records to amounts of water actually received at the Cheyenne Bottoms drop structure, or 2) direct-flow measurements in the canal at times when water is being diverted through the canal. Major problems occur with both of these procedures. Interpretation of historical records is often difficult as records are somewhat unclear. In addition no instrumentation is present on Dry Walnut Creek, and the closest gage on Walnut Creek is near the town of Albert, approximately 10 miles upstream from the junction of Walnut Creek with the inlet canal. This makes

it extremely difficult to determine accurately the amount of water being contributed to Cheyenne Bottoms from the Dry Walnut and Walnut creeks. The following is a brief summary of the historical records.

CHEYENNE BOTTOMS WATER-RECORDS DATA (INLET CANAL)

For the most part, amounts of water contributed by Dry and Wet Walnut creeks were unavailable. Values were listed for Walnut Creek when available and are only estimates based on records from the Albert station. Figure 8.1 shows the amount of water diverted by year.

Records for the years 1954-58 are recorded only as gage heights without equivalent acre/feet amounts. Also no meter readings were found to show the amount of water diverted from the Arkansas River during these years.

1959: 2,990.45 acre/feet of water was recorded as the amount contributed to Cheyenne Bottoms from Walnut Creek for this year. For the same period, 2,482.52 acre/feet was recorded as contributed by the Arkansas River. 2,482.52 acre/feet diverted - 895.97 acre/feet actually received at Cheyenne Bottoms equals 1,586.55 acre/feet or a 83.6% loss, assuming all water was from the Arkansas River.

1960: Records are unclear for this year; the meter was broken at the Arkansas River diversion dam, and it is unclear as to how much was actually diverted to the inlet canal. Personnel at Cheyenne Bottoms estimated that due to conditions there was only a 25% loss of diverted water.

1961: Records are again unclear for 1961. Readings were taken during some periods and estimated at others. It is not known how much water was diverted from the Arkansas River and how much, if any, was contributed by Dry Walnut and Walnut creeks.

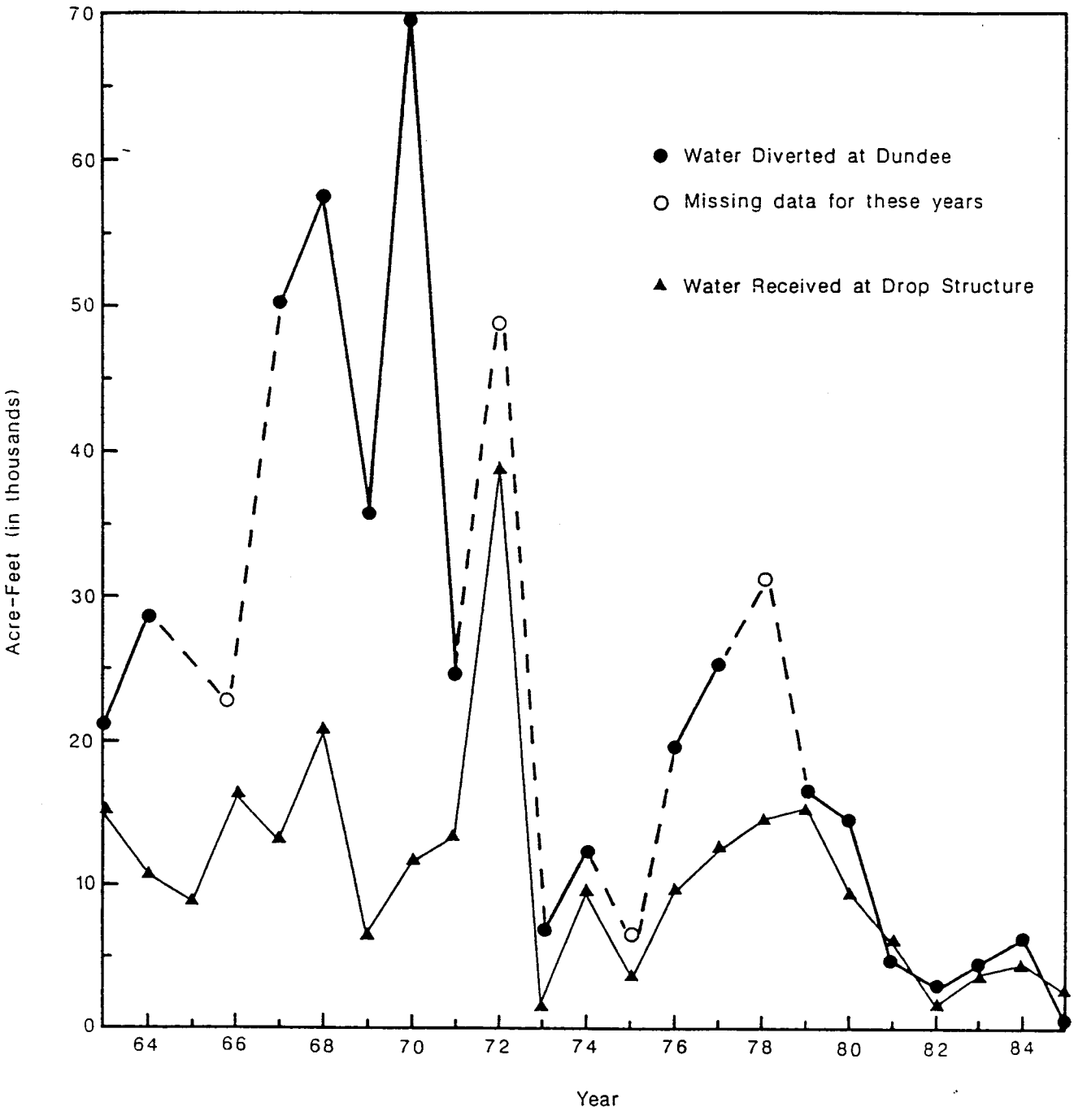

Figure 8.1 Water Diverted to Cheyenne Bottoms

1962: No figures were available as to how much water was diverted from the Arkansas River, Dry Walnut Creek, or Walnut Creek for 1962.

1963: 21,252.3 acre/feet of water was diverted from the Arkansas River during 1963. 15,127.0 acre/feet of water was recorded at the drop structure; no figures were available for amounts of water contributed by Dry Walnut and Walnut creeks for this time. Assuming that all water recorded was from the Arkansas River, there was a 6125.3 acre/feet loss, or about 29%.

1964: According to the meter at the Arkansas River diversion dam 28,791.7 acre/feet of water was diverted from the river during 1964. 11,719 acre/feet was recorded at the drop structure for the same period. Assuming this water is all Arkansas River water there was a 17,072.7 acre/feet loss (59.3%) between the diversion and the drop structure.

1965: 8,847 acre/feet of water was recorded as coming into the Bottoms in 1965. It was not evident from the records how much water was diverted from the Arkansas River and how much water was contributed by Walnut Creek.

1966: 16,083 acre/feet was recorded as received at Cheyenne Bottoms during the year 1966. Again it is not known how much water was diverted from the Arkansas River and how much was contributed by the Dry and Walnut creeks.

1967: 49,899 acre/feet of water was diverted from the Arkansas River during 1967. 13,164 acre/feet of water was received at Cheyenne Bottoms during this time. A conservative estimate of water loss along the inlet canal for this period is 73.6%.

1968: 57,322.3 acre/feet of water was recorded as being diverted from the Arkansas River during 1968. 21,878 acre/feet or a 62% loss, was recorded at the drop structure at Cheyenne Bottoms.

1969: 35,892.3 acre/feet of water was diverted at the Arkansas River diversion dam in 1969. Only 6,887 acre/feet or an 81% loss, was recorded at the Cheyenne Bottoms drop structure for this same year.

1970: Flow meter at the Arkansas diversion dam recorded 70,801.4 acre/feet of water diverted from the river during 1970. During this same period, 11,720 acre/feet was recorded at the drop structure. Assuming no contribution from Dry Walnut or Walnut creeks, there was an 83.4% loss of water entering from the inlet canal in 1970.

1971: The flow meter was broken for the majority of the year; therefore it is unclear as to the amount of water that was diverted into the inlet canal from the Arkansas River. 13,168 acre/feet of water was recorded at the drop structure, 4,018 of which is estimated to have been contributed by Walnut Creek. It is also estimated that 25,000 acre/feet was diverted from the Arkansas River. 13,168 - 4,018 equals 9150 acre/feet of Arkansas River water received; 25,000 - 9150 equals 15,850 acre/feet lost or 63.4%.

1972: In 1972, 38,884 acre/feet of water was recorded at the drop structure. An uncertain amount of water was diverted from the Arkansas River during the year; this uncertainty was likely due to a meter malfunction. 19,288 acre/feet of water was recorded at the Albert station on Walnut Creek for the same year. It is unclear as to how much of this water actually was diverted to Cheyenne Bottoms.

1973: 6,827 acre/feet of water was recorded as diverted from the Arkansas River to the inlet canal for 1973. During this same period, 1,215 acre/feet of water was recorded as entering Cheyenne Bottoms. 6,827 - 1,215 equals 5,612 acre/feet loss, or 82.2%, if it is assumed that all water was from the Arkansas. 69,062 acre/feet of water was recorded at the Albert station on Walnut Creek for 1973. It is not known how much of this water was

diverted into Cheyenne Bottoms. [Records for this year are very unclear, it is believed that the flow meter at the Arkansas River diversion dam was malfunctioning.]

1974: In 1974, 12,659.7 acre/feet of water was recorded as diverted into the inlet canal from the Arkansas River. During this same period, 9,665 acre/feet was recorded as entering Cheyenne Bottoms at the drop structure. If all this water is assumed to be water from the Arkansas River, there was a 2,994.7 acre/feet loss, or 23.6%. No records were available as to how much, if any, water was contributed by Dry Walnut and Walnut creeks for this time.

1975: During 1975, 228.5 acre/feet of water was diverted; however, the flow meter was reported as unoperational for an unknown period of time. For this same period, 3,273 acre/feet of water was recorded as entering Cheyenne Bottoms. 13,502.6 acre/feet of water was recorded as passing the Albert station during 1975. It is not known how much of this was diverted Cheyenne Bottoms.

1976: No exact reading on the amount of water diverted from the Arkansas River during 1976 is available. Cheyenne Bottoms personnel estimate that approximately 19,342 acre/feet of water was diverted during this time. Of the total 17,831 acre/feet of water received at the drop structure during 1976, it is estimated that 9,671 acre/feet was Arkansas River water. 7,410.7 acre/feet of water was recorded at the Albert station along Walnut Creek for this same period. 19,342 - 9,671 equals 9,671, or a 50% loss of Arkansas River water.

1977: Exact readings on the amount of water diverted from the Arkansas River during 1977 were not available. Cheyenne Bottoms personnel estimated that approximately 25,750 acre/feet was diverted to the inlet canal. 12,875 acre/feet was recorded at the drop structure for the same period. 25,750 - 12,875 equals 12,875 loss, or 50%. During 1977, 2,698.2 acre/feet of water

was recorded at the Albert station. It is not known how much, if any, of this water was diverted towards Cheyenne Bottoms.

1978: An unknown amount of water was diverted from the Arkansas River in 1978. It is also unknown as to the amount of water contributed by Dry Walnut and Walnut creeks. At the drop structure for 1978, 14,800 acre/feet of water was recorded as entering Cheyenne Bottoms. 12,334.7 acre/feet was recorded at the Albert station during 1978.

1979: For 1979, 16,718.8 acre/feet of water was diverted from the Arkansas River. According to records, 1,040 acre/feet of this was diverted back into the river, but was recorded at the meter. 41,156 acre/feet of water was recorded along Walnut Creek at the Albert station during 1979. It is likely that a large amount of this water was contributed to Cheyenne Bottoms; however, no records were available to show how much if any was diverted. 16,249 acre/ft of water was received at the drop structure.

1980: 14,703 acre/feet of water was recorded as being diverted from the Arkansas River to the inlet canal during 1980. During this same period, 9,782 acre/feet of water was recorded at the Cheyenne Bottoms drop structure. 10,336 acre/feet of water was recorded as passing the Albert station on Walnut Creek for 1980. As with other years, it is unknown as to how much of this water was diverted towards Cheyenne Bottoms. Assuming all water received at the drop structure was from the Arkansas River, there was a 4,921.1 acre/feet loss, or 33.5%.

1981: 4,992.1 acre/feet of water was recorded as being diverted to the inlet canal from the Arkansas River during 1981. [A stick prevented the propeller on the flow meter from turning for an undetermined amount of time between 5-14-81 and 5-28-81.] 6,113 acre/feet of water was received at the drop structure during 1981. 19,220.5 acre/feet of water was recorded at the

Albert station on Walnut for this same year. No loss estimates can be made for 1981 because of lack of reliable data.

1982: It is estimated that 2,819.7 acre/feet of water was diverted to the inlet canal from the Arkansas River during 1982. The flow meter was removed to be repaired on 7-14-82, and was reset to 0 at this time. It is also estimated that Dry Walnut and Walnut creeks contributed approximately 385 acre/feet during 1982. 1,960 acre/feet of water was recorded at the drop structure for this period. Therefore there was a loss of 1,244 acre/feet during 1982, or 38.8%.

1983: A total of 4,747.7 acre/feet of water was diverted from the Arkansas River during 1983. During this same period 4,586 acre/feet of water was recorded at the drop structure. 4,747.7 - 4,586 equals 161.7 acre/feet loss, or 3.4% loss. It is unknown if any water was contributed by Dry Walnut or Walnut creeks during 1983; however, in looking at losses for previous years, it is likely that a large percentage of the water received at the Cheyenne Bottoms drop structure was from one or both of these streams.

1984: 6,200 acre/feet of water are estimated to have been diverted from the Arkansas River during 1984. 4,608 acre/feet of water was recorded at the Cheyenne Bottoms drop structure for the same period. This results in a 1,593 acre/feet loss, or 25.7%, assuming no contribution by Dry Walnut or Walnut creeks.

1985: The estimated amount of water diverted from the Arkansas River during 1985 was 493 acre/feet. 2,424 acre/feet of water was recorded at Cheyenne Bottoms during the same period. Without knowing the amount of water contributed by Dry Walnut and Walnut creeks, it is not possible to calculate a loss figure for 1985.

INLET CANAL MEASUREMENTS

In order to determine where losses were taking place along the inlet canal, 2 sets of measurements were made during the study along portions of the inlet canal (figure 8.2) (table 8.1). The portion of the canal between Highway 56 and Dry Walnut creek was chosen because there are not additions from surface streams and measurement sites can be accessed and easily controlled.

Table 8.1-INLET CANAL FLOW MEASUREMENTS

DATE: 7-14-86		DATE: 8-22-86	
DISCHARGE (CFS)		DISCHARGE (CFS)	
SITE:	1. 74	SITE:	1. 59.8
	2. 34.5		2. 70.4
	3. 51.2		3. 65.5
	4. 53.4		4. 65.5
	5. 34.5		5. 63.7
	6. 48.8		6. 52.4
	7. 21.8		7. 59.8
	8. 20.5		8. 54.4
	9. 18.3		9. 44.18
	10. 12.9		10. 55.22

The method of measurement was to determine flow at each half mile interval where there are concrete culverts under the roads. The method consisted of determining the drop of the water surface from the upstream side to the downstream site of each set of culverts. The diameter of each Culvert is known (42") so the formula $Q = VA$ applies.

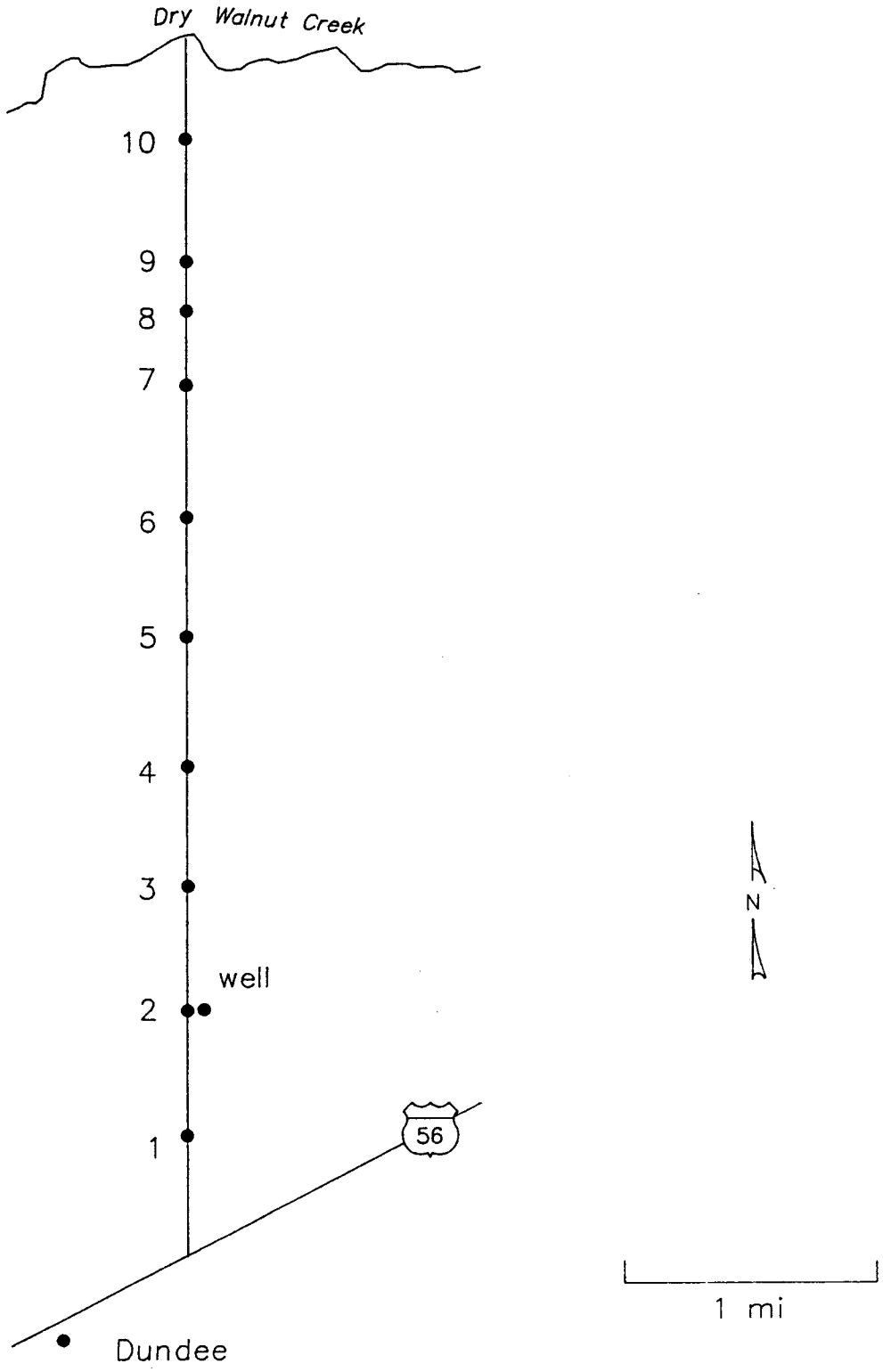

Fig. 8.2 Inlet Canal Measurement site

where Q = discharge in cubic feet/second

V = velocity = $\sqrt{2g(\Delta H)}$

g = 32.2

ΔH = head differential between upper and lower ends of culverts.

A = cross sectional area of water in pipe

$= R^2(\frac{\pi}{2} - Sm^{-1}\frac{R-h}{R}) - (R-h)\sqrt{h(2R-h)}$

where R = radius of pipe

h = height of water in pipe.

ΔH was measured with a surveying level and rod graduated in hundreths of feet. It was sometimes difficult to do this measurement extremely accurately since some ΔH's were only .02' to .12'. Debris in the culverts sometimes casued erroneous readings. Given the difficulties of the method used the flow values listed in table 8.1 are approximate and should be considered for their trends rather than exact flow volumes.

At the time of the 7-14-86 measurement, the maximum amount of water possible was being diverted at the Arkansas Diversion Dam (figure 8.3). Conditions were hot, dry, and windy, temperatures were well above 90°, and winds were gusting from 5 to 15 miles/hour. Numerous irrigation wells were operating in the locality of the canal, at least two of which were within 1/4 mile.

At site 2 (figure 8.2), an irrigation well is located and was running at the time of measurement approximately 100 feet from the east side of the inlet canal. Water records show this well operates at a maximum output of 900 gallons/minute. Figure 8.3 shows the effect of this well on the flow of the inlet canal at this location. A similar situation occurs at site # 5; here an irrigation well is located approximately 1/4 mile west of the inlet canal.

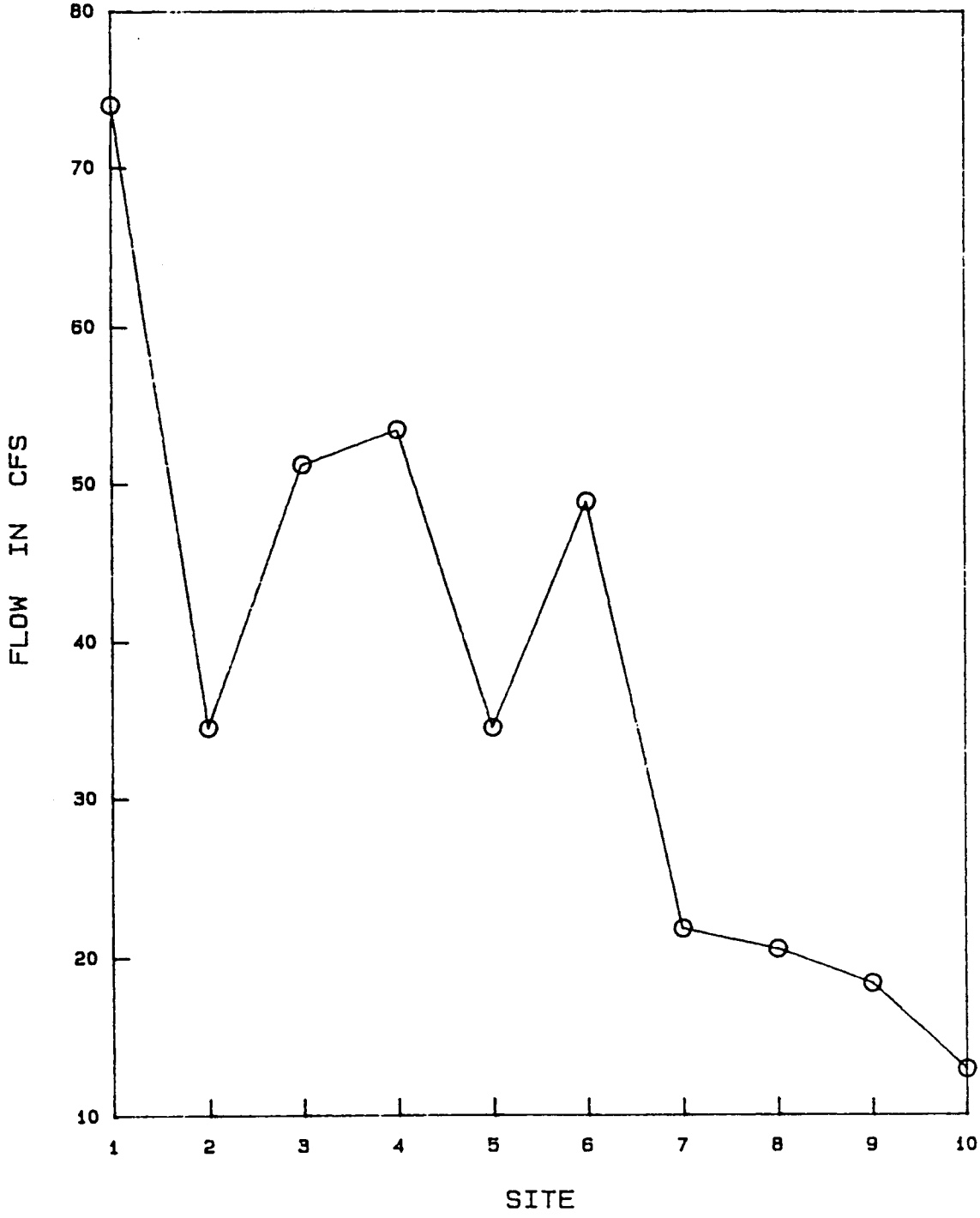

Figure 8.3 Inlet Canal Flow (7-14-86)

The well was running at the time of measurement, but the pumping capacity of this well was not available.

The maximum amount of water possible was being diverted at the time of the 8-22-86 measurement. Conditions however, varied greatly from those during the first measurement. The weather was cool and wet with only a slight breeze. No irrigation wells were observed to be in operation at the time of this measurement. Figure 8.4 shows the flow at the various sites along the canal. For the most part there is a smooth decline in flow from the south to the north. Three sites however, show exception. Site 2 shows a 10.6-cfs increase in flow from site 1, which has yet to be explained. Sites 6 and 9 represent low points of flow along the canal and may be explained in part by debris in the tubes.

Estimated water loss along the canal between sites 1 and 10 for 7-14-86 is approximately 80%. Water loss between the same points on 8-22-86 is approximately 12%. The pronounced difference between the two dates can be explained in part by the difference in weather conditions on the respective days and the number of irrigation wells in operation at the time of measurement. However,it is likely that soil moisture conditions also are influencing the loss of water in the canal. More observations and measurements are necessary before a conclusion can be made as to the actual amount of water lost along this stretch of the inlet canal. It is evident however, that a significant amount of water is lost to evaporation, seepage, and the influence of nearby irrigation wells.

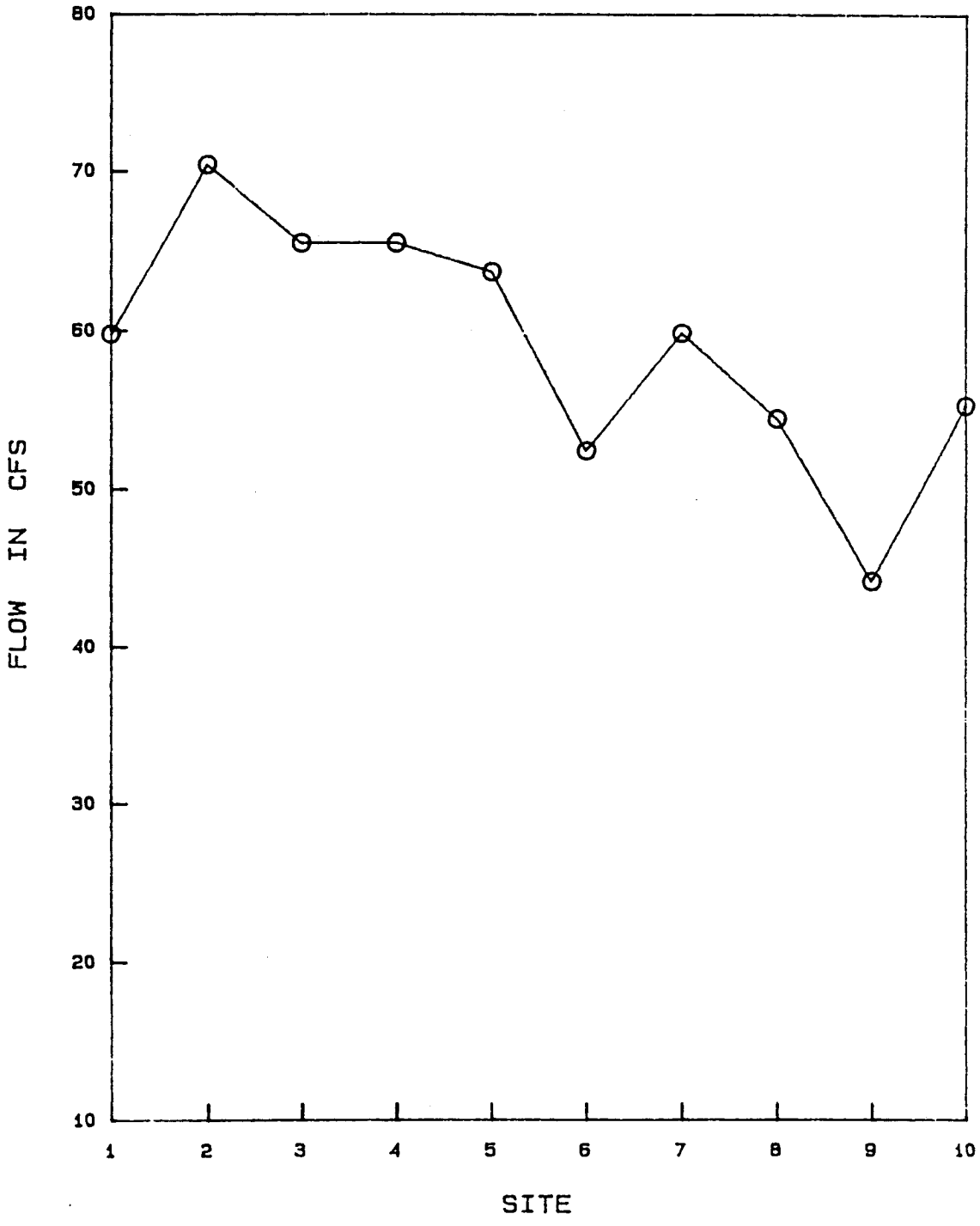

Figure 8.4 Inlet Canal Flow (8-22-86)

CHAPTER 9: WATER RIGHTS AND PUMP TEST

Lynn Vogler, Marios Sophocleous and Thomas McClain

Chapters 4 and 7 of this report document that streamflow is declining in all streams that supply water to Cheyenne Bottoms. The cause of this decline seems to be irrigation (surface water and ground water) and land use changes (terracing, impoundments, and conservation tillage).

In trying to understand more about the causes of this problem Gary Welker, in chapter 7, has quantified runoff declines in the Cheyenne Bottoms basin. This same process could be used on Walnut Creek and the Arkansas River basin but would be much more time consuming due to the size and complexity of the basins. McClain and Shapiro (chapter 10) have drawn parallels between ground water development and streamflow decline in the Walnut Creek Valley.

The first part of the following discussion will attempt to outline ground water and surface water development that has taken place in the vicinity of the Arkansas River upstream from Dundee. The second part will present a brief summary of an attempt to quantify the effect of ground water pumping on streamflow.

Kansas Fish and Game Commission water rights are for 30,000 acre feet (no. 2,427-1954) on the Arkansas River and 20,000 acre feet (no. 439-1948) on Walnut Creek.

In order to obtain an estimate of the existing irrigation development along Walnut Creek and the Arkansas River from Dundee to the Kansas-Colorado state line a compilation of existing water rights was undertaken. The water rights are in the alluvial corridor along each stream. The Arkansas River corridor is 2 miles north and 2 miles south of the river between Dundee and the eastern Ford county line. It is 1 mile north and 3 miles south of the river from the eastern Ford county line to the Kansas-Colorado state line.

The area from Ford county to the state line is presently an Intensive Ground Water Use Control Area (IGUCA) in which essentially no more ground water development can take place. Water rights for the Arkansas River corridor are listed in table 9.1.

The area of Walnut Creek studied is the alluvial valley between Great Bend and Ness City and includes all the water rights in the corridor which ranges from 1 to about 4 miles wide. A summary of the water rights is found in table 9.1.

A review of the Division of Water Resources records indicate that the majority (90% or more) of the ground water rights are junior to Kansas Fish and Game Commission rights for the Bottoms. The records also show that the majority of the surface water rights are senior to the Fish and Game Commission's rights.

A review of table 9.1 indicates there is very lttle surface water development along the Arkansas between Dundee and Ford County. The majority of the development is along the western part of the river where ditch companies have large vested rights. Combined ground water development along both streams is about 550,000 acre feet, the majority of which is junior to the Bottoms rights.

Table 9.1--Estimated water rights along Walnut Creek and the Arkansas River.

	AF Surface Water	AF Ground Water
Walnut Creek	2,000	60,000
Arkansas River Dundee to Ford County	1,000	110,00
Arkansas River Ford County to Kansas-Colorado line	160,000	380,000

Streamflow-Ground-water Interaction

The close association between ground and surface water means that a thorough understanding of wetland hydrology requires the study of both. The hydrologic system, of which the wetland is a part, is sufficiently complex that alterations to one part of the system may have far-reaching effects upon the other components (Carter et al., 1978). For example, heavy pumping of ground water may lower the water table locally, decrease base flows, or induce recharge from wetlands. Disturbance of the river bed by channelization may alter the base flow. Impoundment may cause a rise in local ground-water levels, causing destruction of, creation of, or changes in nearby wetlands.

During the last several years, streamflows in the Arkansas River from Kinsley to Great Bend have been declining so severely that no water could be diverted from the Arkansas River at the Kansas Fish and Game Dundee Diversion Dam to the Cheyenne Bottoms via the inlet canal, specifically designed to provide water to the Bottoms during critical periods. One of the reasons for these streamflow declines is believed to be the large ground-water-based irrigation development in central and western Kansas and eastern Colorado.

In order to quantify the effects of ground-water-based irrigation on streamflow, a pump test was conducted along the Arkansas River near Great Bend (Sec.36, T.19 S., R.13 W.). A 20-inch irrigation well (95-ft deep)

approximately 200 feet from the south bank of the Arkansas River and more than 20 observation wells were installed for the stream-aquifer testing. On April 21, 1986, an 8-day pumping test was initiated with the pumping well discharging 1,750 gpm. In addition to water-level monitoring in the numerous observation wells, streamflow and geochemical measurements also were conducted during the pump-test period.

Analysis of streamflow measurements indicate that during the pump test, streamflow in the Arkansas River decreased at a rate of approximately 1 cubic foot per second (cfs)/day as a result of pumping. The average Arkansas River streamflow decreased from approximately 6 cfs on April 21, before the pump test, to approximately 2 cfs by April 25, the fourth day of pumping. A streamflow recovery was observed after the pumping well was shut off on April 29, as can be seen in figure 9.1. It was also observed that the ground-water gradients just below the streambed were reversed during the pumping test; before the testing, the stream was a gaining stream, i.e. it gained water from the aquifer; during the test, it became a losing stream because it was feeding the aquifer and losing streamflow. When the pump was shut off, the stream again gained water from the aquifer. These gradient reversals can be seen in figure 9.2, where the ground-water gradients between 2 and 3 feet below the streambed are shown, as measured by minipiezometers. Such data prove beyond any doubt the stream-aquifer interrelationship. Data analysis from this test is still continuing, and a more detailed comprehensive report on the stream-aquifer testing will be presented separately when all data analysis is completed.

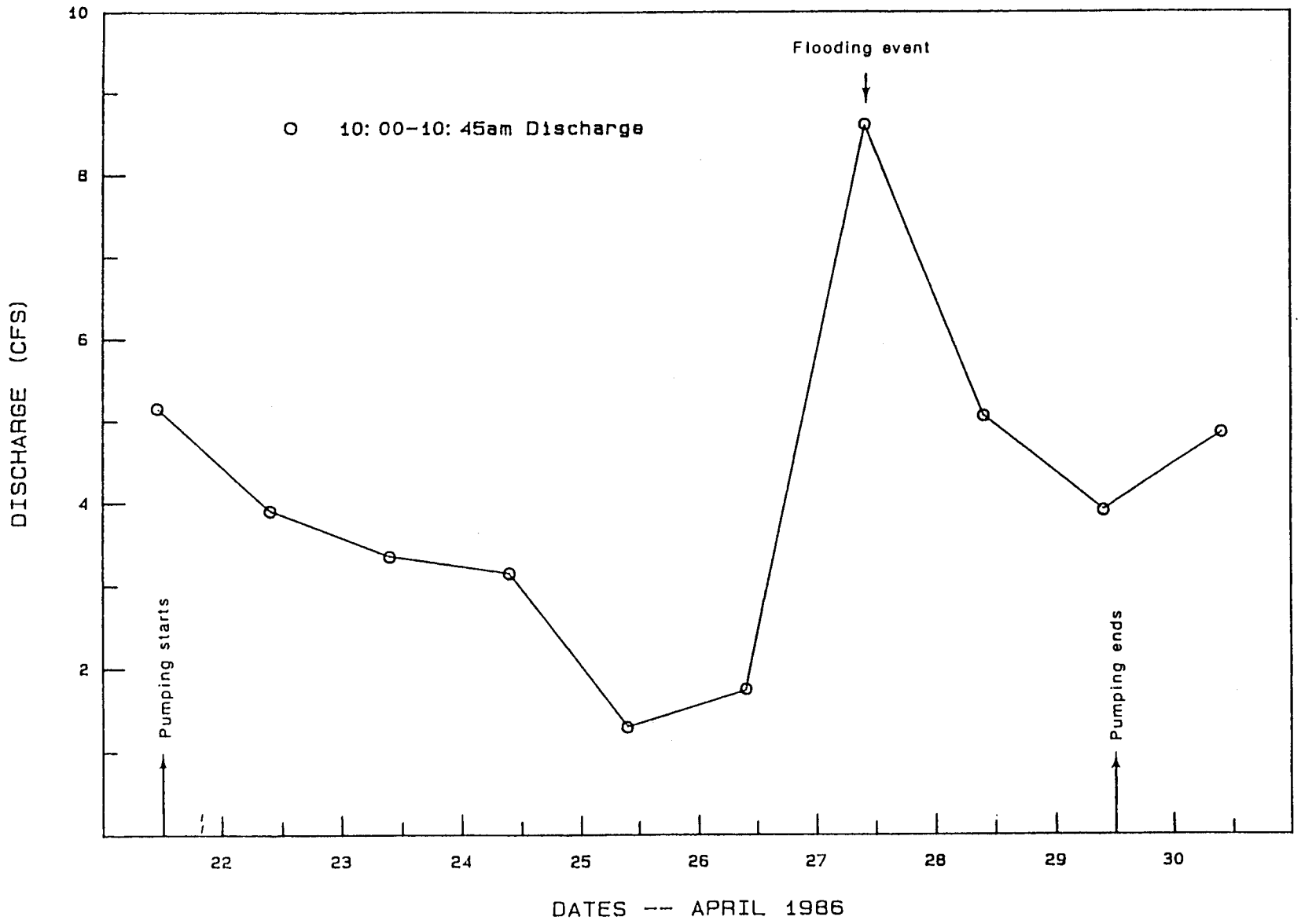

Figure 9.1 Discharge-Time Hydrograph for Weller's Downstream Station

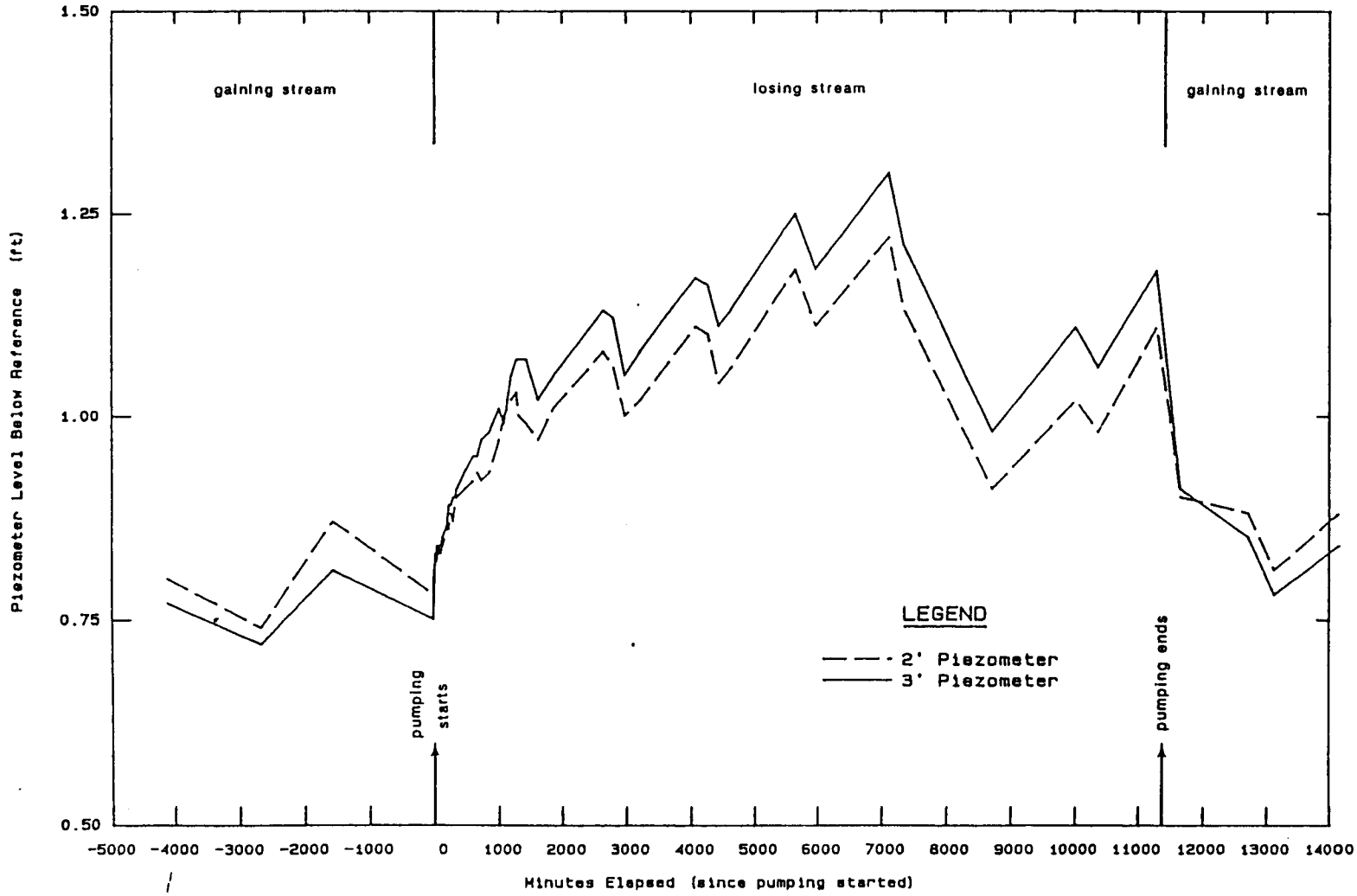

Figure 9.2 Piezometer Level vs. Time

CHAPTER 10: WALNUT CREEK HYDROLOGY

Thomas McClain and Robert Shapiro

INTRODUCTION

The goal of this chapter is a review and analysis of the hydrology of the Walnut Creek valley from Ness City to Great Bend (figure 10.1). The study is appropriate at this time because Cheyenne Bottoms has since the 1950's depended on streamflow from Walnut Creek to augment natural runoff to the marsh. When the diversion dam on the Walnut was completed in 1951, only 11,000 acre feet of ground-water and 1,300 acre feet of surface-water rights existed in the valley area. As the amount of water appropriated, mostly ground water, has increased, annual flow in the stream has decreased. Ground-water pumping for irrigation is not the only cause of streamflow decline, however. Changes in land-use patterns such as terracing and tillage methods along with impoundments also have decreased overland runoff to Walnut Creek. This decline in flow in the Walnut and a decline in flow in the Arkansas River have forced the Fish and Game Commission to alter their management practices at the marsh to cope with the effects of less water.

LOCATION AND EXTENT OF STUDY AREA

Walnut Creek has a drainage basin of about 1,700 square miles, rising in Scott County and flowing through Ness, Rush, and Barton counties before emptying into the Arkansas River 4 miles east of Great Bend. The western part of the basin in Scott and Lane counties crosses the Ogallala Formation. The Ness County portion of the stream generally flows on Cretaceous chalks and shales where the Ogallala has been eroded. Alluvial material along the stream is thin or nonexistent in Scott and Lane counties. Alluvium thickens in Ness County and near Ness City becomes as thick as 75 feet, enough to support wells

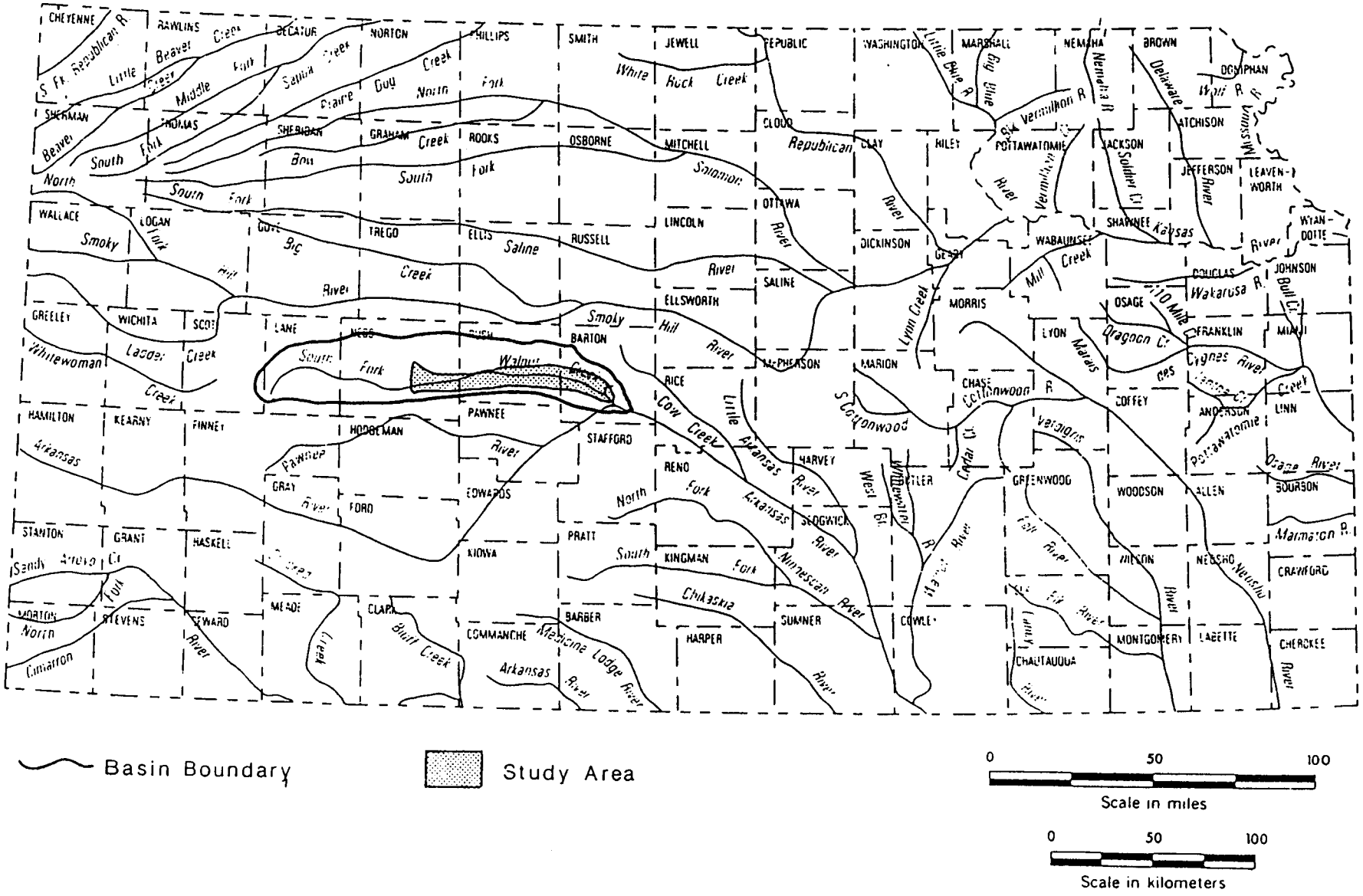

Figure 10.1 Map showing the Walnut Creek Study Area

for irrigation and municipal use. The Rush and Barton County portions of the valley can have as much as 110 feet of alluvium and a saturated thickness of 80 feet.

Previous studies that include the valley were done by Jenkins and Pabst (1977), who studied the hydrogeology of Ness County. McNellis (1973) reported on the geology and ground-water resources of Rush County, and Latta (1950) did a hydrologic study of Barton and Stafford counties which included the lower end of the valley.

Cheyenne Bottoms and the Walnut Creek Valley are separated by a ridge of Dakota Formation capped by as much as 50 feet of loess (see chapter 2). Water in the creek is diverted through this ridge by a diversion dam and a canal north of Great Bend.

GEOLOGY

The Walnut Valley aquifer is composed of gravel, sand, silt, and clay deposited by Walnut Creek. Terrace deposits on the sides of the valley are composed of similar material. Both deposits yield water to wells although the valley fill in the predominant aquifer. The alluvial material rests on bedrock of Cretaceous age. It consists of the Greenhorn Limestone, Graneros Shale, and Dakota Formation. Neither the Greenhorn nor the Graneros is an aquifer in the Walnut Valley area. The Dakota Formation is an aquifer and supplies water for domestic and stock uses as well as irrigation, municipal, and industrial use. The Dakota and alluvium are in contact along much of the lower end of the valley. The nature of the contact was not investigated in this study.

HYDROLOGY

The aim of this study is to outline the present water resources of the Walnut Valley and compare and contrast these with earlier reports and data.

Figure 10.2A shows a graph of long-term precipitation for three stations in the valley, Great Bend, Bison, and Ness City. Annual precipitation for all three stations was averaged to obtain a precipitation value of 23.1 inches for the lower part of the valley. Precipitation which falls on the valley and infiltrates the alluvium and recharge from irrigation, in addition to recharge from streamflow, are the primary sources of ground-water recharge. Figure 10.2 shows the comparison among precipitation, streamflow, ground-water levels, and ground-water appropriations.

In order to compare water levels in this study with earlier studies, water levels in 122 wells in the study area were measured in January of 1980, 1981, and 1982. Where possible, the same wells were measured as in earlier studies. Figure 10.3a and 10.3b show the ground-water-level contours for 1982.

Comparing the 1982 levels with those of Jenkins and Pabst, taken in 1960, there seems to be no obvious long-term rises or declines. Figure 10.4C shows the hydrograph for well 19-23-08 CBB in Ness County; minor changes of plus or minus several feet have taken place, but these occur due to recharge from precipitation or streamflow or discharge from wells. The aquifer in this area is not heavily pumped so there does not seem to be a long-term decline in the water table.

Ground-water levels in the Rush and Barton County portions of the valley have generally declined. Declines of as much as 18 feet have taken place in Rush County between 1960 and 1982 (figure 10.4A and 10.4B). If the 1982-86 period is taken into account, the decline is even greater. The Rush County

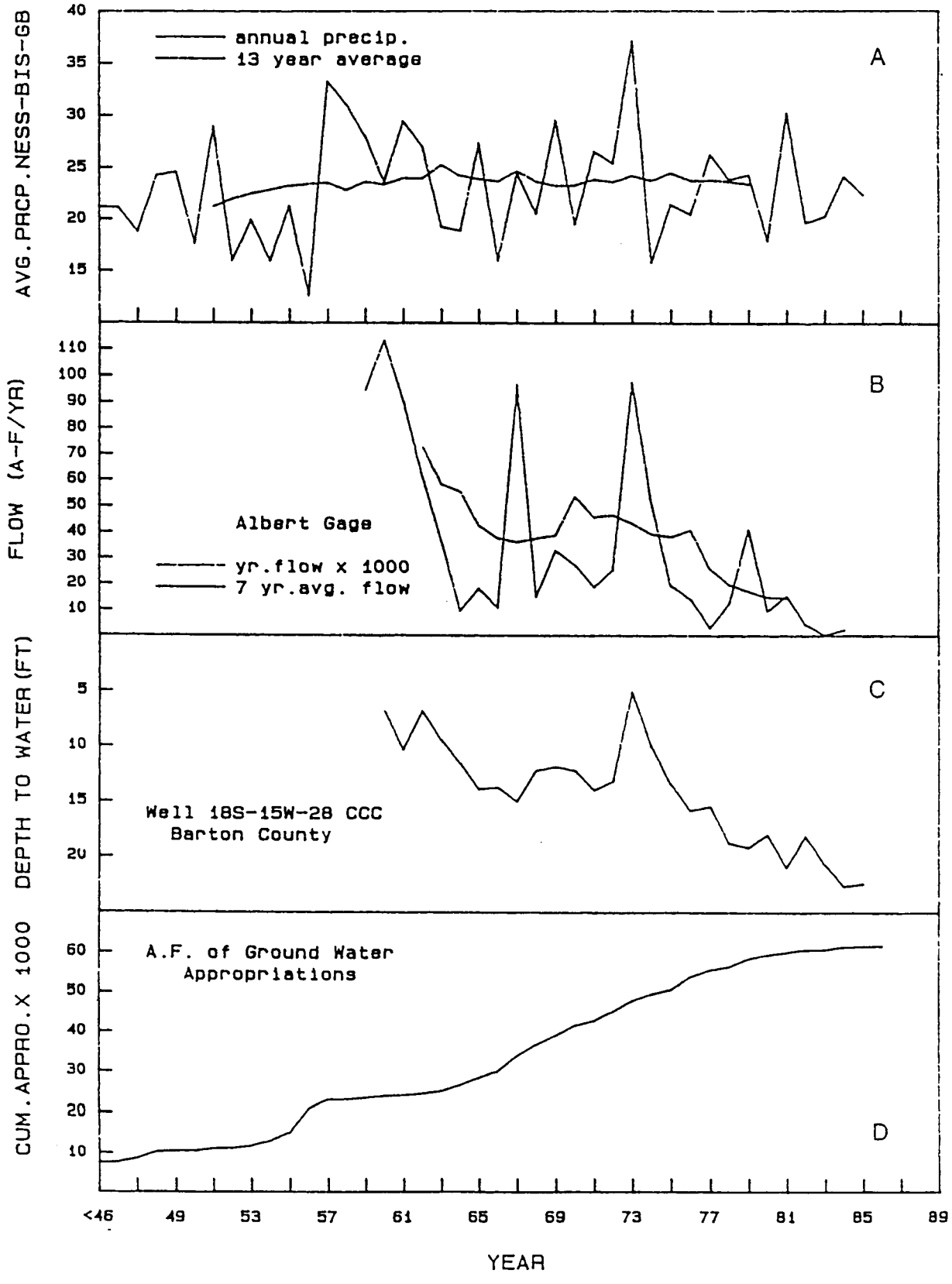

Figure 10.2 Comparison of Precipitation, Streamflow, Groundwater, and Water Right Appropriations

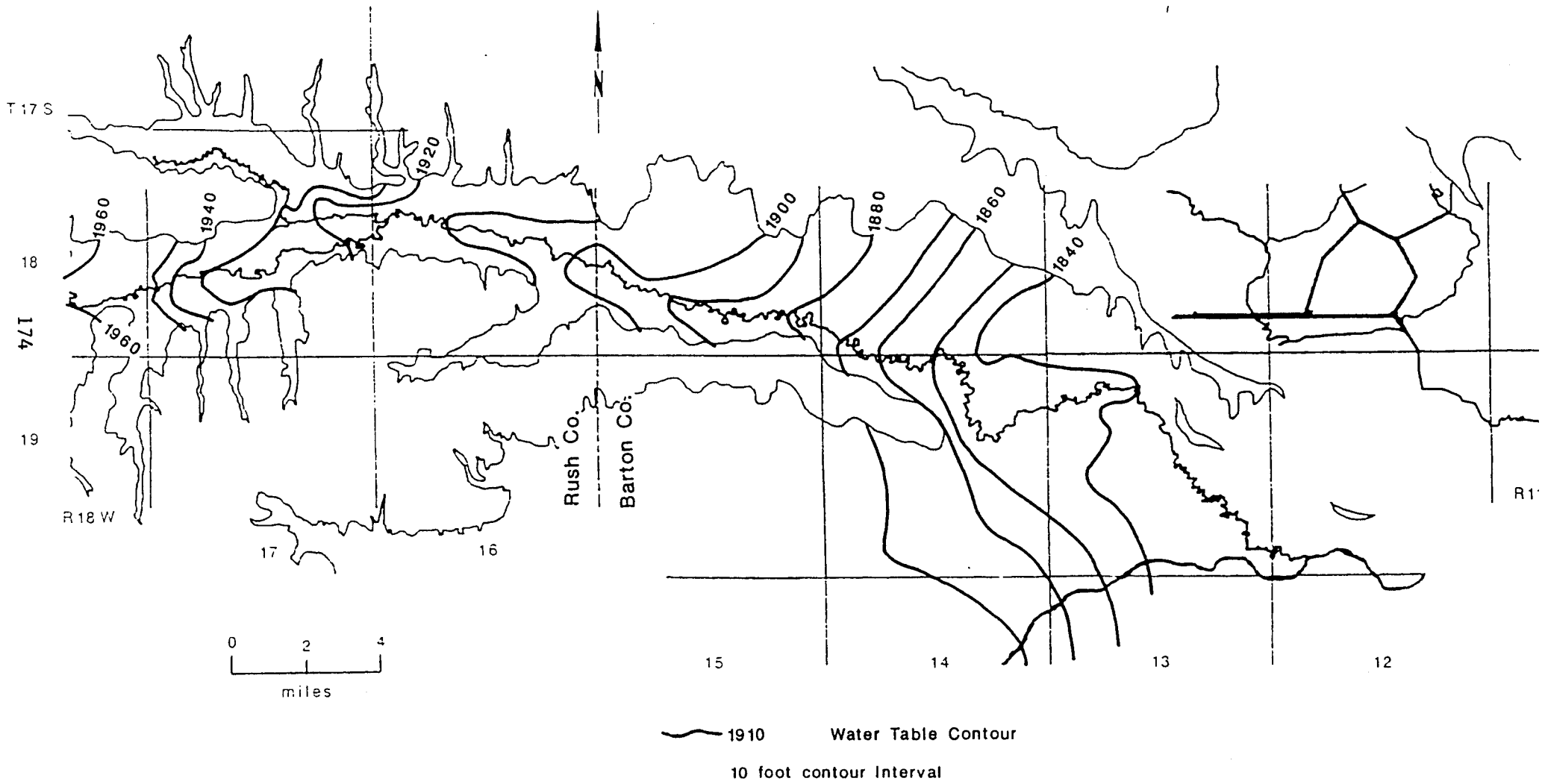

Figure 10.3a 1982 Water Level Contours (East Half)

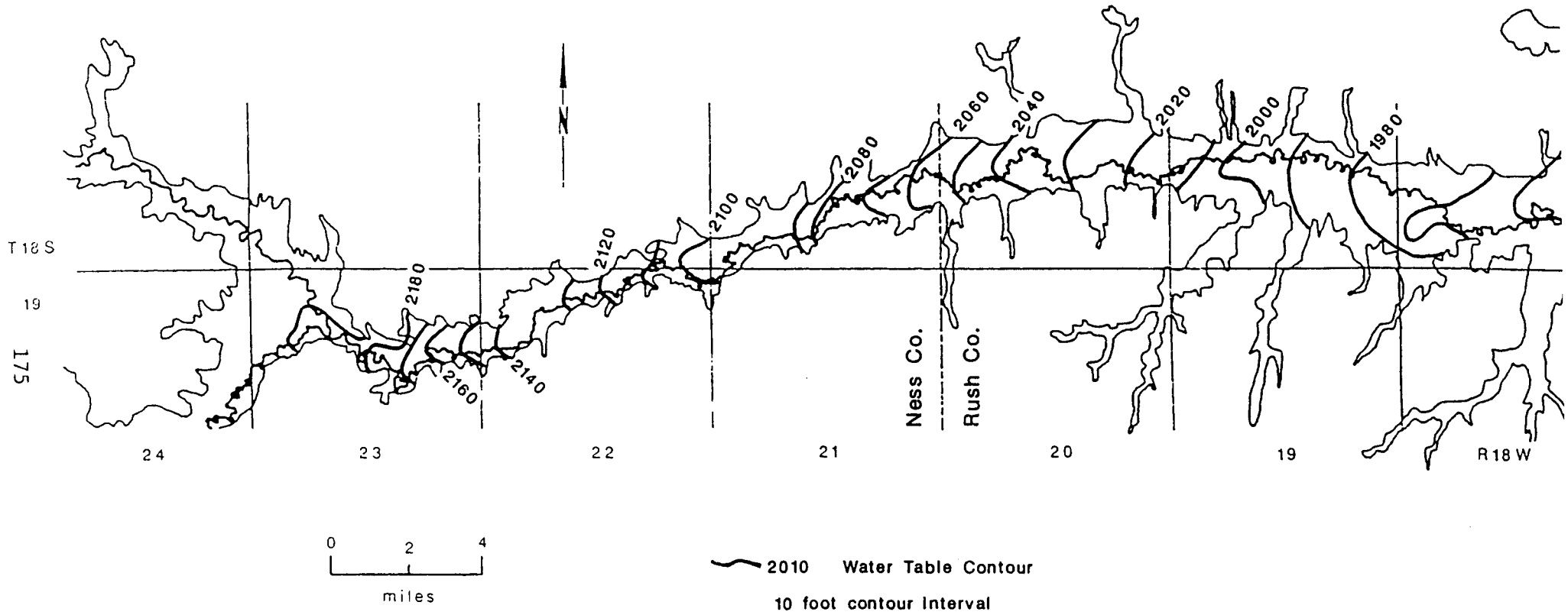

Figure 10.3b 1982 Water Level Contours (West Half)

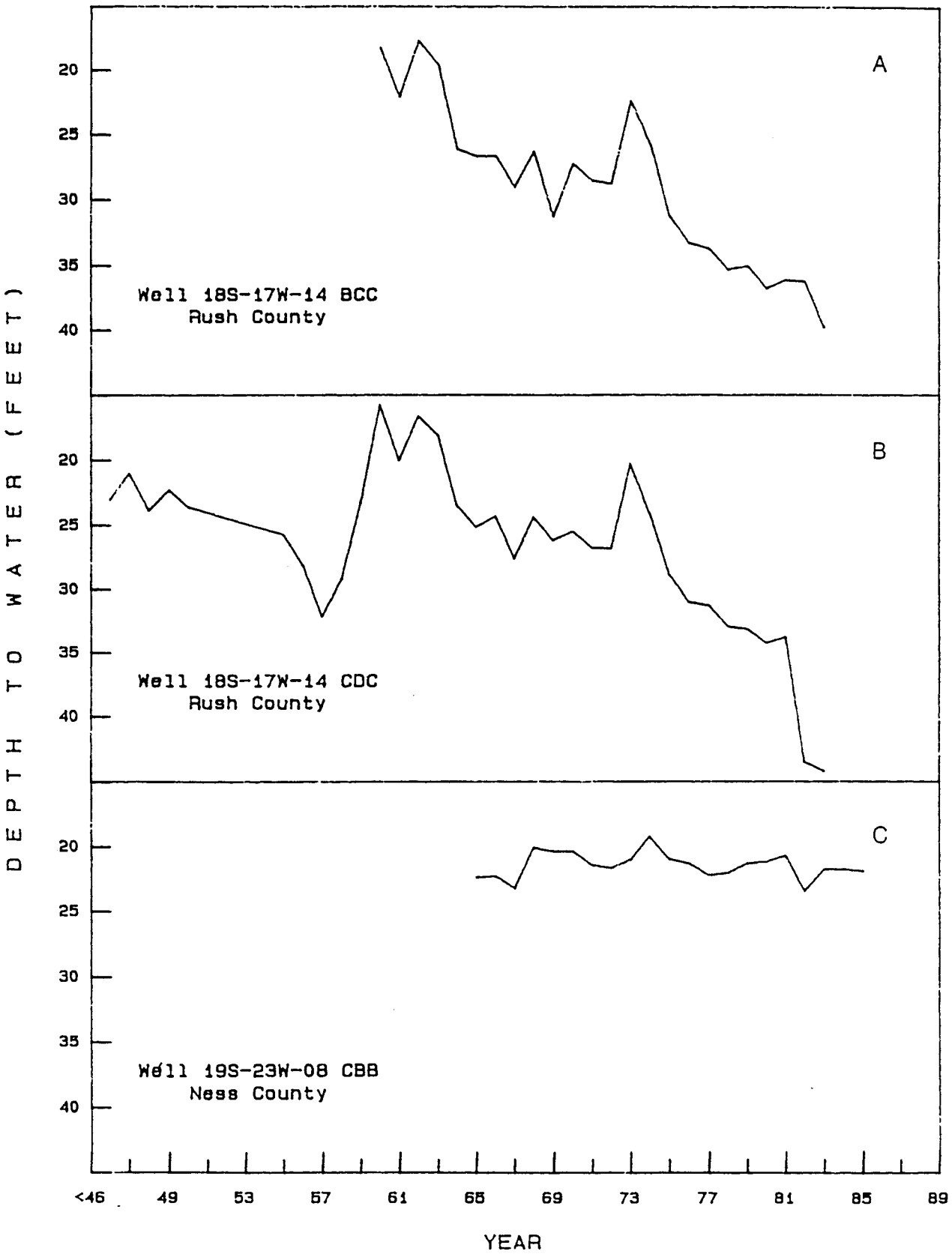

Figure 10.4 Well Hydrographs

portion of the valley has had the greatest decline because the amount of saturated material is relatively small compared to the number of large-capacity wells there. Delcine in water levels in the Barton County part of the valley are somewhat harder to document because there are fewer long-term observation wells there. However, by comparing data from Latta(1950) and 1982,and taking what observation wells there are, water-level declines of as much as 15 feet can be documented. Figure 10.2C shows the hydrograph for well 18-15-28 CCC in Barton County. Figures 10.5a and 10.5b show the composite declines for the alluvial aquifer. It must be remembered that the periods of change are 1974-1982 for Ness County, 1960-1982 for Rush County, and 1942/1944-1982 for Barton County.

Causes of ground-water-level declines can be traced directly to ground-water pumping and indirectly to a decline in runoff due to agricultural practices. As McNellis (1973) points out, the alluvial aquifer discharges and recharges relatively rapidly when streamflow rises and falls. Recharge takes place due to precipitation falling directly on the aquifer as well as seepage through the bottom of the stream channel. Consequently, as runoff declines, streamflow declines and recharge to the aquifer declines.

STREAMFLOW

Volume of streamflow out of a basin can be thought of as a gauge of the health of the basin. Under natural conditions streamflow is composed of two parts: overland flow from surface runoff of precipitation and baseflow which is ground-water contribution from the aquifer through which the stream flows. Decline in streamflow is then caused by a decline in runoff and/or a decline in baseflow. Appendix 4.1 lists the records of annual flows at the Albert gage 1 mile east of the Rush-Barton County line. Figure 10.2B shows a graph of these flows and the relationship among ground water, precipitation,

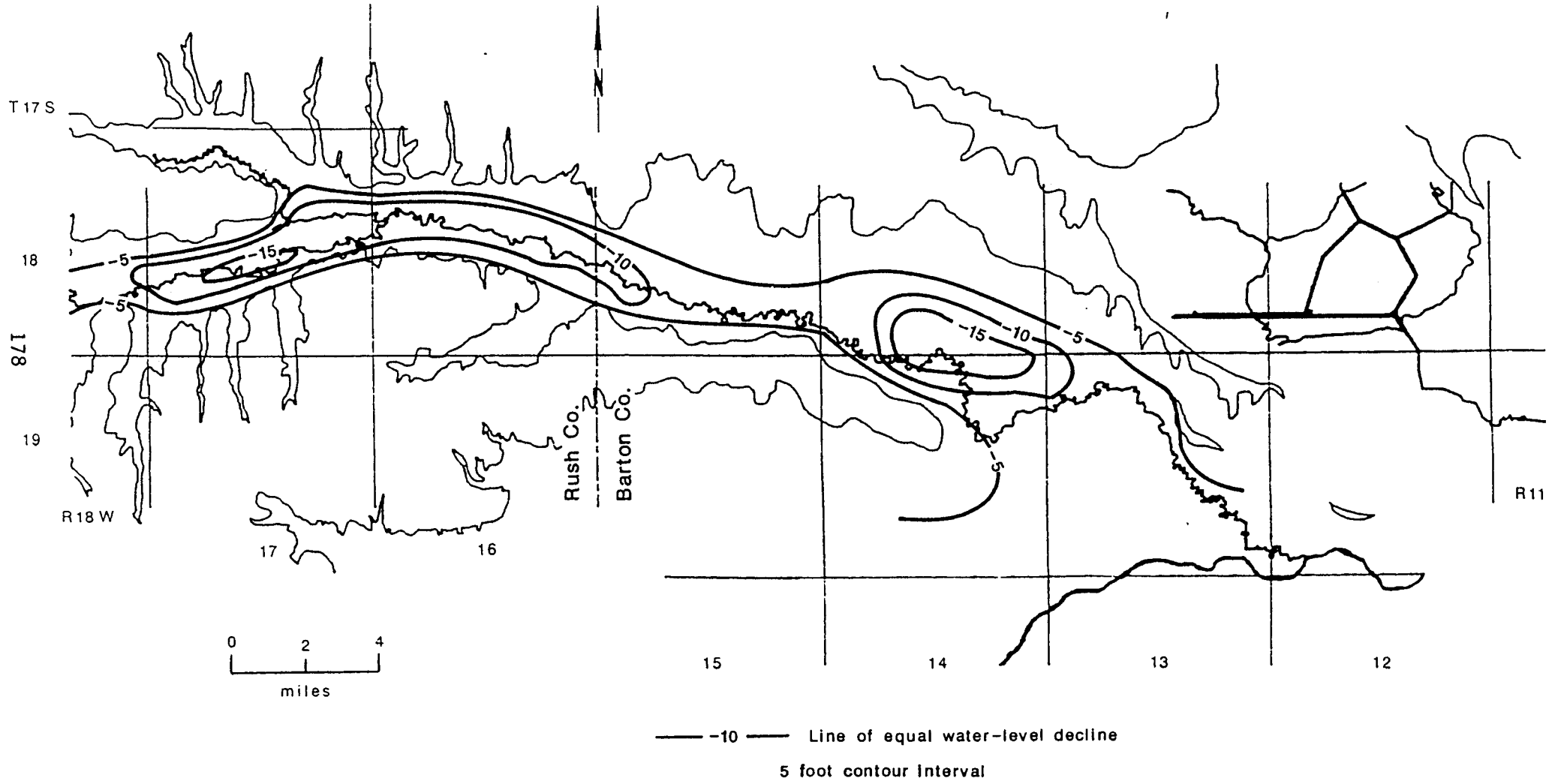

Figure 10.5a Water Level Decline Contours (East Half)

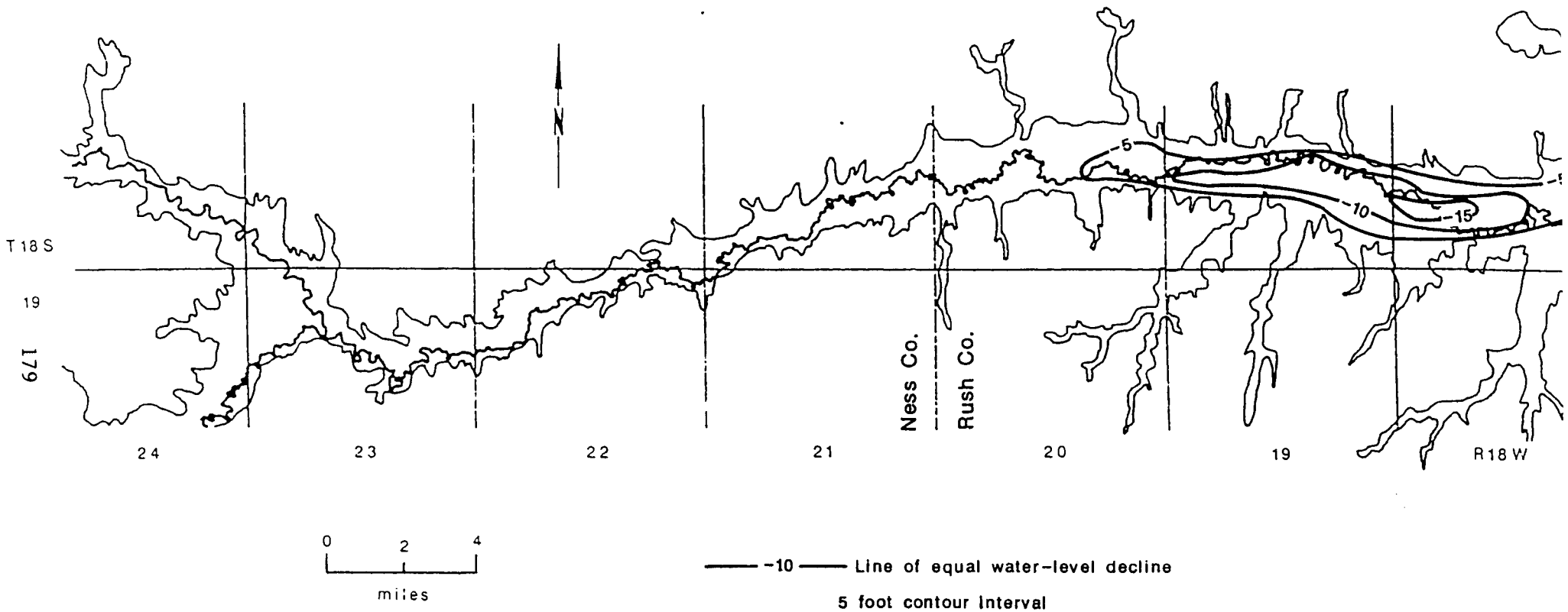

Figure 10.5b Water Level Decline Contours (West Half)

streamflow and ground-water appropriations. Long-term average flows have declined from about 60,000 acre feet per year in the early 1960's to about 12,000 acre feet per year in the early 1980's. Assuming that Walnut Creek was a gaining stream prior to large-scale development of irrigation, even by the early 1960's there were periods of no flow indicating a decline in groundwater in storage. A comparison of present ground-water in storage with amounts estimated in previous studies was made by using the data from McNellis. McNellis (1973, p. 20) calculates the volume of saturated deposits to be 1,610,000 acre feet. Assuming a storage factor of 0.15, the volume of water available for pumping in 1960 was determined to be 241,500 acre feet. Using the same technique as McNellis, the 1982 volume of saturated material was calculated to be 1,150,000 acre feet with a total volume of water of 172,500 acre feet, a 29% decline of water in storage since 1960.

WATER-RIGHTS APPROPRIATIONS

Figure 10.2D shows the increase in acre feet of ground water appropriated for all uses in the Walnut Valley between Ness City and Great Bend. The amount varies from about 7,700 acre-feet in 1946 to about 62,000 acre-feet in 1985.

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CHAPTER 11: EFFECTS OF THE BARTON COUNTY LANDFILL ON WATER QUALITY

Michael Kukuk

INTRODUCTION

Municipal sanitary landfills are often cited as sources of ground-water contamination. The regulations promulgated on May 19, 1980, by the Environmental Protection Agency (EPA) under the Resource Conservation and Recovery Act (RCRA), are intended to minimize ground-water contamination due to landfill leachate. This is accomplished by regulation of landfill construction practices and establishment of onsite monitor-well networks. These networks are specified to have one upgradient and three downgradient monitor wells installed in the uppermost aquifer adjacent to the land-disposal facility. The ultimate goal is to minimize the environmental impacts of landfills. A major environmental impact resulting from the disposal of solid waste into a sanitary landfill occurs when water passes through the solid waste, accumulates various contaminants, and percolates or leaches into underlying ground waters or downgradient surface waters, seriously degrading water quality. Overall, the effectiveness of the regulations depends on siting considerations as well as on design and management procedures.

Presented here are the results of a site investigation of the Barton County sanitary landfill near Great Bend, Kansas. The location of water quality sampling points are shown in figure 11.1. The investigation was completed by the Kansas Geological Survey (KGS), with technical assistance provided by the Kansas Department of Health and Environment, and in cooperation with the Barton County Engineers Office. The primary purpose of this study was to give an initial indication of possible leachate formation and the effects any such leachate might have on the local water quality. This

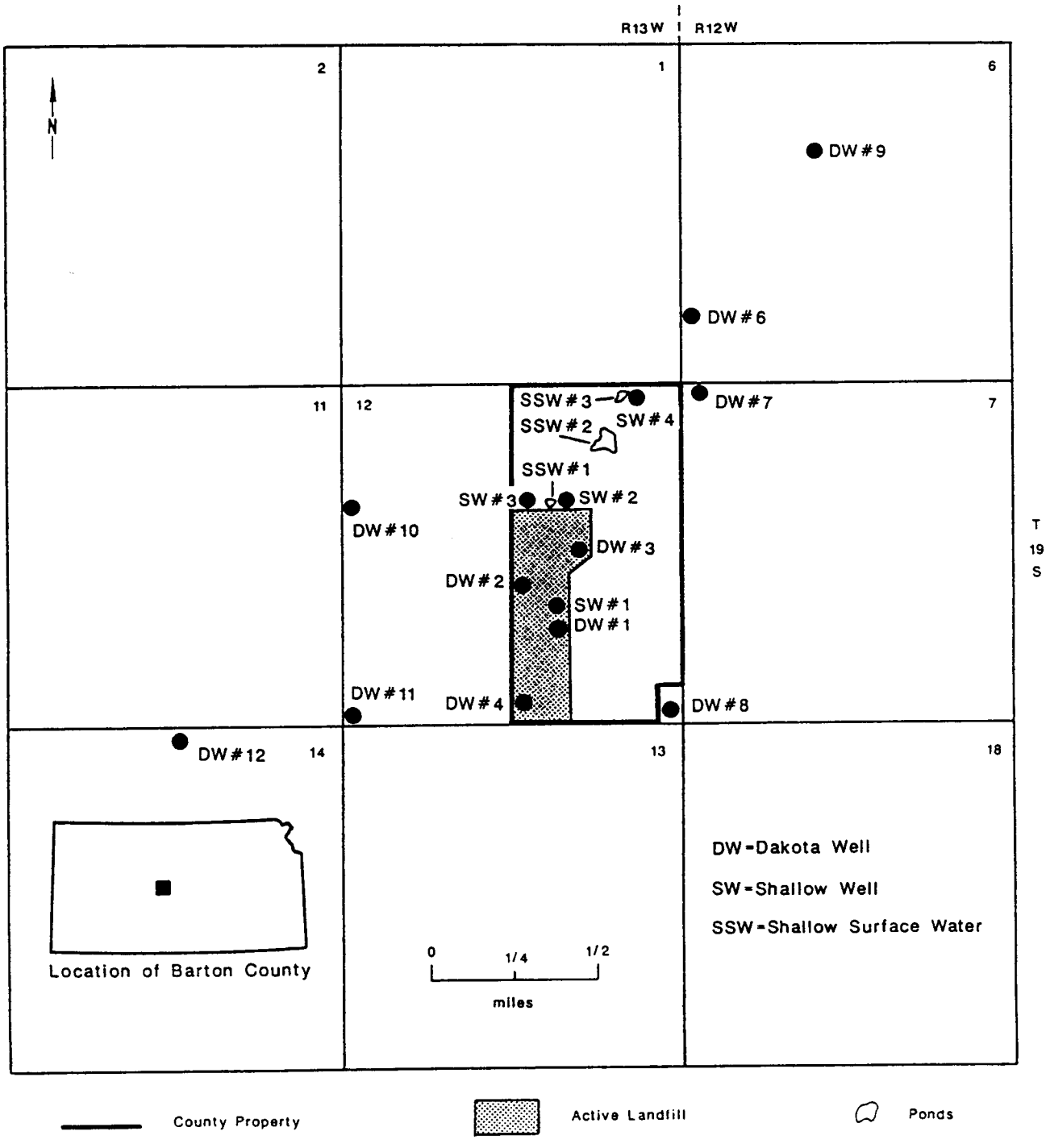


Figure 11.1 Location of Water-Quality Sampling Points

includes the local drinking-water aquifer as well as long-term water-quality effects on the Cheyenne Bottoms Waterfowl Refuge, a downgradient wetland.

SITE DESCRIPTION

STUDY LOCATION

The predominant industries in Barton County are agriculture and petroleum. The county has approximately 32,000 residents and is located in south-central Kansas. For the past 14 years, residential, commercial, and industrial refuse has been disposed of at the county landfill. The landfill site is composed of about 240 acres and is situated on the Cheyenne Bottoms-Arkansas River valley divide in the eastern half of sec. 12, T. 19 S. R. 13 W.

The landfill site is positioned in a ravine on the north slope of the divide that drains directly towards the Cheyenne Bottoms. The ravine represents a local watershed that exists inside the landfill's property line. The Cheyenne Bottoms-Arkansas River valley divide is a ridge of Dakota Formation covered with wind-deposited loess that separates the Arkansas River valley from the Cheyenne Bottoms. The divide is from 1 to 3 miles wide and extends roughly from U.S. Highway 281, north of Great Bend, to a point northwest of Ellinwood, Kansas.

HISTORY OF THE BARTON COUNTY LANDFILL

The Barton County landfill began operation on January 1, 1972. It was one of the first sanitary landfills to begin operation in the state of Kansas. The landfill receives approximately 90 tons of solid waste per day for approximately 302 days each year according to the county engineer. Residential, commercial, industrial and some permitted hazardous wastes such as pesticides, acids, caustics, asbestos, and solvents have been disposed of at the landfill over its 15-year history.

The waste-disposal operation began in the southernmost portion of the ravine and proceeded northward as the ravine was filled (figure 11.2). The design of the landfill has employed the use of trenches excavated approximately 20-40 feet into the loess. The wastes bear directly on the loess. A typical trench would have dimensions of 30 feet in width and 200-300 feet in length. Once a trench is excavated, approximately 6 feet of compacted solid waste is accumulated followed by a 6-inch layer of loess to cover the waste cell. A period of three to four weeks is usually required before the 6-foot thickness of solid waste can be attained. The creation of waste cells is continued until the top of the trench is 3 feet below the desired final land-surface elevation.

Following the completion of a solid waste trench, a 3-foot mantle of soil consisting of 2 feet of loess and 1 foot of topsoil is compacted on top of the uppermost cell. The 3-foot mantle is then sloped to provide surface drainage from the site northward. It was observed that proper surface drainage was not consistently achieved over the completed areas of the landfill. Many small depressions in the soil mantle were noted which allowed water to accumulate after a storm event. These depressions are suspected to be caused by differential settlement of the decomposing solid waste, coupled with inadequate sloping of the soil mantle.

When it rains, solid waste is deposited in what has been termed as the landfill's "wet pit." The "wet pit" is a north-south trending open trench that is approximately 100 feet wide, 700 feet long, and 40 feet deep. The "wet pit" is located due north of the scale house near the entrance of the landfill in order to reduce the travel distance of vehicles manuevering over muddy roads.

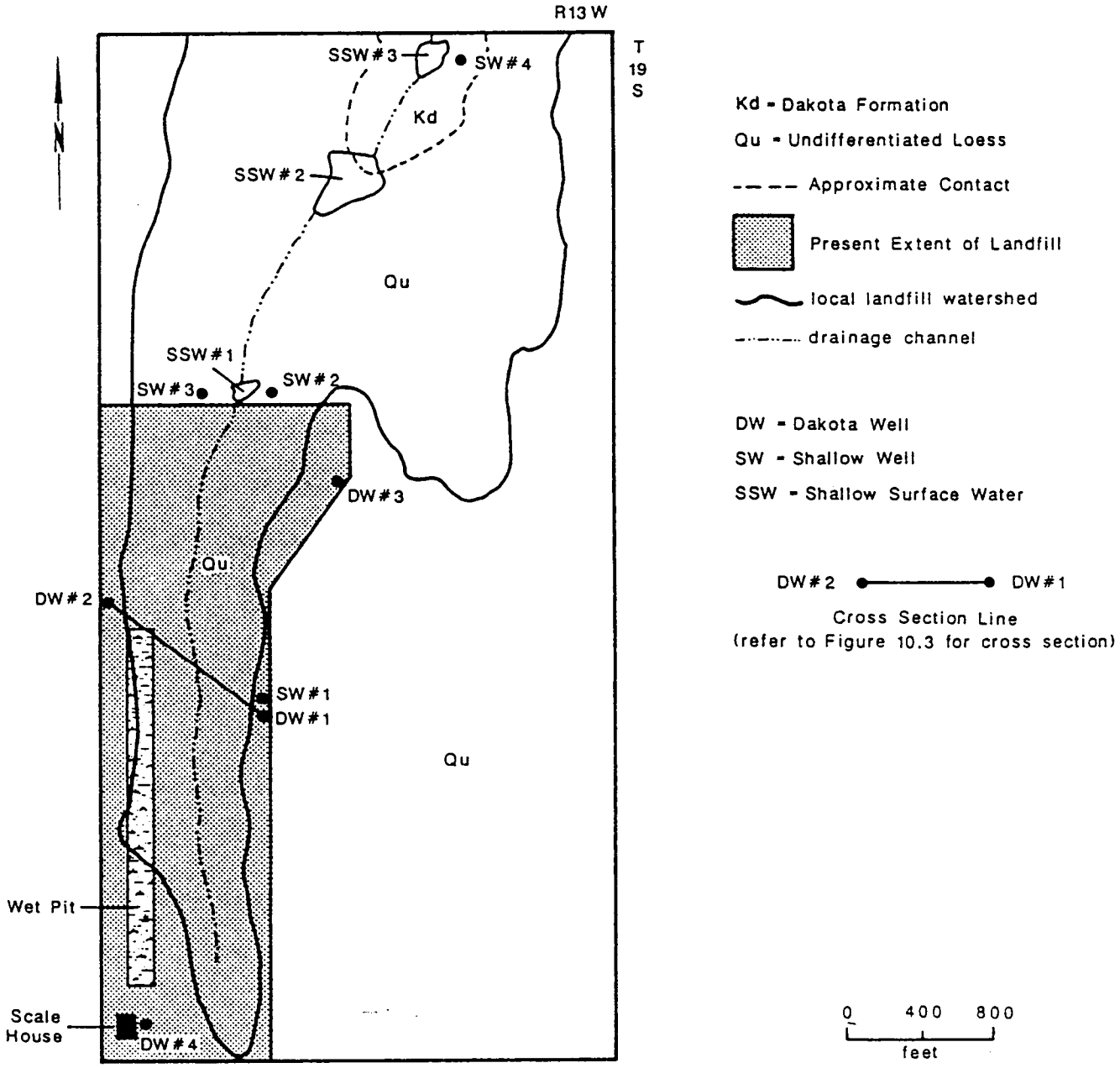


Figure 11.2 Barton County Landfill

Solid waste accumulated in the "wet pit" is covered with soil once or twice during the year and is open to the atmosphere the remainder of the time. The "wet pit" is a cause of concern for officials of the Kansas Department of Health and Environment because the pit can easily accumulate several feet of standing water in its lowest point. This water is in direct contact with the wastes in the pit which can result in direct leaching from the wastes.

The Barton County landfill opened eight years prior to the RCRA legislation. Therefore, as was the case with the majority of landfills in operation before RCRA, no monitor wells were installed prior to the opening of the site. Additionally, no soil borings were completed at the site to determine geologic-unit thicknesses and the depth to water. However, geologic information from the numerous oil-well logs in the area were used to determine the suitability of the site for the location of the landfill.

SITE GEOLOGY

Geologic formations at the site consist of a lower bedrock unit, the Cretaceous Dakota formation which is overlain by Pleistocene loess. The loess is late Pleistocene in age and is composed chiefly of loess or loess like silt, with some sand and gravel deposits near the bottom of the formation. The silt is tan, yellow tan, brown, and gray in color and contains some fine sand, clay, and caliche nodules. Fragments of "algal limestone," Cretaceous sandstone, and "ironstone" are common at the base of the formation.

The Dakota Formation is Cretaceous in age and is composed of alternating beds of varicolored clay, shale, siltstone, and sandstone. Clay is the dominant type of rock in the Dakota Formation and is light to dark gray, white, tan, brown, yellow, or red in color. White, gray, yellow, tan, and brown fine- to coarse-grained sandstone occurs as thin beds in the clay and as

lenses ranging from a few feet to more than 30 feet in thickness. The sandstone lenses occur as discontinuous bodies that may be encountered in any part of the formation.

Approximately 90% of the landfill-site land surface is underlain by undifferentiated loess which ranges in depth from several inches near SSW #2 and thickens to more than 60 feet at the south fenceline. The loess unconformably overlies the Dakota Formation, which is 200-300 feet thick in this area (figure 11.3). The Dakota Formation crops out in the north end of the ravine between SSW #2 and SSW #3, where the loess has been removed by erosion (figure 11.2).

SITE GEOLOGIC HISTORY

Cretaceous deposits were laid down on a long-eroded, deeply weathered Permian surface. During the Early Cretaceous, the sea was transgressing northward over the area and deposited the Cheyenne Sandstone on the shoreline of the transgressing sea. Marine sediments of the Kiowa Shale followed (chap. 2, figure 2.3). A general regression of the sea marked the end of the Early Cretaceous and the beginning of the deposition of the Dakota Formation. This regression of the sea was not continuous but was marked by minor fluctuations of the shoreline resulting in marine and continental beds being interbedded.

The Dakota Formation generally is considered to have been deposited under marine conditions from this regressing sea and under non marine conditions in a bordering low-lying coastal and deltaic plain. At the beginning of Late Cretaceous time, the area was again submerged beneath a shallow sea and many hundreds of feet of shale and limestone (Graneros Shale, Greenhorn Limestone, Carlile Shale, and Niobrara chalk) were deposited.

During most of the Tertiary Period, the surface was exposed and several hundred feet of Late Cretaceous rocks were eroded, hence their absence in the

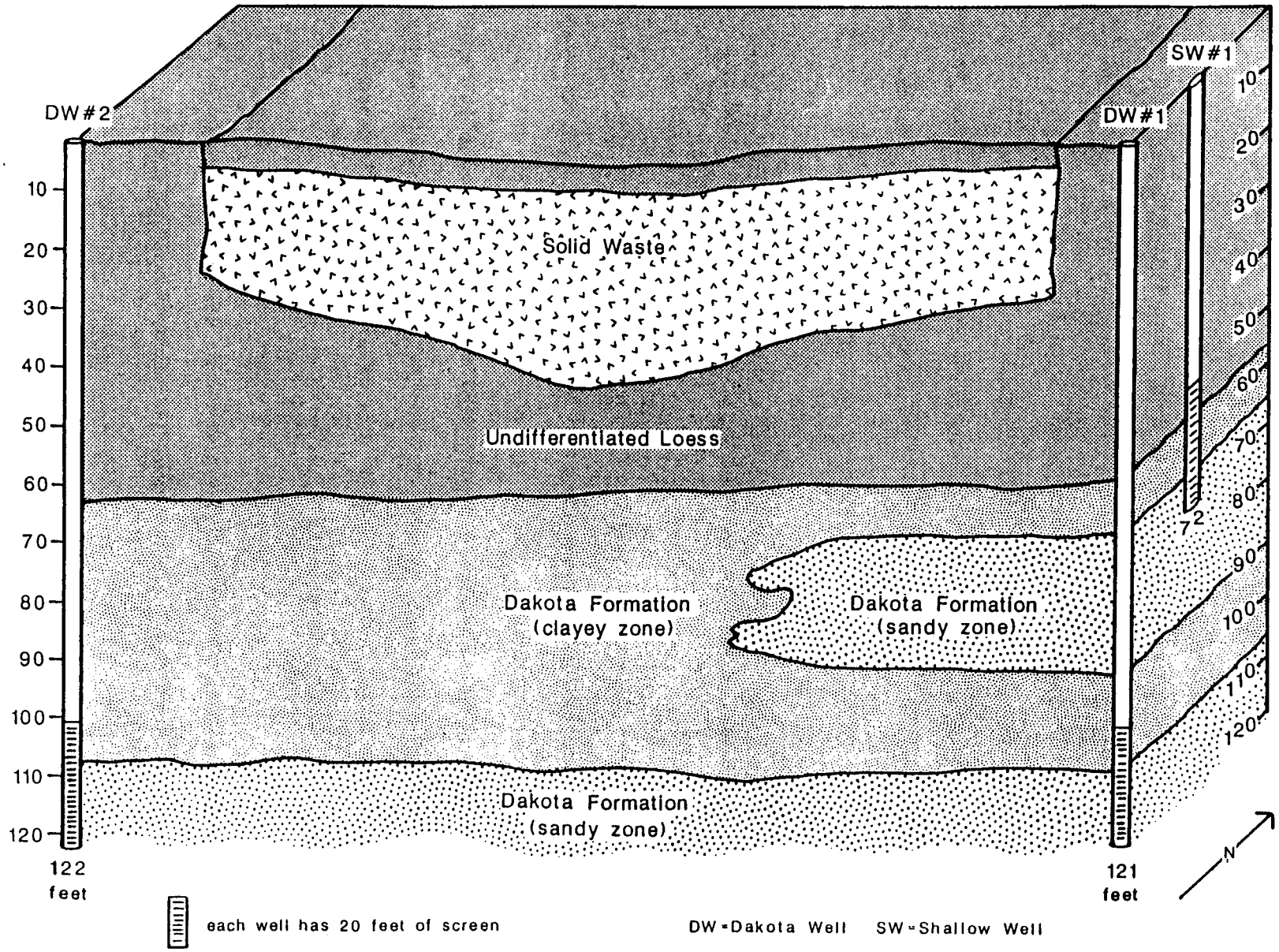


Figure 11.3 Geologic Cross Section from DW#2 to DW#1

drilling logs. Deposition of sediments of the Ogallala Formation occurred during the Pliocene epoch of the Tertiary. These deposits were thin in this area and were removed by erosion during Pleistocene time. Much of the present topography of this area is the result of erosion which began during the Pleistocene and has continued to the present time (Latta, 1950; Keene and Bayne, 1977; Bayne, 1977).

The Pleistocene history of this area is very complex and accurate interpretation is difficult. Late in the Pleistocene erosion occurred in the Cheyenne Bottoms Valley that removed the silt, sand, and gravel of the Undifferentiated Pleistocene Formation which was deposited during the early Pleistocene. These eroded sediments had been originally deposited by streams carrying material from the Rocky Mountains and from areas of Tertiary rocks to the west. This late Pleistocene erosion was followed by stream deposition of silt, sand, and gravel in the valleys and windblown silt on the divides (undifferentiated loess).

SITE WATER RESOURCES

The importance of maintaining suitable ground-water resources in this portion of the state is illustrated by the fact that the entire population of Barton County obtains its water supply from wells. In addition to human uses, wells supply water for livestock, waterfowl, and fishing ponds throughout the county.

The water-bearing formations that underlie the Barton County landfill are in the Dakota Formation as well as in a thinner water-bearing zone at the unconformable contact between the loess and the Dakota clay. This thinner zone will be referred to in this paper as the upper aquifer. Currently, the upper aquifer is not known to be used as a water supply in the area.

The discontinuous sandstone lenses of the Dakota Formation are the chief sources of water in the upland areas of Barton County, which includes the Barton County landfill area. Approximately one-third of the recorded wells in Barton County during the 1940's obtained their water from the Dakota Formation, thus making it a very important water resource (Latta, 1950). The shallowest sandstone lens that is tapped for domestic use near the landfill occurs at a depth of approximately 105 feet below the land surface of the top of the divide. Three monitor wells were placed in this aquifer to provide water-quality information concerning the local drinking-water aquifer, the results of which will be discussed later.

Water from the Dakota Formation in the vicinity of the landfill is under confined pressure. The Dakota clay layers above the sandstones, and the Kiowa Shale below, act as confining beds. The quantity of water available from the wells is quite variable with yields which range from a few gallons per minute to a few hundred gallons per minute.

The general flow of ground water in the Dakota Formation is in an east-northeasterly direction. This is due to recharge of the aquifer in the uplands to the west and the discharge area to the northeast, (figure 11.4). The contours are generalized due to the limited number of wells in the study area as well as to the wide range of well-completion depths, screened intervals, and gravel-pack intervals. These factors can all have an effect on water levels inside the well casing. Water-level measurements that were recorded specifically for this study to determine ground-water-flow direction were in concordance with ground-water-flow direction suggested by Bayne and Keene (1977) for similiar Lower Cretaceous rocks.

As was mentioned earlier, the upper aquifer is located on an unconformity between the loess and the Dakota Formation. An unconformity is a surface that

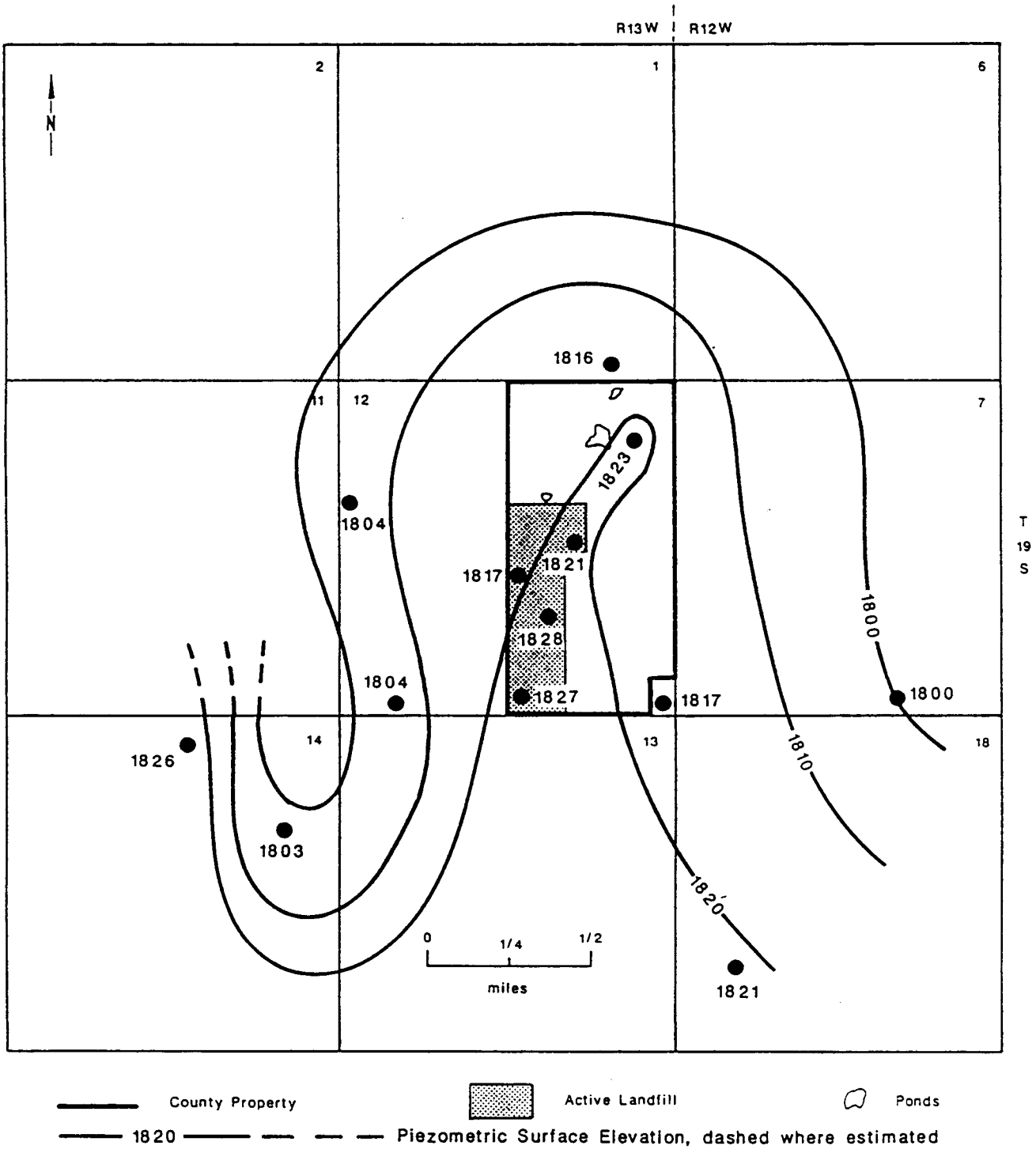


Figure 11.4 Piezometric Surface of the Dakota Formation

represents a time interval during which deposition was nonexistent, or the surface of the existing rocks was weathered, eroded, or fractured. Aquifers are commonly associated with unconformities, either in the weathered or fractured zone directly underlying the surface of the buried landscape or in permeable zones in coarse-grained sediments laid down on top of this surface when the system entered a new era of accretion (Freeze and Cherry, 1979). Coarse-grained sediments were documented as being present at the same depth as the upper aquifer in the drilling logs and the gamma logs (appendix 11.1 and 11.2).

The upper aquifer underlies the landfill locally and is much closer in vertical distance to the waste cells. However, there is not sufficient water-level data to construct a water-level contour map. In an effort to get a general understanding of the water-level gradient in the upper aquifer, a contour map of the top of the Dakota Formation was prepared with the assumption that the water levels basically follow the slope of the contact between the loess and the Dakota clay (figure 11.5). This contour map will be presented later in this paper in respect to possible contaminant-migration pathways.

The lower section of the loess (5-15 feet) contains more coarse sand and fine gravel than the upper part of the formation. The upper 2-5 feet of clay in the underlying Dakota Formation also has a much higher sand and gravel content than the lower Dakota clays. The combination of the porous loess with the porous upper Dakota allows for the accumulation and migration of water in the upper aquifer. This upper aquifer has had very little documentation in the literature because it generally does not yield water in sufficient quantities to be used as a water supply.

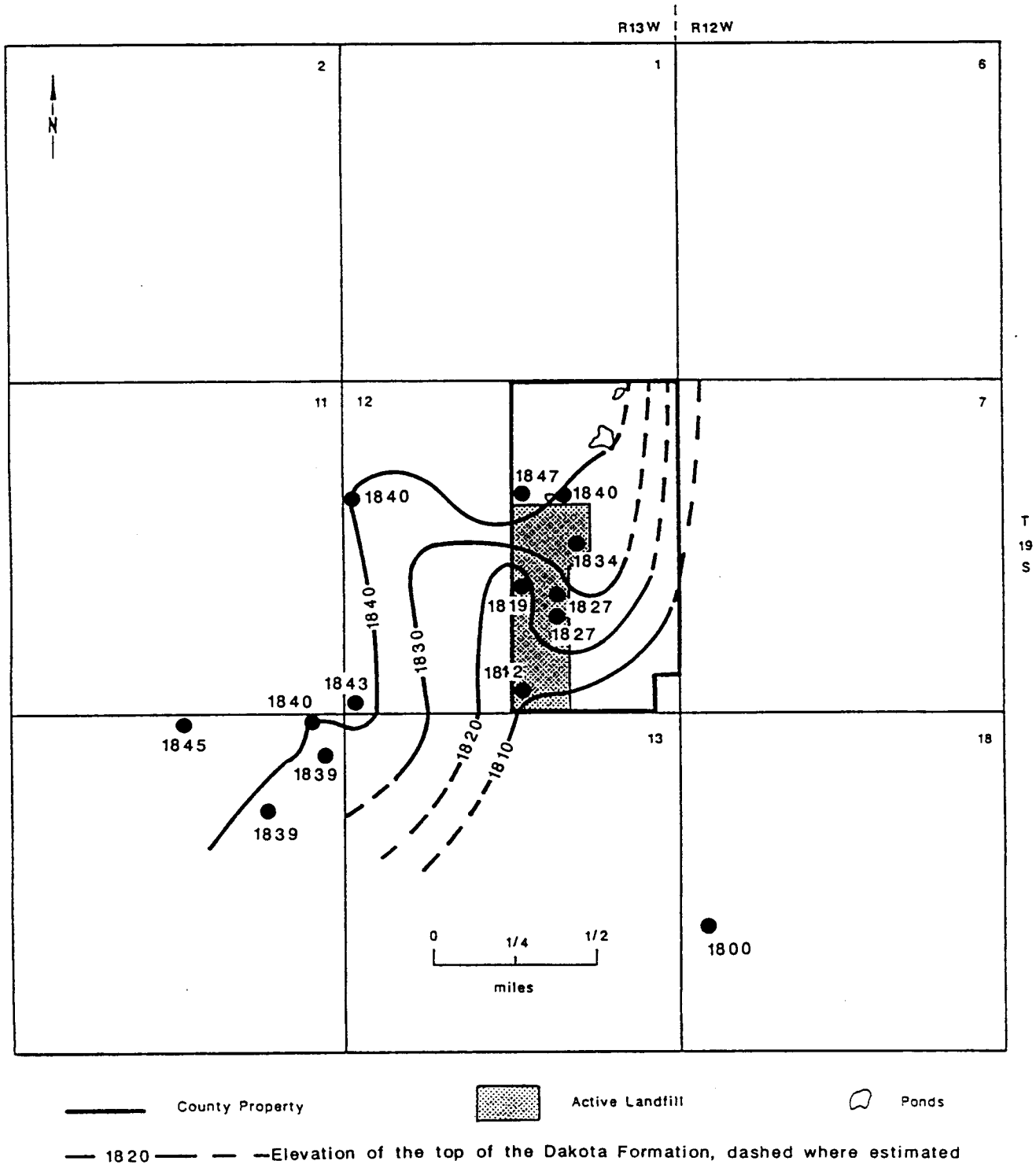


Figure 11.5 Elevation of the Top of the Dakota Formation

The Loess-Dakota contact on which the upper aquifer is located, crops out near the currently inactive north boundary of the landfill in the lower portions on the ravine. During the course of the field work, no springs or seeps were observed near the contact outcrop. It should be noted that this contact has not been observed during or after a prolonged storm event.

Also located in the north section are three surface-water ponds which are connected in series by a drainage channel. The ponds are referred to in this report as SSW #1, SSW #2, and SSW #3, going from south to north. SSW represents shallow surface water as shown in figure 11.1. These ponds act as holding basins for the surface runoff generated upslope, in the active portion of the landfill, as well as for a drinking-water supply for cattle. When the ponds reach their respective water-holding capacities, water flows over a spillway northward to the next pond until, eventually, the water will flow out of the SSW #3 and enter a small drainageway that discharges onto the dry flatlands of the Cheyenne Bottoms.

DESIGN AND CONSTRUCTION OF THE MONITOR WELL NETWORK

WELL PLACEMENT

The emphasis of this part of the study was to identify if and where ground water was being contaminated by leachate from the landfill. To obtain this data, seven monitor wells, 2 inches in diameter, were installed by the Kansas Geological Survey near the fenced boundaries which surround the active portion of the landfill (figure 11.2). Of the seven wells installed, three wells (DW #1,2,3), were considered deep wells or Dakota wells and were completed to a depth of approximately 122 feet by a mud rotary drilling rig. The locations of the wells in reference to the active portion of the landfill are as follows: DW #1 to the east, DW #2 to the west, and DW #3 to the northeast. The wells penetrate approximately 15 feet into a sandstone lens of

the Dakota Formation. Machine-slotted well screen was placed over the lower 20 feet of borehole. This sandstone lens represents the shallowest source of drinking water presently being used in the area. The purpose of the Dakota wells was to provide ground-water-quality data on the shallowest drinking-water aquifer that would be affected first by leachate which originated from the landfill.

The remaining four wells are considered to be shallow wells (SW #1,2,3,4), and their purpose was to provide ground-water-quality data for the upper aquifer. SW #1 is 15 feet north of DW #1 and was drilled and constructed in the same manner as the Dakota wells (rotary drilling and 20 feet of well screen). This well provides a control to compare water quality between the upper aquifer and the drinking-water aquifer at the same location. SW #1 is 72 feet in depth and penetrates the upper 6 feet of a 23-foot sandstone lens encountered 6 feet below the Loess-Dakota contact. This sandstone lens is typical of sandstones in the Dakota in that it was discontinuous over the site and was not encountered in the other Dakota wells. The 20-foot screened interval allowed ground water from the upper aquifer as well as any water in the upper sandstone lens to be sampled.

SW #2 and #3 are located directly north of the current landfill fence line and are positioned on the east (#2) and west (#3) sides of SSW #1. SW #2 is 26 feet in depth and SW #3 is 27 feet in depth. Both wells penetrate several feet into the top of the Dakota Formation. The screened interval is 10 feet. This allowed the sampling of water obtained exclusively from the upper aquifer. These wells are also topographically downgradient from the waste cells.

SW #4 is located near the north boundary of the landfill just to the east of SSW #3. The well is 20 feet in depth of which the entire length is in

Dakota clay. The screened interval is 10 feet, but no water has been found in the well. The purpose of this well was to provide downgradient, shallow ground-water data at a reasonable distance from the active landfill, but obviously no data can be attained from a dry well. SW #2, 3, and 4 were drilled with a hollow-stem auger.

The areal placement of the wells was chosen with respect to the amount of drilling time available (two weeks) balanced with an attempt to ensure sufficient coverage on all sides of the landfill with an emphasis on downgradient wells. Safety precautions were taken during the actual drilling of the monitor wells to ensure the safety of all personnel working in direct contact with the water from the wells. All personnel who handled the water or handled the equipment that came in contact with the water from the wells wore rubber gloves in the event the water was contaminated. Also, a GasTechtor Model 3220S was used to monitor air quality above the well head. Gas production is a common byproduct of the decomposition of solid wastes. No gases were detected by the Gas Techtor.

WELL CONSTRUCTION

Materials used in construction of the monitor wells were provided by Barton County and included 2-inch Schedule 80 Polyvinyl Chloride (PVC) threaded well casing and screen, gravel pack and fine sand, cement, slip caps, bailers, and poly rope. Miscellaneous items were provided as needed by the Kansas Geological Survey. The gravel pack and fine sand were supplied by the Stone Sand Company of Great Bend. Two loads of the gravel pack and one load of fine sand were rejected upon arrival at the landfill due to contamination by diesel fuel and asphalt being dispersed throughout the sand matrix. The truck that had hauled the sand had previously contained asphalt; diesel fuel had been used to clean out the truck bed prior to hauling the gravel pack and

fine sand to the landfill. Following the rejection of the contaminated sand, a clean truck was dispatched that delivered clean sand for use in the monitor wells.

The seven wells were constructed in accordance with KDHE requirements (see figure 11.6, appendix 11.3 and appendix 11.4). Deviations from standard monitor-well construction which were approved by KDHE included: the screened interval did not extend over the entire aquifer thickness; 2-inch diameter casing was used instead of 4 inch; drilling rig and equipment were not decontaminated between each well; boreholes were grouted beginning approximately 10 feet above the well screen and continuing to land surface; very fine sand was used between the gravel pack and bentonite seal to prevent encroachment of the grout into the gravel pack. When grout invades the upper portion of the gravel pack the result often is an erroneously high pH when water samples are analyzed. The gravel pack, bentonite pellets, fine sand, and grout were placed beginning at the bottom of the borehole and continuing upwards using 1/2-inch PVC tremie pipe. This procedure was employed in the three Dakota wells as well as SW #1. SW #2, 3, and 4 were shallow enough to allow materials to be poured in from the land surface.

The importance of a proper grout seal is to prevent migration of water or contaminants down the borehole to ensure the isolation of the particular aquifer of interest. Temperature logs were run on DW #1 seven hours after grout placement and DW #3, 14 hours after grout placement. This procedure was undertaken to verify that the grout placed down the hole actually was resting on top of the gravel pack and was not lodged higher up in the annulus of the borehole. The temperature probe was able to detect the depth of the grout seal because the heat of hydration of curing grout was sufficient to produce measurable warming inside the well casing.

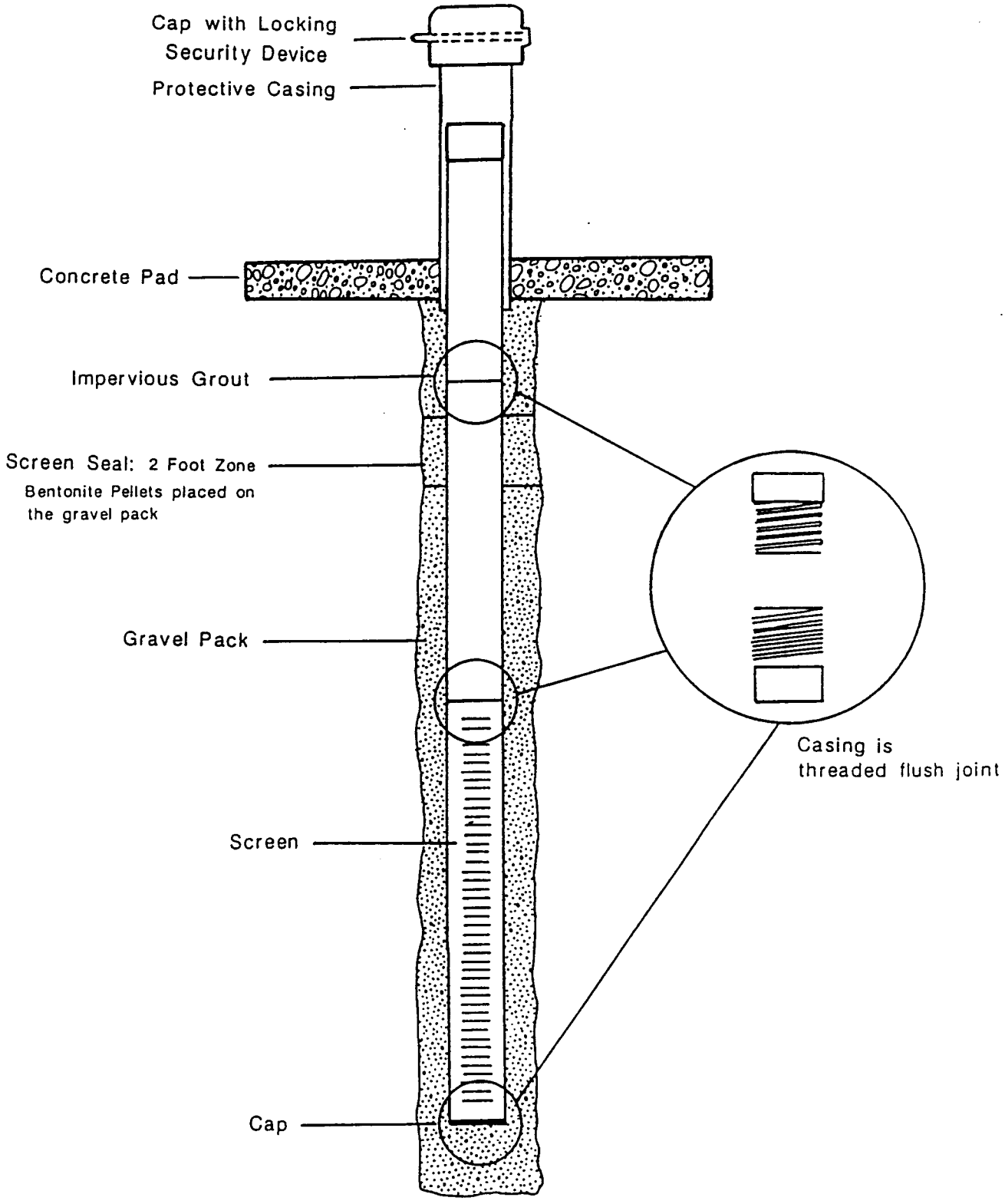


Figure 11.6 Standard Monitoring Well Design (from KDHE 1986)

To prevent cross contamination between wells during the development and sampling processes, an individual bailer was dedicated to each well. Conventional bailers have been shown to produce little sample alteration (Houghton and Berger, 1984). The six monitor wells that produced water were extensively developed with the bailers immediately after the grout cured. Developing involves the removal of well water in order to clear the well of drill cuttings and mud. Extraneous matter could affect the chemical analysis of the water. To quantify how well the well water was cleaned during development, water samples were collected from DW #2 and DW #3 prior to and after development. These samples were analyzed by the Kansas Geological Survey using X-ray diffraction to determine a general ratio between the quantity of drilling mud (bentonite) and the quantity of Dakota clay present before and after development. The results showed a significant reduction in the amount of bentonite left in the post-development water sample. Grout was allowed to cure for approximately 24 hours before development was started. This lag time was included to further reduce the chance of uncured grout being pulled into the gravel pack by the sudden evacuation of water from the well.

SAMPLING PROCEDURES AND ANALYTICAL METHODS

A total of 17 water-sample locations were used during this initial investigation of the Barton County landfill (figure 11.1). Of the 17 sample locations, six samples were from the monitor wells installed by the KGS, eight from local domestic wells, and three from the downgradient surface-water ponds. The samples were collected on July 8 and 9 of 1986, and were kept on ice until they were transferred to their respective analytical locations on July 10. The samples were analyzed for volatile organic chemicals (VOC) using the gas chromatograph/mass spectrophotometer (GC/MS) in the environmental-organic laboratory of the KDHE. Dissolved organic carbon (DOC) analyses were

performed by the author using a Xertex/Dohrmann Total Organic Carbon Analyzer (Model DC-80) at the Environmental Health Department of the University of Kansas. The inorganic analyses were performed in the geochemistry laboratory of the KGS.

The procedure for collecting ground-water samples was as follows:

- Water levels were recorded in each well prior to sampling.

- At least three casing volumes were extracted from the wells using either a bailer or a Bennett Sample Pump to remove the stagnant water inside the well. Domestic wells were evacuated by removing 50 gallons of water through outdoor spigots.

- Immediately following evacuation of the well casing, samples were collected for laboratory analysis along with field tests for temperature, pH, and specific conductivity. Samples were obtained using the same method that was employed to evacuate the wells.

- Samples were refrigerated after collection and transported to the respective laboratories for analysis.

Sampling procedures were in accordance with KDHE regulations on obtaining representative samples. Samples for the determination of VOC's were collected in 40-mL glass bottles with teflon septa and plastic hole caps, provided by the environmental-organic laboratory of the KDHE. The bottles were completely filled with sample to prevent any air from coming in contact with the sample and volatilizing any of the VOC's before analysis.

DOC samples were collected in 400-mL glass bottles with teflon-lined screw caps. Approximately 150 mL of water was collected in each bottle. The DOC samples were acidified in the field to a pH of two units with concentrated phosphoric acid. The low pH coupled with the refrigeration of the samples should have retarded any biological activity that could have degraded some of

the carbon before analysis. The acid also converts the inorganic carbon (bicarbonate alkalinity) to CO_2 gas which was driven out of solution by aeration. In the laboratory, the samples were first filtered through a .45-micron (um) glass-fiber filter followed by a five-minute purging with nitrogen gas to remove any inorganic or volatile carbon in the samples. Samples for determination of all inorganic constituents except phosphate were collected in 250-mL polyetheylene bottles and acidified. Samples for phosphate determination were collected in unacidified 500-mL polyetheylene bottles.

Dakota wells #1 and #3 were sampled using the closed-system Bennett Sample Pump. The other four monitor wells were sampled with the individual bailer dedicated to the well. Domestic wells (DW #4,6,7,8,9,10,11,12) were sampled directly from the nearest outdoor spigot that was available. The shallow surface-water ponds (SSW) were sampled by wading out into the pond and filling sample bottles directly with pond water. Rubber gloves were worn by all personnel when handling the sample water.

ANALYTICAL RESULTS AND DISCUSSION

Laboratory results of the chemical analyses are shown in tables 11.1 and 11.2. Table 11.1 lists VOC and DOC concentrations in the samples. Table 11.2 is a summary of the inorganic-constituent concentrations dissolved in the samples. The data indicate that SW #1 is the well affected most by the landfill. This was to be expected since this well is the closest to any of the buried waste cells. The approximate location of the top of the well screen in reference to the buried waste is 10 feet to the east of and 15 to 30 feet below the bottom of the waste cells. SW #1 is screened completely through the upper aquifer and extends 6 feet into an upper Dakota sandstone lens (figure 11.3).

Table 11.1-Organic constituents in water samples (July 1986); all values in µg/L except for DOC.

	Dakota wells (DW)											Shallow wells (SW)			Shallow (SSW) surface waters		
Volatile organics	#1	#2	#3	#4	#6	#7	#8	#9	#10	#11	#12	#1	#2	#3	#1	#2	#3
Chloromethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bromomethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vinyl chloride	--	--	--	--	--	--	--	--	--	--	--	19.7	--	--	--	--	--
Chloroethane	--	--	--	--	--	--	--	--	--	--	--	19.6	--	--	--	--	--
Dichloromethane	--	--	--	--	--	--	--	--	--	--	--	187	--	--	--	--	--
1,1-Dichloroethylene	--	--	--	1.7	--	--	--	--	--	--	--	699	--	--	--	--	--
1,1-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--	263	--	--	--	--	--
Trans &/or Cis 1,2-Dichloroethylene	--	--	--	--	--	--	--	--	--	--	--	122	--	--	--	--	--
Trichloromethane (THM)	--	--	--	--	--	--	--	--	--	--	0.8	1.4	1.0	--	--	--	--
1,2-Dichloroethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1,1-Trichloroethane	--	--	--	1.9	--	--	--	--	--	--	--	1090	--	--	--	--	--
Tetrachloromethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bromodichloromethane (THM)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,2-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--	0.8	--	--	--	--	--

Table 11.1 Continued

Trans 1,3-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichloroethylene	--	--	--	--	--	--	--	--	--	--	--	685	--	--	--	--	--
Benzene	--	--	--	--	--	--	--	--	--	--	--	2.2	--	--	--	--	--
Dibromochloromethane (THM)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
CIS 1,3-Dichloropropane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2-Trichloroethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Bromoform (THM)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,1,2,2-Tetrachloroethane	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tetrachloroethylene	--	--	--	--	--	--	--	--	--	--	--	13.3	--	--	--	--	--
Toluene	--	1.9	--	--	--	--	--	--	--	--	--	3.6	--	--	--	--	--
Chlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ethylbenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Meta-Xylene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ortho &/or Para-Xylene	--	--	--	--	--	--	--	--	--	--	--	1.0	--	--	--	--	--
1,3 Dichlorobenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
1,2 &/or 1,4-Dichlorolobenzene	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dichlorofluoromethane	--	--	--	Det.	--	--	--	--	--	--	--	Det.	--	--	--	--	--

Table 11.1 Continued

Trichlorofluoromethane	--	--	--	--	--	--	--	--	--	--	--	Det.	--	--	--	--	--
Dimethyl Disulfide	--	--	--	--	--	--	--	--	--	--	--	--	Det.	--	--	--	--
DOC, (mg/L)	0.98	0.66	0.68	1.22	0.57	0.49	0.75	0.51	0.42	0.57	0.85	2.68	5.26	3.08	4.79	8.08	10.19

NOTE: Det. = detected
Samples collected 7-10-86

TABLE 11.2-Inorganic constituents in water samples (July 1986).

	Dakota wells (DW)											Shallow wells (SW)			Shallow (SSW) surface waters		
	#1	#2	#3	#4	#6	#7	#8	#9	#10	#11	#12	#1	#2	#3	#1	#2	#3
Silica, mg/L	17	12	9.6	29	19	10	27	15	13	12	24	38	26	22	10	10	15
Calcium, mg/L	76	83	58	151	82	49	143	77	74	74	71	241	158	48	26	27	34
Magnesium, mg/L	12	15	14	16	13	15	15	21	19	19	6.4	24	25	8.7	2.7	3.2	4.2
Sodium, mg/L	53	92	121	36	71	182	34	376	98	88	25	54	310	115	13	14	16
Potassium, mg/L	3.9	5.0	5.0	5.2	3.3	6.2	4.6	8.2	3.9	3.8	2.3	6.5	4.9	5.5	5.0	8.5	10
Bicarbonate, mg/L	295	305	345	255	321	337	286	216	297	271	256	466	316	315	98	102	135
Sulfate, mg/L	36	80	60	38	40	106	20	176	81	115	11	31	343	57	12	10	11
Chloride, mg/L	52	92	80	181	73	134	132	521	104	84	23	274	366	48	11	15	16
Nitrate, mg/L	2.9	0.3	0.2	12	1.4	0.5	59	0.2	0.2	0.2	3.0	9.9	39	15	0.4	1.4	0.1
Ammonium, mg/L	0.1	0.1	0.1	<0.1	<0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	<0.1	0.1	0.1	0.1	0.1
*Phosphorous as PO_4, mg/L	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.30	<0.05	<0.05	0.07	0.07	0.24	0.46
Field pH	7.35	7.45	7.25	6.90	7.20	7.10	6.75	7.30	6.85	7.15	7.05	6.90	7.25	7.55	8.35	7.25	8.30
Lab pH	7.55	7.60	7.65	7.45	7.55	7.65	7.50	7.95	7.45	7.65	7.60	7.40	7.70	8.00	8.10	8.05	8.30

Table 11.2 Continued

Field specific conductance,	µmhos/cm	750	1100	1000	1300	750	1400	1150	2500	1040	940	600	1750	3250	850	220	220	250
Lab specific conductance,	µmhos/cm	700	920	900	1060	800	1140	1000	2300	935	900	481	1600	2250	775	211	243	286
Field temp,	°C	17.0	18.0	17.0	16.0	16.0	17.0	16.5	--	17.0	17.0	16.0	16.0	16.0	18.0	30.5	28.0	30.5

*Unacidified samples

VOLATILE ORGANIC CHEMICALS

Very high concentrations of VOC's were found in samples from SW #1, while much smaller concentrations were found in DW #2, #4, #12, and SW #2. VOC's are chemicals used or produced in the manufacturing of many products such as detergents, pharmaceuticals, dyes, and insecticides. VOC's also are found in household products such as spot removers, rug cleaners, drain cleaners, air fresheners, shoe polish, and solvents. These chemicals do not occur naturally in ground water; thus, their presence is an indication of manmade contamination.

VOC's are becoming a new focus of concern due to their potential health effects from long-term consumption. Some VOC's have been shown to be carcinogenic and/or have adverse effects on the central nervous system, liver, and kidneys. The degree of toxicity varies widely from chemical to chemical and long-term effects of low dosages are not known for many VOC's.

Neither the KDHE nor the EPA currently have enforceable standards for VOC contamination. The EPA is in the process of developing guidelines or standards for specific VOC concentrations in drinking water which will be called the Recommended Maximum Contaminant Levels (RMCL). RMCLs are nonenforceable health goals set at levels which would result in no adverse health effects and include an adequate margin of safety. Also, the EPA plans to propose Maximum Contaminant Levels (MCL) for volatile organic chemicals. MCL's are enforceable standards established to prevent possible adverse health effects to individuals drinking the water. Table 11.3 lists the nine VOC's which have proposed RMCL's.

For the more frequently found VOC contaminants, KDHE has established Kansas Notification Levels (KNL) and Kansas Action Levels (KAL; table 11.4). The Kansas Notification Level is defined as the concentration of a VOC above

Table 11.3-Federal recommended maximum contaminant levels for volatile organic chemical, proposed 40 CFR 141.50, Federal Register (6-12-84)

	VOC	Proposed RMCL ug/L
1.	Trichloroethylene	0
2.	Tetrachloroethylene	0
3.	Tetrachloromethane (carbon tetrachloride)	0
4.	1,1,1-Trichloroethane	200
5.	Vinyl chloride	0
6.	1,2-Dichloroethane	0
7.	Benzene	0
8.	1,1-Dichloroethylene	0
9.	p-Dichlorobenzene	750

Table 11.4-Kansas volatile organic chemical notification and action levels; all values in ug/L (ppb); KDHE, 1985.

VOLATILE ORGANIC CHEMICALS	KNL	KAL	DETECTION LIMIT
Chloromethane	+	id	5.0
Bromomethane	+	id	1.2
Vinyl chloride	1.0	10.	0.8
Chloroethane	+	id	3.7
Dichloromethane	+	150	0.9
1,1-Dichloroethylene	0.23	70	0.6
1,1-Dichloroethylane	+	id	0.5
Trans 1,2-Dichloroethylene	+	270	0.5
Trichloromethane (THM)	100*	*	0.5
1,2-Dichloroethane	0.7	7.	0.6
1,1,1-Trichloroethane	16.8	168	0.7
Tetrachloromethane	0.27	2.7	0.7
Bromodichloromethane (THM)	100*	*	0.5
1,2-Dichloropropane	+	id	0.4
Trans 1,3-Dichloropropene	+	id	0.8
Trichloroethylene	1.8	18	0.6
Benzene	0.67	6.7	0.4
Dibromochloromethane (THM)	100*	*	0.7
Cis 1,3-Dichloropropene	+	id	0.9
1,1,2-Trichloroethane	0.6	6.	0.6
Bromoform (THM)	100*	*	1.5
1,1,2,2-Tetrachloroethane	0.17	1.7	0.6
Tetrachloroethylene	1.0	10.	1.1
Toluene	3.5	340	0.4
Chlorobenzene	+	id	0.4
Ethylbenzene	+	id	0.7
Meta-Xylene	+	620**	0.4
Ortho &/or Para-Xylene	+	620**	0.4
TVOC	10	id	

Note: Cis 1,2-Dichloroethylene is reported as Trans 1,2,-Dichloroethylene.
KNL - Kansas Notification Level
KAL - Kansas Action Level
THM - Trihalomethane
TVOC - Sum of all VOC, except THM's and 1,1,1-trichloroethane.
+ - Any positive detection.
* - THM is requlated by Kansas Drinking Water Standards, total THM < 100 ug/L
id - Insufficient data to establish a level.
** - Sum of all xylene isomers present.

which KDHE has the option to require notification to the consumers and recommend appropriate preventative action be taken by the well owner. Kansas Action Levels are defined as the concentration above which KDHE will require both notification to the consumers and mandatory action by the well owner (KDHE, 1985). The KAL's are levels of VOC's which do not present any short-term consumption health problems and are based on possible adverse health effects from long-term consumption.

The detection limit in the volatile organic chemical analysis is in the range of 1.0 ug/L (parts per billion). This is comparable to a drop of the contaminant in a swimming pool of water measuring 50 feet by 50 feet by 8 feet deep (McCool, 1986). The Environmental Organic Laboratory's VOC analysis detects the presence of 32 different chemicals. These chemicals mainly include chlorinated organics and components of petrochemical products. The four chemicals which make up the trihalomethane group also can be detected. Trihalomethanes are formed when natural organics in the ground water react with chlorine which is used as a disinfectant.

The main contaminants found in the landfill are common in commercial and industrial solvents (1,1,1-trichloroethane, trichloroethylene, 1,1-dichloroethylene). Also found at the landfill were lower concentrations of gasoline and petrochemical compounds such as xylene, benzene, and toluene. Sources for these chemicals are abundant in the area, especially near Great Bend, which is the regional center for industry and oil-field operations.

In summary, the VOC contamination at the landfill was generally confined to SW #1. The analyses showed that six out of the nine regulated VOC's from table 11.3 were present in SW #1 and all exceeded the proposed RMCL. The concentration of 1,1 dichloroethylene was found to exceed the proposed RMCL in DW #4. A total of 14 VOC's were present in SW #1 and, except for

trihalomethane, all of their concentrations exceeded the Kansas Notification Level. Seven out of the 14 also exceeded the Kansas Action Level. The 1,1 dichloroethylene concentration in DW #4 exceeded the KNL but did not exceed the KAL. Although VOC concentrations were detected in DW #2 and #12 and SW #2, the concentrations were below both the EPA's proposed RMCL and KDHE's KNL and KAL.

DISSOLVED ORGANIC CARBON

Dissolved organic carbon concentrations were determined from each of the sampling locations and are presented in table 11.1. In a study conducted by Leenheer et al.(1974), DOC levels were determined from 100 different sites in 27 states. The levels of the DOC in ground-water samples collected were generally very low, but values ranged from undetectable to as high as 15 mg/L, with 85% of all the values below 2 mg/L. Six samples collected in sandstone aquifers had a median value of 0.7 mg/L and a mean value of 1.0 mg/L. A recently conducted study of DOC concentrations in Kansas ground water included three samples from the Dakota Formation which had a mean concentration of 0.59 mg/L (Miller et al., 1986). The DOC levels from the present study also are generally very low with the exception of the shallow wells that penetrate the upper aquifer and the surface-water ponds, which will be discussed.

DOC levels have been shown to decrease with increasing depth of the sample in an unpolluted aquifer (Junk et al.,1980). The major sources of organic carbon in an unpolluted aquifer are from the overlying soils, surface vegetation, and surface-water infiltration. Surface waters normally contain higher levels of DOC originating from decaying organic matter on the banks and bottom sediments. The surface-water ponds downgradient from the landfill also have organic matter being added by the excretions of the livestock that use the ponds for drinking water.

DOC levels obtained from this study follow the trend of decreasing DOC with increasing depth. The surface waters show the highest levels with a mean ($\bar{x}$) value of 7.69 mg/L followed by the shallow wells ($\bar{x}$ = 3.67 mg/L) and finally the Dakota wells ($\bar{x}$ = 0.70 mg/L). Dakota wells # 1 through #4 which are located within the fenced-in portion of the active landfill show slightly higher mean DOC levels ($\bar{x}$ = 0.89 mg/L) than do Dakota wells # 6 through #12 ($\bar{x}$ = 0.59 mg/L), which can be considered unpolluted background wells. DW #4, which is the water supply for the scale house at the landfill, had the highest DOC value of all the Dakota wells (1.22 mg/L). Poor well maintanence could account for this high value in DW #4 because the PVC casing that extends above the land surface is cracked and open to contaminants entering the well from the land surface. Overall, DOC levels in samples from the Dakota wells have not been significantly affected by the landfill.

Organic contamination often will cause an increase in DOC levels of one or more orders of magnitude over background DOC levels. Values greater than the threshold levels of DOC (> 5 mg/L) could indicate contamination and possibly organic materials moving into the aquifer from sources such as surface-water infiltration and subsurface waste-disposal operations (Malcolm and Leenheer, 1973). DOC levels in shallow wells #1, 2, and 3 are approximately one order of magnitude higher than the Dakota wells. All three of the shallow wells are near the active landfill and are in the general direction of ground-water flow. Unfortunately, no background DOC data are available for water in the upper aquifer. Therefore, it is impossible to quantify how much effect the landfill has had on the DOC levels in the upper aquifer, and the DOC levels reported in table 11.1 might be normal DOC levels for the upper aquifer.

Surface-water infiltration from SSW #1 is not considered to be a factor in the DOC levels of SW #2 and #3 because the inorganic analyses showed the waters to differ greatly, with no significant infiltration and mixing evident. SW #2 (5.26 mg/L DOC) contained the greatest level of all the ground-water wells and this is possibly due to some landfill leachate migrating to the well through the upper aquifer. More shallow wells are needed on all sides of the active landfill. Of these proposed wells, at least one should be placed to provide reliable upgradient, unpolluted, background water samples so that a more definitive statement can be made on the effects of the landfill on the DOC values in the upper aquifer. These wells would also help document the natural spatial variability of DOC in the upper aquifer.

INORGANICS

The concentrations of inorganic constituents in ground water collected in the sampling program are given in table 11.2. Table 11.5 shows the various inorganic constituents in the landfill samples compared to concentration ranges reported for leachate and to the EPA's drinking-water standards. Shallow wells #1 and #2 seem to be impacted by the landfill, as also was seen in the VOC and DOC analyses. It should be recognized that much higher concentrations of the ions shown in table 11.5 can occur naturally, especially in Kansas, and cannot be definitively associated with landfill leachate until a better understanding of background levels of inorganic constituents in the upper aquifer is reached.

The effect of the landfill on SW #2 can be illustrated by the comparison of the inorganic-constituent concentrations in the well with those of SW #3. These two wells are in close proximity (approximately 600 feet), and tap the upper aquifer. These factors would normally result in very similiar water

Table 11.5-Comparison of inorganic water quality to ranges for various inorganic constituents in leachate from sanitary landfills (from Freeze and Cherry, 1979).

	Leachate range	SW#1*	SW#2*	SW#3*	DW#4	DW#8	DW#9*	EPA drinking-water standards
Calcium	100-3000	241	158	22	151	143	77	None
Sodium	200-1200	54	310	115	36	34	376	None
Chloride	300-3000	274	366	48	181	132	521	250
Sulfate	10-1000	31	343	57	38	20	176	250
Nitrate	0.1-10	9.9	39	15	12	59	0.2	45

Note: All values in mg/L
* denotes well not presently used for drinking water

types between the two wells. The cation (Ca, Mg, Na) and anion (SO_4, Cl, NO_3) concentrations are much higher in SW #2 than SW #3 (table 11.2). These higher concentrations can be attributed to the location of the well, which is northeast (topographically downgradient) of the majority of the waste cells. SW #3 is located to the northwest of the majority of the waste cells, which is upgradient from the predicted direction of ground-water flow. SW #1 also contained high levels of Ca, HCO_3, and Cl, and as has already been shown, was contaminated with VOC's from the landfill.

It should be noted that Dakota wells #4, 7, 8, 9, and 10 are screened at lower depths within the Dakota Formation which contain ground water with higher Cl levels. In general, the water in the Dakota Formation naturally increases in salinity with increasing depth. Also samples from wells DW #4 and #8 contained elevated levels of nitrate that could be caused by sources other than the landfill. These alternative sources could be scale-house septic-tank leakage or poor well construction, which could allow nitrates to enter the wells at or near the land surface. A possible natural alternative could be the nitrification of ammonium ions migrating upwards from deep, anaerobic sediments.

Tin cans and ferrous metals comprise approximately 8% by weight of the typical physical composition of municipal solid wastes (Tchobanoglous et al., 1977). Considering this fact, future water samples could be analyzed for metals such as iron, which would be a good indicator of the presence of leachate. Even with the relatively neutral pH of the ground water, some iron should be present in the water samples if leaching of the wastes is occurring. Iron analysis would improve the ability to track the leachate plume because background iron concentrations should be small (0.01 to 10.0 mg/L), especially in the upper aquifer.

ASSESSMENT OF LEACHATE GENERATION AND MIGRATION

LEACHATE GENERATION

It is evident from analytical results that some leachate is being generated by the landfill. This leachate has the potential to become a human-health problem by entering the local drinking-water aquifer and to threaten stock animals and wildlife by degrading the water quality in the Cheyenne Bottoms and the other surface waters between the landfill and the Bottoms. Therefore, getting some estimate of the amount of leachate being generated by the landfill and the directions it might migrate is important.

A quantitative description of leachate generation from the landfill is essential for determining its effects on water quality and the value of control methods. Methods of estimating leachate generation include field tests, physical and mathematical models, and monitoring of actual installations. All of these methods attempt to produce accurate estimates of leachate generation; but, due to the numerous factors involved in leachate generation, such estimates are only accurate within an order of magnitude. This lack of accuracy is due primarily to the inability to measure the surface-runoff coefficients and evaporation rates of the landfill site and adjacent area (Duval et al., 1979). Other problems include estimation of the in situ permeabilities (i.e. hydraulic conductivities) of wastes and of the underlying and cover soils. All these factors contribute to the problem of estimating leachate volume.

Leachate-volume generation at the landfill is dependent on many factors. In general, the most important factors are (Remson et al., 1968):

* Availability of water

* Landfill-surface conditions

* Solid-waste conditions, and

* Underlying soil conditions.

The primary contributor to the availability of water to the landfill is direct precipitation. Climatological data were obtained from the Great Bend (#3218) weather station, located at latitude 38°, 21' N and longitude 98°, 46' W along the Arkansas River south of the Cheyenne Bottoms Waterfowl Refuge. The average annual precipitation is 24.7 inches based on 52 years of record from 1931 to 1982 (see chapter 4). The average annual precipitation since the opening of the landfill in 1972 to 1982 was 26.74 inches; 73% of this precipitation occurs during the months of April through September. Water reaching the landfill surface by precipitation may evaporate, transpire, infiltrate through the landfill surface, or leave the site as surface runoff. Surface conditions which may effect leachate generation include vegetation, cover material, surface topography, temperature, humidity, and wind speed above the landfill.

Once field capacity of the surface cover material is attained, leachate will percolate through the solid wastes. Field capacity is defined as the maximum moisture content which a soil or solid material can retain in a gravitational field without producing continuous downward percolation. Studies of typical municipal solid waste show that approximately 40% of the total solid waste is composed of paper products (Tchobanoglous et al., 1977). Paper has a large water-holding capacity; thus, once the wastes are saturated, they have the potential to hold moisture between cover-soil wetting and drying cycles. Each time the field capacity of the cover soil is

attained, a slug or pulse of leachate can be generated by the waste cell provided that the wastes have remained at field capacity.

The Versatile Budget Version 2 (VB), a soil-moisture computer model, was used to simulate the water budget in the area of the landfill. See chapter 6 for a more detailed description of the VB. The VB program uses readily available data (soil and cropping patterns, daily temperatures, and precipitation) to calculate a simple water budget. The model produces estimates of soil-moisture deficit (SD), runoff (RO), actual evaporation (AE), and deep drainage (DR). Deep drainage is considered to be the water which percolates below the rooting depth. Vegetative growth requires the usage of large amounts of water, which is the reason that any water migrating below the rooting zone is considered to be deep drainage (Baier et al., 1979). This simple budget provides enough data to make some general interpretations of the water balance at the landfill. The most important parameter which affects leachate production is drainage below the rooting depth.

The input parameters used by the model were adjusted to become as site specific as possible for the landfill. Common parameters include 1) crop (vegetation) coefficients, 2) solar energy at the top of the atmosphere, 3) soil available water capacity (AWC), 4) daily temperatures and precipitation, and 5) Z-table values (representing the relationship between the ratio of actual to potential evaporation as a function of soil moisture available to vegetation).

The Z-table chosen for the landfill simulates clayey-silt soil. The crop coefficients of Brome grass were used because they are considered to be the equivalent to natural growth. Vegetative cover for the completed portions of the landfill consists of native grasses that have rooted on the landfill. In calculating the root-zone depth parameter for the AWC, a rooting depth of 3

feet was used for the grass on the landfill. Brome grass is normally modeled using a 5-foot rooting depth but was shortened because of the landfill's cover-soil thickness of 3 feet and the fact that solid waste does not provide a suitable rooting material.

In estimating the amount of leachate generated, it was assumed that the solid waste was at field capacity and that the deep drainage values represent the amount of water that reaches the top of the solid waste. Thus, if the wastes are at field capacity, any additional infiltration will push leachate through the bottom of the waste cell. Consequently, the values shown in table 11.6 are the theoretical-maximum leachate estimates for the completed portions of the landfill.

The controlling factor in this scenario is the moisture content of the solid waste. If the waste is not at field capacity, then the rate and magnitude of leachate generation would be lower. Based on personal obervations, it is thought to be doubtful that field capacity of the solid wastes is very often achieved in completed portions of landfill. This is due to the climatic conditions of the area along with the initial dehydrated condition of the wastes and the intermediate-soil-cover layers that usually exist before the final cover is placed. If significant precipitation has not occurred immediately before the addition of the final cover, the wastes and intermediate-cover soils are very low in moisture content. Of course, this is not the case if wastes were allowed to be saturated by standing water in the bottom of the trenches, or if proper drainage of the cover soil is not provided. In these cases, the initial dry conditions of the wastes would not be significant because the wastes would become saturated over time.

If field capacity of the entire thickness of the waste cells is rarely attained at the landfill, the major methods for the generation of leachate

Table 11.6-Estimates of leachate generation.

Water year	Precipitation	Actual evapotranspiration	Runoff	Deep drainage	Acre-feet/year maximum leachate
1957	36.56 in.	28.10 in.	2.38 in.	5.55 in.	37.00
1984	23.02 in.	18.93 in.	1.50 in.	6.09 in.	40.00
1956	12.21 in.	15.92 in.	0.76 in.	0.48 in.	3.20

would be by channeling of water through the pores of the wastes and the direct leaching of wastes by standing water in trench bottoms. Allowing water to accumulate in the bottom of active trenches and the "wet pit" is thought to be the major cause of leachate generation.

Computer runs were made for water years with precipitation that were average (figure 11.7, 1984-23.02 inches), above average or wet (figure 11.8, 1957-36.56 inches), and below average or dry (figure 11.9, 1956-12.21 inches). In table 11.6, deep drainage for the three different years is 5.55 inches/year (wet), 6.09 inches/year (average), and 0.48 inches/year (dry).

It should be noted from table 11.6 that the drainage for the wet year (1957) is slightly less than the average year (1984). It would be expected that greater precipitation would result in higher drainage through the soil, but this is not the case in this situation. Three wet years were modeled and all created less drainage than the average year.

Two conditions can be proposed to account for this situation. The first condition that affects the amount of drainage is the times during the year that precipitation occurs. The months between November and March usually have low precipitation, but the average water year (1984) had above-average precipitation in November. This brought the soil near field capacity for the winter months. Additional precipitation during December through February when the majority of the cover soil was saturated and frozen, allowed deep drainage to begin with the start of the spring rains (figure 11.7). Secondly, during the modeled wet years, the majority of the yearly precipitation occurred in large storms (> 2 inches) during the spring and summer months (figure 11.8). This results in a high run-off situation and coincides with the period that plant use of water and direct evaporation are greatest. Thus, a lower drainage value could be expected.

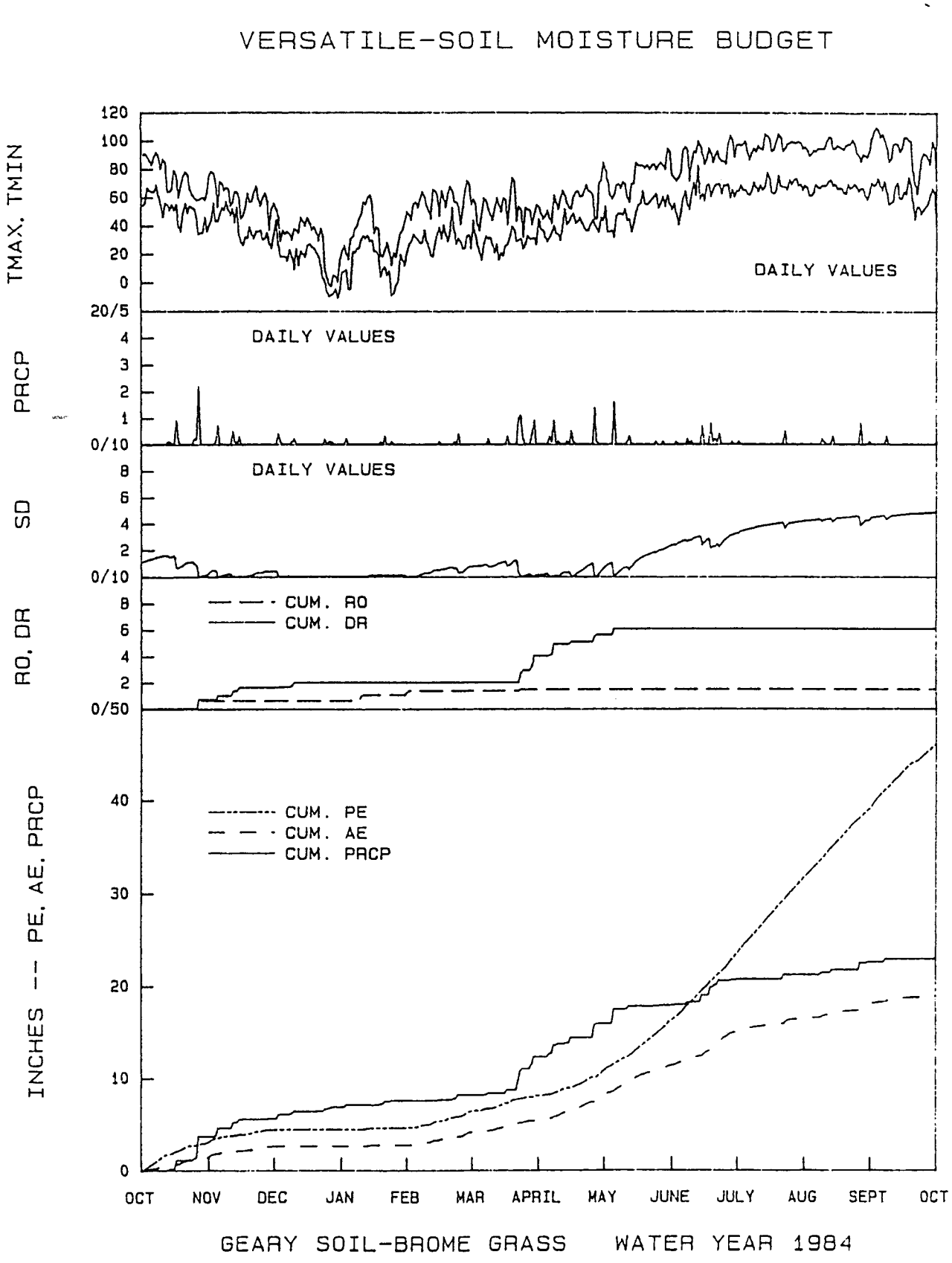


Figure 11.7 Cumulative Landfill Water Balance - Average Year

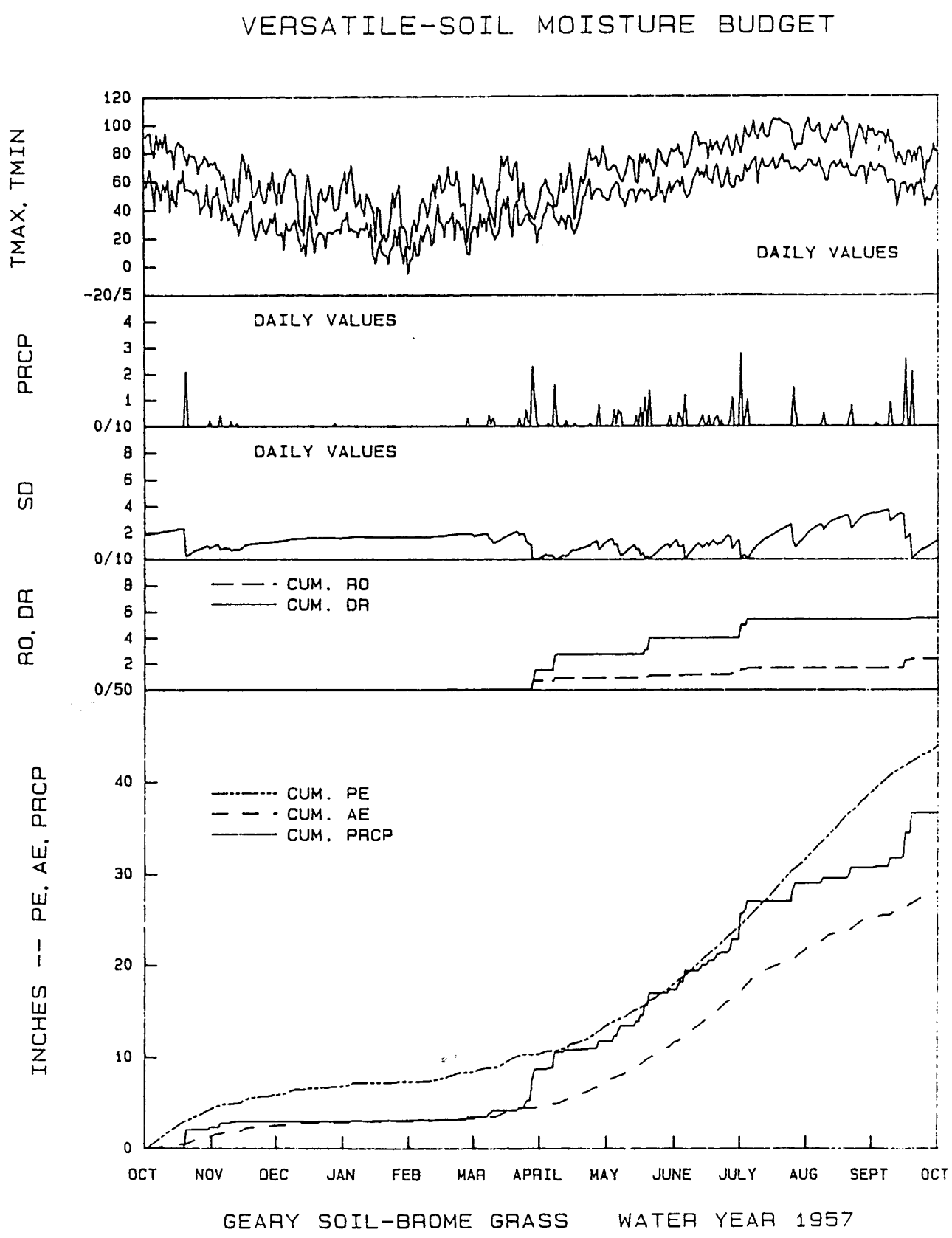


Figure 11.8 Cumulative Landfill Water Balance - Wet Year

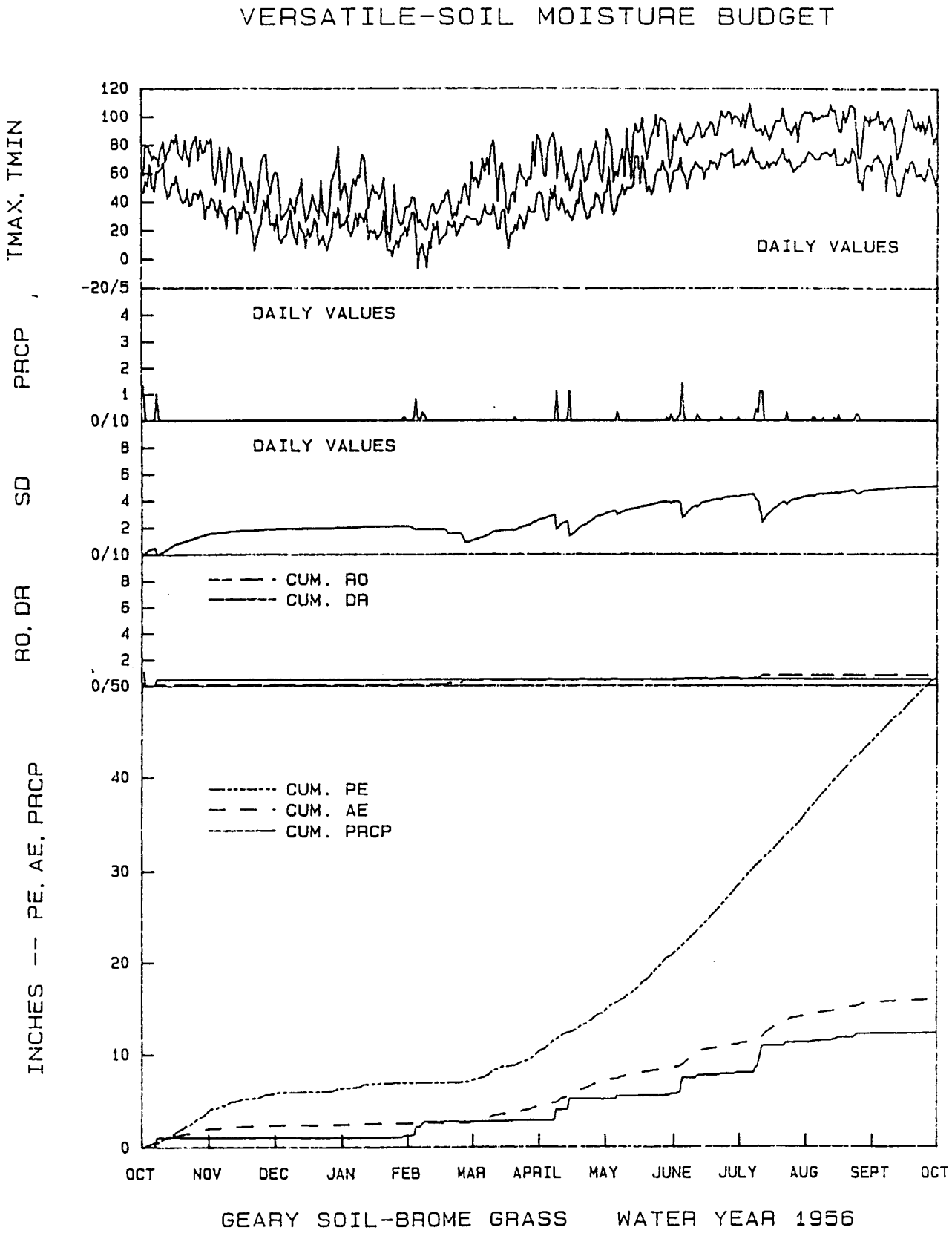


Figure 11.9 Cumulative Landfill Water Balance - Dry Year

The leachate values generated by this model are estimates for the completed portion of the landfill that have the 3-foot soil mantle in place. The "wet pit" and the active trenches will have different values for leachate generation than the completed portions of the landfill. These two areas are either uncovered or have a 6-inch layer of soil over the solid waste. Also, these trenches receive surface run-on water until the time they are completely filled and graded to the proper slope. These conditions allow for a higher rate and magnitude of leaching from the wastes that could only be quantified by a leachate-collection system.

LEACHATE MIGRATION

The water-quality data collected from the Dakota wells indicate that the leachate presently is confined to the upper aquifer. The Dakota wells, which draw water from the shallowest local drinking-water aquifer, show no impact from the landfill leachate. DW #4 does show a small amount of VOC contamination as well as elevated nitrogen levels, but this cannot positively be connected with the landfill due to the poor well-head condition.

One concern about the concentration and direction of the contaminants in the upper aquifer is that there are several local domestic wells near the landfill. These wells are generally gravel packed from 10 feet below land surface to the bottom of the well. If the contamination plume reaches the wells by lateral movement, pollutants could enter the well annulus from the upper aquifer and flow down into the drinking-water aquifer.

Another concern is that the upper aquifer possibly discharges towards stock ponds and the Cheyenne Bottoms. In the event that contaminated water were to seep from the upper-aquifer outcrop on the north slope of the divide, downgradient surface-water bodies could be contaminated. This situation might

already exist at the landfill as the water quality of the shallow-surface water ponds decreases with increasing distance from the landfill.

It would be expected that if only polluted runoff water from the active landfill were flowing into the ponds, then water quality would improve with increasing distance from the landfill because of dilution effects and biological stabilization of the contaminants in the landfill-runoff water. The inorganic and DOC analyses actually show decreasing surface-water quality with increasing distance from the landfill. No VOC's were found in the ponds. This was expected because the pond water is exposed to the atmosphere which would likely volatilize any VOC's present. The decreasing water quality could be the result of leachate from the upper aquifer discharging into the ponds from the outcrop in the landfill ravine. In the northern portion of the landfill ravine, the upper aquifer crops out near the northern edge of SSW #2 and on all sides of SSW #3. Thus, discharges into the ravine from the upper aquifer could be degrading the water quality of SSW #2 and the downgradient SSW #3.

It has not been proven that runoff water from the landfill is heavily polluted. If runoff water is relatively pure, water quality would naturally degrade with time and increasing distance from the landfill as was seen in the surface-water analyses. With increasing water age, DOC concentrations in the ponds would increase due to algal production by-products and run-off water from the surrounding pasture. Also, the concentration of salts would increase due to evaporation and increased dissolution of minerals from the surrounding sediments. Considering the minimal data that are currently available, the natural-degradation theory is a more likely cause of the surface-water degradation than is the upper-aquifer discharge theory. In light of these

facts, it is important that the direction of transport of the pollutants in the upper aquifer be investigated.

Two soil samples were collected to determine vertical hydraulic conductivities of the Dakota Formation underlying the landfill. The samples were analyzed by the author in the Kansas Geological Survey's porous-media laboratory. Hydraulic conductivities were determined using the constant-head permeability test. The samples were taken at depths of 1 foot and 10 feet from the top of the Dakota Formation. The samples consisted of red sandy clay and were relatively undisturbed by the sampling procedure. Hydraulic conductivities were measured to be 1.56 feet/day and 2.25 feet/day for the 1-foot and 10-foot samples respectively.

The measured values are higher than the average values for Dakota clay due to the sand content in the clay in the upper portion of the Dakota in this area coupled with the fact that sampling always affects the in situ permeabilities somewhat. Samples of Dakota clay inspected during drilling showed the sandy clay present only at the top of the formation with lower samples consisting of hard clay. Literature reports that the confining clay layers of the Dakota Formation have vertical hydraulic conductivities ranging from 0.001 foot/day to 0.00001 foot/day (Butler, 1982).

Below the landfill, the thickness of the Dakota clay separating the contaminated upper aquifer from the shallowest sandstone drinking-water aquifer ranges from 17 feet below DW #1 to 60 feet below DW #3. The clay thicknesses were determined from the drilling logs. The conservative calculation of only 17 feet of clay thickness below DW #1 was made with the assumption that contaminants are completely dispersed throughout the 23 foot thick discontinuous sandstone lens. In reality, this may not be the case, as many organic contaminants are lighter than water and would only be found near

the top of the saturated zone. The thickness of these Dakota clays, along with the low vertical hydraulic conductivity of the confining clay layers, would indicate a lateral direction of contaminant transport as opposed to vertical.

Figure 11.5 shows a contour map of the top of the Dakota clay. This map indicates that the top of the Dakota clay dips in a east-southeasterly direction below the landfill. Considering the low permeability characteristics of the underlying clay, the contaminants are expected to migrate in a similiar direction. The effects of this can possibly be reflected in the poor water quality of DW #4. This well is located downgradient, in reference to the upper aquifer, from the "wet pit" and the earliest waste cells that were constructed at the landfill. Upper-aquifer leachate flow towards the well could be affecting the water quality. As with the potentiometric-surface map, the limited amount of data points only allow for a generalized contour map of the clay.

The physical processes that control the transport of dissolved substances (solutes) in a ground-water-flow system are advection and hydrodynamic dispersion. Advection is the process by which solutes are transported by the bulk motion of the flowing ground water. Hydrodynamic dispersion is the process that causes the solutes to spread out from their expected advection-flow paths and also causes dilution of the solutes. It occurs because of mechanical mixing during fluid advection and because of molecular diffusion due to the thermal-kinetic energy of the solute particles. At low ground-water velocities, molecular diffusion is the controlling factor in the dispersion of the contaminants. At high velocities, mechanical mixing is the dominant dispersive process. Ground-water velocities were not measured or estimated in this study; thus, the dominant dispersive process in the upper

aquifer is unknown. For the initial study, it is sufficient to conclude that the contaminants will probably migrate along the top of the Dakota clay.

It is possible that the upper aquifer as described may be a perched water table occurring only in the vicinity of the landfill. The upper aquifer could be recharged through the bottom of the "wet pit" as well as through the uncompleted trenches. This would result in a limited quantity and areal extent of water in the upper aquifer which will vary over time with the amount of precipitation that the landfill receives. In a perched water table, the ground-water velocities would be low, allowing molecular diffusion to become the controlling factor in the dispersion of the contaminants. It is also not known if the discontinuous upper-sandstone lens penetrated in the boreholes of DW #1 and SW #1 was previously contaminated along with the upper aquifer which rests on top of it. Currently, SW #1 is screened through both the upper aquifer and the sandstone lens; thus, determining if the sandstone aquifer was contaminated prior to drilling is impossible. A well screened to isolate the upper-sandstone lens would be needed to determine if contamination has invaded the sandstone. It is possible that the upper discontinuous sandstone lens is now locally contaminated by the vertical pathway created by SW #1. Considering the high permeability of the sediments in this zone and the fact that only 7 feet of Dakota sandy clay separate the loess and the sandstone lens, it is thought that the sandstone lens was at least partially contaminated before SW #1 was drilled. As a precaution, SW #1 could be drilled out with an oversized bit and plugged with grout to eliminate the vertical pathway for contaminants. These points reinforce the need for more shallow wells or auger probes to better define the areal extent of water and contaminated water, along with a better understanding of the water-level gradient in the upper aquifer.

SUMMARY AND CONCLUSIONS

Potential pollution from a sanitary landfill must be considered in its design and location. Understanding the factors and conditions involved in the production of leachate is necesary for its elimination and control. A major goal in planning, designing, and operating a sanitary landfill should be to minimize all sources of water reaching the wastes so that leachate production is eliminated. Leachate production can be minimized or nearly eliminated by preventing water contact with the wastes by the use of surface and subsurface drainage and properly selected cover material that is graded and seeded with a high-evapotranspiration crop.

The Barton County sanitary landfill is located in a geologic environment favorable for minimizing the environmental impacts on ground-water supplies in the area. The landfill has the potential to produce undesirable effects on the downgradient surface-water bodies through surface runoff and possible discharges from the upper aquifer. The considerable thicknesses coupled with the low permeabilities of the Dakota clay have protected the drinking-water aquifer from contamination up to this point and should continue to do so.

In regard to possible effects on the Cheyenne Bottoms Waterfowl Refuge, it appears that the landfill has had no impact on water quality in the Bottoms. The contaminated upper aquifer does not underlie the Bottoms and crops out approximately 2 miles to the south of Pool 5. In the event that the upper aquifer ever accumulates enough water to begin discharging substantial quantities of leachate towards the Bottoms, microbial activity, natural aeration and evaporation (for VOC's), dilution effects, and clay adsorption and ion exchange would probably stabilize any contaminants before they reach the Bottoms. Improved management and operation practices at the landfill would be very beneficial in safeguarding against future pollution problems.

OPTIONS AND RECOMMENDATIONS

Several options are available to attempt to prevent any further contamination of the water resources surrounding the landfill. The first step would be to install more shallow wells on the east, west, and south sides of the landfill to define the extent of contamination in the upper aquifer.

To facilitate correlation of the upper aquifer to the drinking-water aquifer, it would be desirable for two of the new shallow wells to be placed near Dakota wells #2 and #3. One shallow well could be placed on the west side near DW #2 and the other on the east side near DW #3. A distance of 15 feet separating the wells like SW #1 to DW #1 would be advisable to minimize cross-contamination possibilities. On the east side of the landfill where contamination has been found, at least three more shallow wells should be installed. This would provide better coverage paralleling the wastes in the general direction of ground-water flow. It is recommended that two of the wells be located at least 500 feet to the east of DW #1 and #3. The third well could be located 500 feet east of the southeast corner of the current landfill fenceline (figure 11.10). A shallow well or wells could be placed along the south boundary between the scale house and east fenceline. According to the dip of the Dakota clay, wells on the south and east sides should have the greatest chance to show contamination. If contamination also is found in these proposed wells, additional wells would be needed at a further distance from the landfill's fenceline until the limit of the plume can be determined.

It is thought that contamination will move laterally over the top of the relatively impermeable Dakota clay. The plume could eventually affect the local domestic wells as described in the leachate-migration section. It is suggested that any new domestic wells drilled in the vicinity of the landfill

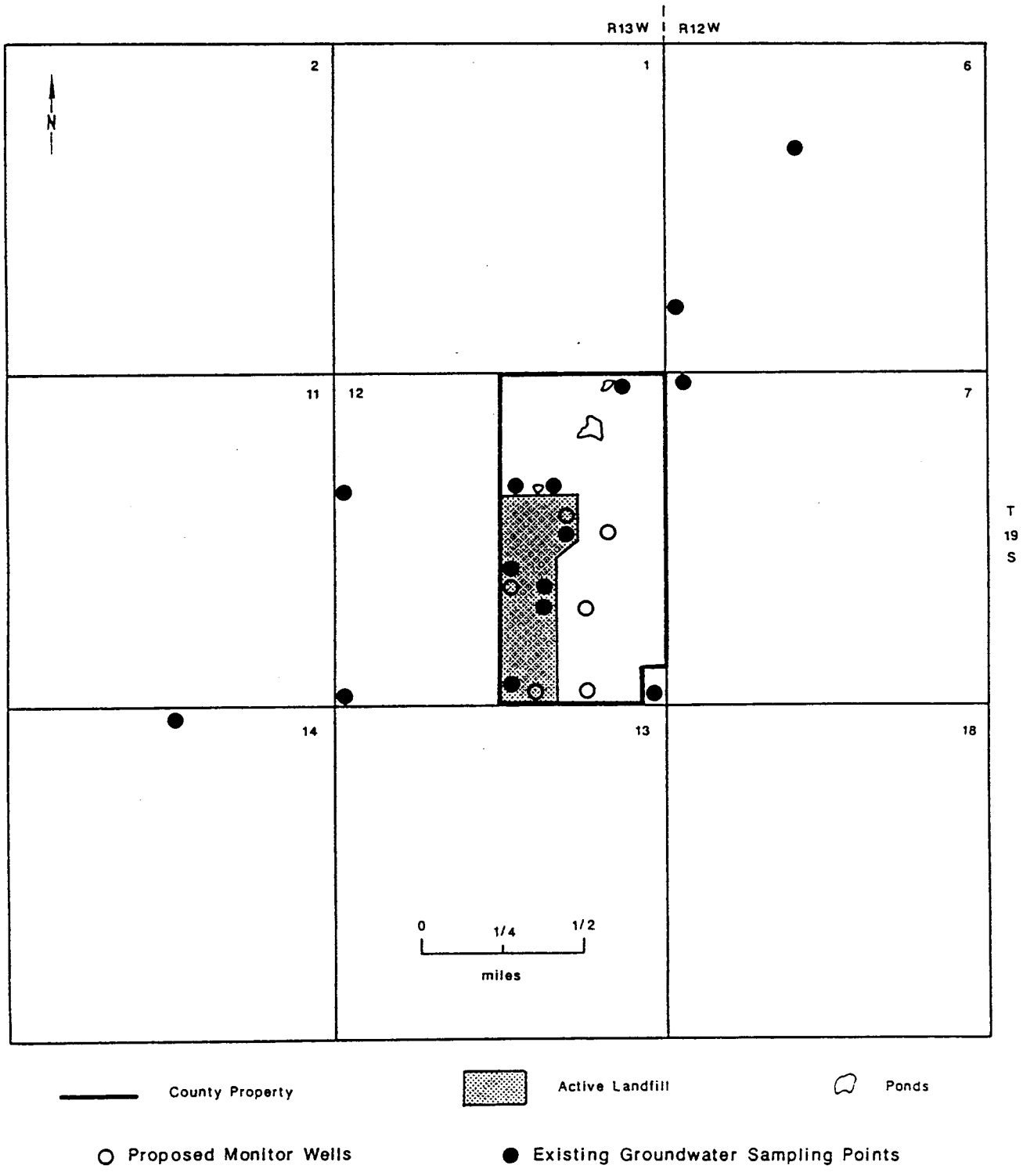


Figure 11.10 Location of Proposed Monitor Wells

be screened and gravel-packed only in the producing zones greater than 105 feet. A grout seal should be placed starting above the well screen and extending up to land surface.

If the extent of contamination is determined to be widespread by the chemical analysis provided by the proposed shallow wells, remedial alternatives must be considered. Alternatives could include 1) impermeable surface liner for the completed portions of the landfill, or liners placed in the bottom of waste trenches prior to filling, 2) installation of a leachate-collection and treatment system, 3) improved site drainage and seeding of completed areas with a high-evapotranspiration crop, 4) provision of a daily soil cover for waste cells and the "wet pit," and 5) following a storm event, standing water in the bottom of active trenches or the "wet pit" should be pumped out as soon as possible to minimize infiltration into the underlying wastes. Alternatives 3, 4, and 5 could be combined together and probably be less expensive than either alternative 1 or 2. An economic analysis of the above options was not completed. It should be noted that alternatives 3 and 4 are considered normal sanitary-landfill practices but were not consistently being implemented at the time this study was completed.

As was mentioned earlier, the plugging of SW #1 should be considered to prevent contaminants from migrating downwards through the upper discontinuous sandstone lens and coming that much closer to the drinking-water aquifer. Another option that should be considered is the future use of DW #4 as a water supply for the scale house. This well seems to be downgradient from the upper aquifer, and some contamination was evident in the chemical analyses. More samples should be analyzed from the well, with the results being compared to those of this study. If contamination is again detected, a new water supply

for the scale house should be considered. At the time of this study, DW #4 was being used as a source of drinking water as well as for other uses.

This study has provided a general indication of the extent of groundwater contamination from the Barton County landfill. It has also provided an assessment of future effects pollution from the landfill could have on surrounding homeowners and the Cheyenne Bottoms Waterfowl Refuge. Presently, the landfill does not seem to have affected any usable water supplies. Unfortunately, as is the case with every subsurface waste-disposal operation, the landfill does hold potential for future adverse environmental impacts if the management and operation of the site do not meet sanitary-landfill standards.

Appendix 11.1-Geologic logs of monitor and domestic wells.

DW #1 19-13-12dbd. Sample log of borehole; drilled by KGS in June, 1986. Surface elevation, 1886 feet.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Silt, clayey, red-brown	8	8
Silt, clayey, brown, some red	12	20
Silt, clayey, tan-gray; contains some caliche nodules and coarse sand and fine gravel	15	35
Silt, clayey, tan-gray; contains some caliche nodules	21	56
Silt, clayey, sandy, tan-gray; contains some caliche nodules and a sandstone lens at 57.5 feet	3	59
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, silty, red-tan; contains abundant coarse sand and fine gravel	3	62
Clay, multcolored; contains some free sand	6	68
Sandstone, weathered; contains some gray sandy clay	12	80
Sandstone, gray, very porous	11	91
Clay, multicolored; contains sandstone lens at 96.5 feet	17	108
Sandstone, weathered, yellow-gold; contains some multi colored clay	4	112
Sandstone, white, tight	1	113
Clay, multicolored; contains bits of sandstone	8	121

DW #2 19-13-12bbd. Sample log of borehole; drilled by KGS in June, 1986. Surface elevation 1882 feet.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Road fill	1	1
Silt, clayey, sandy; red-brown	27	28
Silt, clayey, sandy, gray and red-brown; contains a few caliche nodules	9	37
Silt, tan-brown; contains caliche and coarse sand and fine gravel	26	63
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, red, sandy; contains fine gravel	2	65
Clay, white-buff	2	67
Clay, red-tan	6	73

Clay, red	2	75
Clay, tan-white	6	81
Clay, brown	6	87
Clay, sandy, brown	2	89
Clay, multicolored	18	107
Sandstone, weathered, fine grained, yellow-gold; contains some multicolored clay	15	122

DW #3 19-13-12acd. Sample log of borehole; drilled by KGS in June, 1986. Surface elevation, 1886 feet.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Silt, clayey, gray-tan	9	9
Silt, clayey, dark brown	6	15
Silt, clayey, red-brown	4	19
Silt, clayey, sandy, tan-brown; contains caliche nodules beginning at 23.0 feet	32	51
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, multicolored; contains fine to medium gravel in upper 5.0 feet	6	57
Clay, tan-yellow	7	64
Clay, gray	5	69
Sandstone, weathered, yellow-gold; contains some multicolored clay	2	71
Clay, sandy, multcolored	5	76
Clay, multicolored	5	81
Clay, sandy, multicolored	5	86
Clay, multicolored; contains sand lenses at 100 ft, 103 ft and 109 ft	20	106
Clay, sandy, multicolored	8	114
Sandstone, weathered, yellow-gold; contains multicolored clay	7	121

DW #4 19-13-12dcc. Driller's log of domestic well.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Topsoil	2	2
Silt, clayey, brown	62	64
Silt, clayey, brown; contains broken sandstone	9	73
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, multicolored	31	110
Clay, multicolored; contains sandstone bits	46	156
Clay, multicolored	30	186
Sandstone; contains some clay streaks	44	230

DW #5 19-13-12aac. No log available; no water-quality sample taken.

DW #6 19-12-06ccb. No log available; domestic well.

DW #7 19-12-07bbb. Driller's log of domestic well.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Silt, clayey	150	150
CRETACEOUS-GULFIAN		
Dakota Formation		
Sandstone	23	73

DW #8 19-13-12ddd. No log available; domestic well.

DW #9 19-12-06bdd. Driller's log of domestic well.

	Thickness ft	Depth ft
CRETACEOUS-GULFIAN		
Dakota Formation		
Topsoil with multicolored clay	80	80
Sandstone, brown, tight	55	135
Sandstone, brown, soft	33	168
Pyrite, hard	8	176
Sandstone, brown, soft	19	195

DW #10 19-13-12bdd. Driller's log of domestic well.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Clay	10	10
CRETACEOUS-GULFIAN		
Dakota Formation		
Shale	70	80
Sandstone	44	124

DW #11 19-13-12ccd. Driller's log of domestic well.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Topsoil	3	3
Clay, brown; contains limestone	54	57
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay	63	120
Sandstone and clay	10	130
Clay	30	160

	Thickness	Depth
Clay and sandstone streaks.....	18	178
Clay.....	10	188
Sandstone and clay streaks.....	52	240

DW #12 19-13-14abb. Driller's log of domestic well.

	Thickness	Depth
QUATERNARY-PLEISTOCENE	ft	ft
Undifferentiated loess		
Topsoil and brown clay.....	65	65
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, yellow-white.....	1	66
Sandstone, brown, soft.....	33	99
Clay, red-gray.....	9	108

SW #1 19-13-12dbd. Sample log of borehole; drilled by KGS in June, 1986. Surface elevation, 1886 feet.

	Thickness	Depth
QUATERNARY-PLEISTOCENE	ft	ft
Undifferentiated loess		
Silt, clayey, dark brown.....	2	2
Silt, clayey, gray-brown.....	14	16
Silt, clayey, tan and light brown; contains caliche beginning at 25.0.....	27	43
Silt, clayey, tan and light brown; contains some fine gravel.....	14	57
Silt, clayey, tan and light brown; contains some sand and fine gravel.....	2	59
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, sandy, multicolored; contains some broken sandstone and sand.....	2	61
Clay, sandy, multicolored; contains less broken sandstone and sand.....	5	66
Sandstone, yellow-white; contains some sandy clay.....	6	72

SW #2 19-13-12aca. Sample log of borehole; drilled by KGS in June, 1986. Surface elevation, 1862 feet.

	Thickness	Depth
QUARTERNARY-PLEISTOCENE	ft	ft
Undifferentiated loess		
Topsoil.....	2	2
Silt, clayey,yellow-brown.....	3	5
Silt, light tan.....	11	16
Silt, clayey, yellow.....	6	22

	Thickness ft	Depth ft
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, multicolored.....	4	26

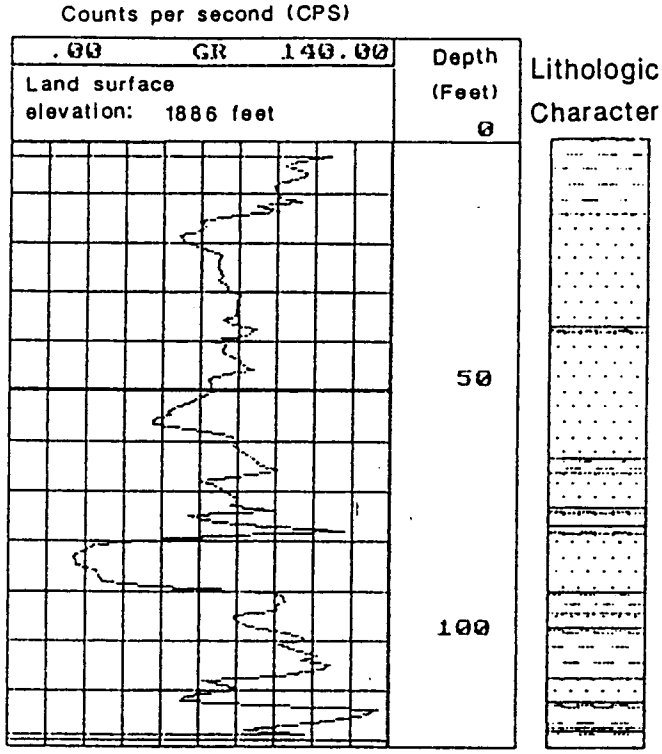
SW #3 19-13-12acb. Sample log of borehole; drilled by KGS in June, 1986. Surface elevation, 1870 feet.

	Thickness ft	Depth ft
QUATERNARY-PLEISTOCENE		
Undifferentiated loess		
Topsoil.....	2	2
Silt, clayey, yellow-brown.....	6	8
Silt, clayey, light tan; contains caliche nodules.....	1	9
Silt, clayey, light tan; contains caliche nodules and occasional gravel with iron oxide at 23.5 ft.....	14	23
CRETACEOUS-GULFIAN		
Dakota Formation		
Clay, red.....	4	27

SW #4 19-13-12aab. Sample log of borehole; drilled by KGS in June, 1986. Surface elevation, 1835 feet. Hole plugged from 20.0 ft to 50.0 ft with grout.

	Thickness ft	Depth ft
CRETACEOUS-GULFIAN		
Topsoil.....	1	1
Clay, red-brown.....	2	3
Clay, sandy, red-brown.....	2	5
Clay, red-brown with gray stringers.....	3	8
Clay, light gray.....	5	13
Clay, multicolored.....	37	50

DW#1



Common parameters for all logs:

Probe speed = 10 feet/minute

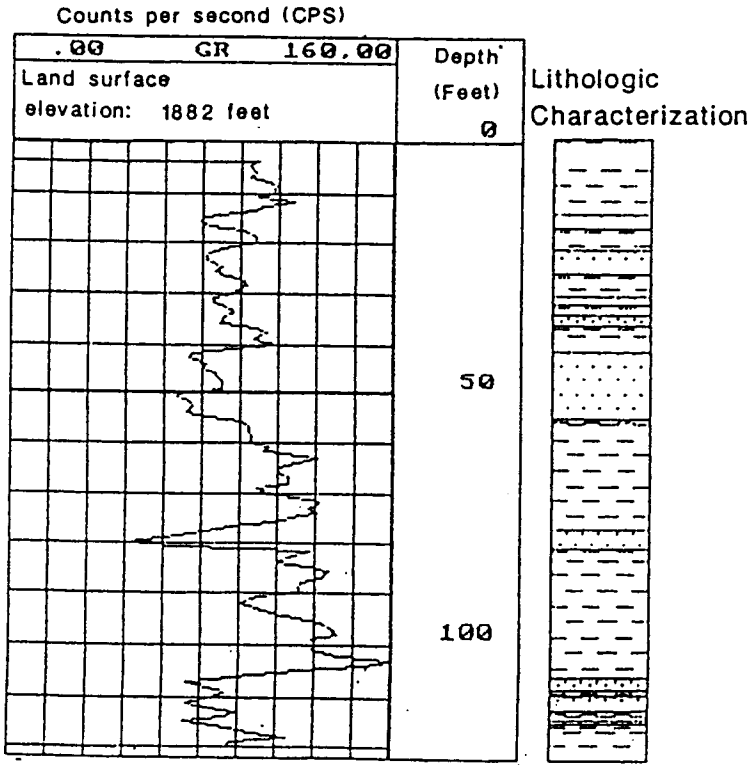
Horizontal displacement = 0

Time constant = 2 seconds

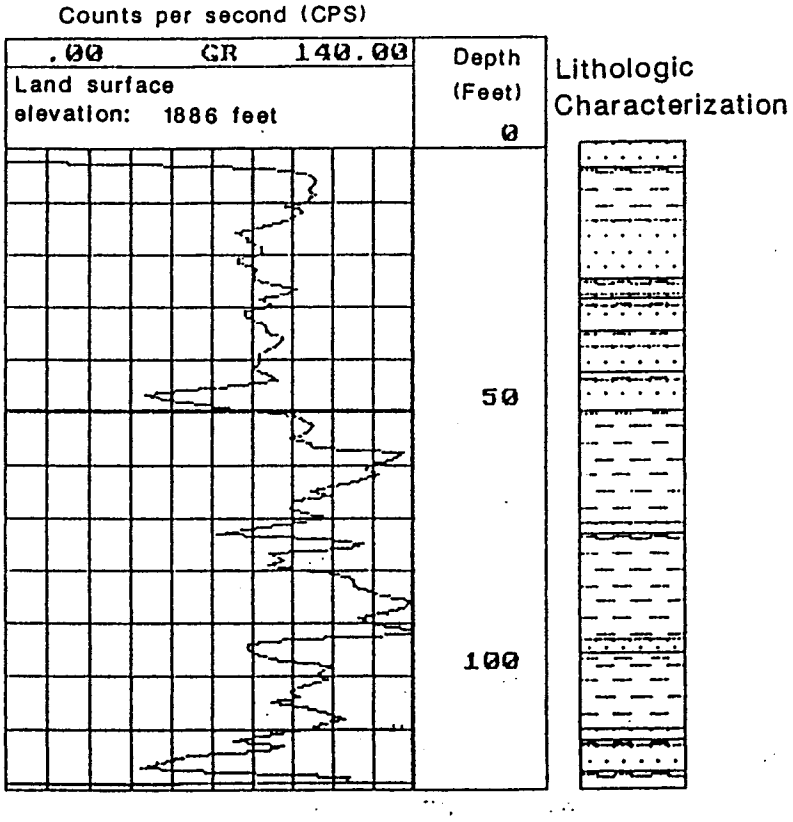
Clayey zone

Sandy zone

DW#2



DW#3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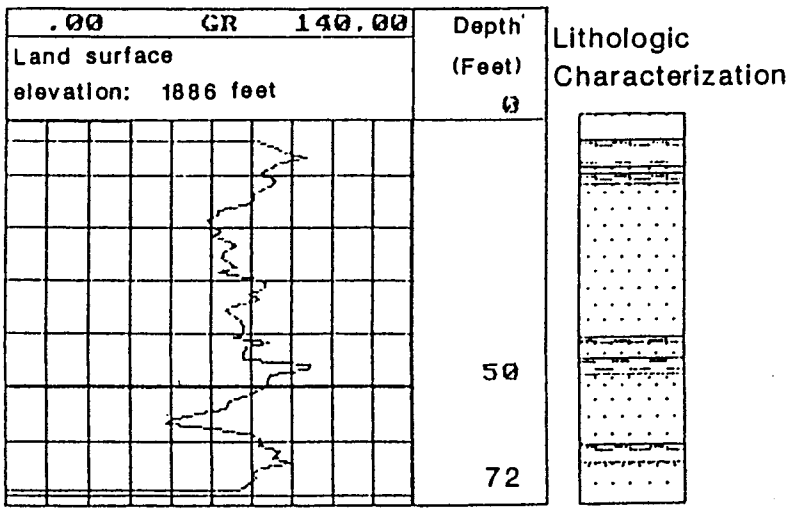
GR
140.00
Land surface
elevation: 1886 feet
Depth
(Feet)
0
50
100
Lithologic
Characterization

SW#1


Counts per second (CPS)
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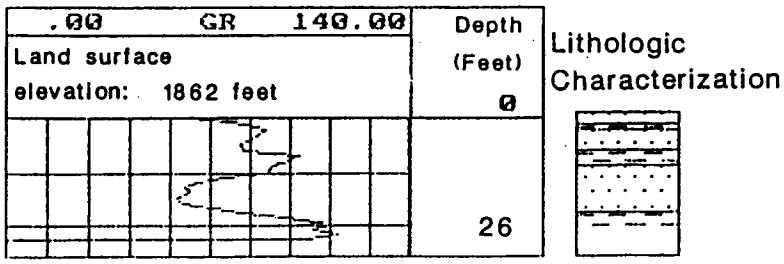
GR
140.00
Land surface
elevation: 1886 feet
Depth
(Feet)
0
50
72
Lithologic
Characterization

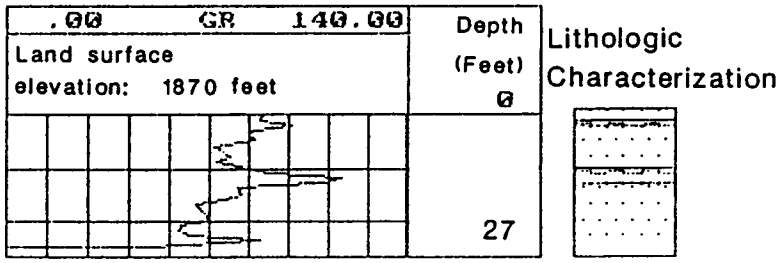
SW#2

Counts per second (CPS)



SW#3

Counts per second (CPS)



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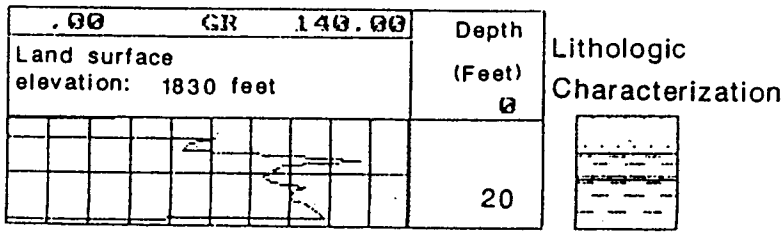

Appendix 11.3-Monitor and Domestic Well Construction Specifications.

Well number	Well type	Well depth (feet)	Land surface elevation (feet)	Static water level (feet)	Water-level measurement date	Screen interval (feet)	Gravel-pack interval (feet)	Bentonite interval (feet)	Grout interval (feet)	Casing diameter (inches)	Casing material	Water-bearing zone
DW #1	M	121	1886	1827	July 1986	101-121	96-121	94-96	0-94	2	PVC	Dakota Sandstone
DW #2	M	122	1882	1816	July 1986	102-122	90-122	89-90	0-89	2	PVC	Dakota Sandstone
DW #3	M	121	1886	1821	July 1986	101-121	90-121	88-90	0-88	2	PVC	Dakota Sandstone
DW #4	D	230	1888	1827	May 1986	180-230	40-230	None	0-40	5	PVC	Dakota Sandstone
DW #6	D	NL	1830	NL	NL	NL	NL	NL	NL	NL	NL	Dakota Sandstone
DW #7	D	173	1875	1777	May 1986	153-173	?	None	4-14	5	PVC	Dakota Sandstone
DW #8	D	NL	1887	1817	NL	NL	NL	NL	NL	NL	NL	Dakota Sandstone
DW #9	D	195	1799	1792	October 1985	135-168 176-195	10-195	None	0-10	8	PVC	Dakota Sandstone
DW #10	D	124	1850	1804	May 1986	104-124	10-124	None	0-10	5	PVC	Dakota Sandstone
DW #11	D	240	1900	1801	November 1976	160-240	?	None	0-10	5	Styrene	Dakota Sandstone

DW #12	D	108	1910	1827	January 1986	80-100	74-108	None	0-10	5	PVC	Dakota Sandstone
SW #1	M	72	1886	1833	July 1986	52-72	47-72	45-47	0-45	2	PVC	upper aquifer
SW #2	M	26	1862	1852	July 1986	16-26	14-26	12-14	0-12	2	PVC	upper aquifer
SW #3	M	27	1870	1851	July 1986	17-27	15-27	14-15	0-14	2	PVC	upper aquifer
SW #4	M	20	1835	None	July 1986	10-20	8-20	6-8 20-23	0-6 23-50	2	PVC	Dakota clay no water

NL = No log available
PVC = Polyvinyl chloride
M = Monitor well
D = Domestic well

Appendix 11.4-Well-construction requirements; KDHE, 1986.

1. Six-inch steel or PVC protective casing with water-proof cap will be placed over the well. The casing should be set in a concrete pad and extend 36 inches above the ground line.

2. A 2-foot zone of bentonite pellets is to be placed on top of the gravel pack.

3. Gravel pack for wells may be sand, gravel, chat, or crushed sandstone meeting the requirements of Type U.D.-1. Source area for gravel pack must be identified.

4. Manufactured 4-inch well screen or horizontal-slotted schedule 40 or manual-slotted PVC schedule 40 shall be used. Maximum slot size 1/8 inch. Maximum vertical distance between slots is 6 inches.

5. Pipe specifications: Schedule-40 threaded PVC casing or better. No joint solvent should be applied.

6. Upper 10 feet of hole shall be grouted.

7. Prior to the drill rig entering the area of investigation, the drill rig, bits, rods, and any other hardware which could come into contact with the borehole or drilling fluid must be washed with hot potable water to remove any contaminants. The water pump and drilling-rig plumbing system should be thoroughly flushed with potable water to flush any contaminants present.

8. This decontamination procedure shall be used after the completion of each monitoring well to eliminate cross contamination between wells.

9. All casing used to complete monitoring wells shall be decontaminated by washing (inside and out) with biodegradable soap (i.e. Alconox), followed by a thorough rinsing with a potable-water supply.

10. During the construction of the monitoring wells, the use of lubricating oils or solvents on drill-rod threads should be eliminated or very minimal to avoid contamination of the ground water by hydrocarbon or organic solvents.

11. All drilling fluids (water) should be obtained from an offsite potable-water supply of known chemical quality. Samples should be collected from the drilling water source prior to intial drilling and submitted to the Kansas Department of Health and Environment for chemical analysis.

12. Flush-joint thread, 4-inch Schedule-40 PVC casing, has been specified to be used in all monitoring wells. The casing should be connected by the threads, hand-tight, with no solvent or cementing material used on the casing joints.

13. All drilling-fluid muds or additives shall be approved by the KDHE prior to use in the construction of the wells.

14. All wells shall be developed by pumping and flushing by the drilling contractor to sufficiently remove drilling fluids and muds. The wells must be developed until the pump-stream discharge is characteristic of the aquifer waters.

15. All wells shall be completed to the shale contact (40-45 feet in depth). All wells should be screened from the static water level to the shale contact. Any changes in the screening interval of the wells shall be made by the Department's representative present as the wells are being constructed.

16. The source of the gravel pack used to complete the monitoring wells must be approved by KDHE.

17. All grouting materials and grout mixtures must meet specifications defined in Article 30, Water Well Contractor License and Water Well Construction Regulations.

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CHAPTER 12: THE VEGETATION OF CHEYENNE BOTTOMS

Ralph E. Brooks and Carol Kuhn

INTRODUCTION

Vegetation is a primary component of habitat, a provider of shelter, food, and other resources for wildlife. The vegetation of Cheyenne Bottoms also serves as an integral part of an in situ educational and research facility as well as a recreational facility. Cheyenne Bottoms is located in a climatic region that regularly experiences short- and long-term extremes in water availability. With such extremes the plant communities remain in a continuous state of flux. Therefore, rather than attempting to precisely quantify the vegetation as it currently exists at the Bottoms, this report reflects on 1) specific plants that are known to occur within the boundary of the refuge, 2) the kinds of plant communities present and their distribution with regard to water availability, and 3) the short- and long-term phenology of these communities. Also included are comments regarding rare, endangered, and unusual plants of the region, the National Wetlands Inventory, and an annotated list of the known vascular plant flora of Cheyenne Bottoms.

REGIONAL AND HISTORICAL PERSPECTIVE

Cheyenne Bottoms lies in the center of the Great Plains of North America in a region referred to as the Mixedgrass Prairie. The Mixedgrass Prairie is an area with boundaries that fluctuate through the years as rainfall amounts vary such that the zone creeps eastward in dry periods and retreats westward in wetter times (Kuchler, 1972). On a smaller scale, yet one more easily observed, the boundaries of the plant communities at Cheyenne Bottoms expand or contract from year to year as well as during a single season, in response to moisture availability.

The vegetational history of Cheyenne Bottoms prior to its impoundment in the late 1950's is not well documented, despite the fact that the area was well known to botanists in the region. Few herbarium specimens exist which were collected prior to 1950, and in the literature one encounters only a few brief notes regarding the Bottoms.

There have been periods of substantial water availability when wetland vegetation must have been in abundance. Notes written by Dr. Frederick Wislizenius on a journey in 1839 are witness to this (Barry, 1972):

". . . the water was not very deep and the ground pretty firm . . . . my horse often slid down on grass and reeds. . . . all sorts of water birds swarmed around from all sides. Never have I seen together such quantities of swans, cranes, pelicans, geese and ducks, as were here. The swamp was fairly covered with them, and they seemed to feel themselves so safe that I could have killed hundreds of them with the shot of my double-barreled weapon . . . . [some] tall reeds, and the second half of the swamp still lay before me. My horse now would not budge . . . . so I dismounted and dragged it after me by the bridle. The water sometimes reached to my chest . . . . The sun was sinking when I finally reached the other side of the swamp."

September 28, 1839

During the late 1800's and early 1900's, water was so plentiful that area landowners comtemplated utilizing the "lake" for local irrigation and as a boating facility. Yet there were times in the recent past, such as in the 1930's, when the Bottoms became a dry wasteland devoid of wetland vegetation. From the standpoint of managing plant communities for wildlife, history indicates that the task will not be an easy one.

The earliest vegetation study known for the Bottoms is an unpublished study conducted by F. W. Uhler and F. A. Warren in June 1929 (Uhler, 1929).

The study was made just two years after the heaviest rainfalls ever recorded for the Bottoms and following a time (1926) when the Bottoms had been completely dry. The marsh flora described and mapped by Uhler and Warren was by their own admission, and rightly so, a "young" flora--one that had had limited time to develop. The area consisted of a large shallow central pool of open water. Aquatic plants in the open water were rare because "wave action keeps the water so turbid with suspended particles of clay. . . . until the marsh vegetation becomes more widely established in the now open areas and retards wave action." In the shallowest areas of the "permanent" water were small, scattered stands of several bullrush species. Surrounding the main pool, except on the northeast side, were spikesedge (Eleocharis sp.) flats. On these flats scattered stands of the following plants were noted by Uhler: Rumex (sp.?), Echinochloa crusgalli, Polygonum (five spp.), Sagittaria latifolia, and Triglochin maritima. Beyond the spikesedge community were saltgrass flats that gradually merged with wheatgrass communities. Neither the alkalinity nor salinity of the soil at that time was viewed as especially detrimental to the flora.

Two post-dike construction vegetation studies have been conducted at Cheyenne Bottoms. The first, in 1960, examined plant-community structure on the entire refuge (Sonnenberg, 1961) and the second, in 1969, was a similar work conducted in Pool 3 (Hastings, 1970). Both studies found that the vegetation in the Bottoms was characterized by secondary successional development, due in large part to the fluctuations in water availability to the different plant communities. Hence both concluded that area management was highly dependent on seasonal rainfall. While more refined and specific in nature, both studies portrayed plant-community types similar to that found earlier by Uhler (1929).

DESCRIPTION AND DISTRIBUTION OF PLANT COMMUNITIES IN 1986

The plant communities in Cheyenne Bottoms are distributed in zones which directly relate to elevation and water availability; without the pool dikes these communities would form more or less concentric zones around the main pool. Five general community types are herein described, and their distribution across Cheyenne Bottoms is illustrated in figure 12.1. Figure 12.2 represents a diagrammatic cross section of community distributions in the Bottoms, to best illustrate the relation of these communities to elevation, which in this case directly influences water availability. It cannot be stressed enough that the boundaries of these communities fluctuate in time as the climate and weather in the area change. Thus figure 12.1 is presented simply as a gross approximation of community distribution in 1986 and its accuracy in other years may not be dependable.

Open-water/Mudflat Communities

Open-water habitats may occur in any of the pool areas at Cheyenne Bottoms given enough rainfall. On the average, however, this habitat is restricted to the center pool (1) and adjacent areas of the bordering pools. Especially in pools 2 through 5, it is not uncommon for these areas to be covered by a few inches of water in the spring and then become mudflats or dry flats by mid-summer. Likewise, they may become covered with water at any time of the year after heavy rainfall in the area. Depending on the weather, the water may remain for a time or evaporate in a matter of days.

Not surprisingly, such open-water habitat as exists at the Bottoms provides a poor environment for submersed or floating-leaved aquatic plants typical of many lacustrine habitats. Adding to the harshness of the environment is wind and wave action which together result in high turbidity, reducing the availability of light and causing mechanical damage to the

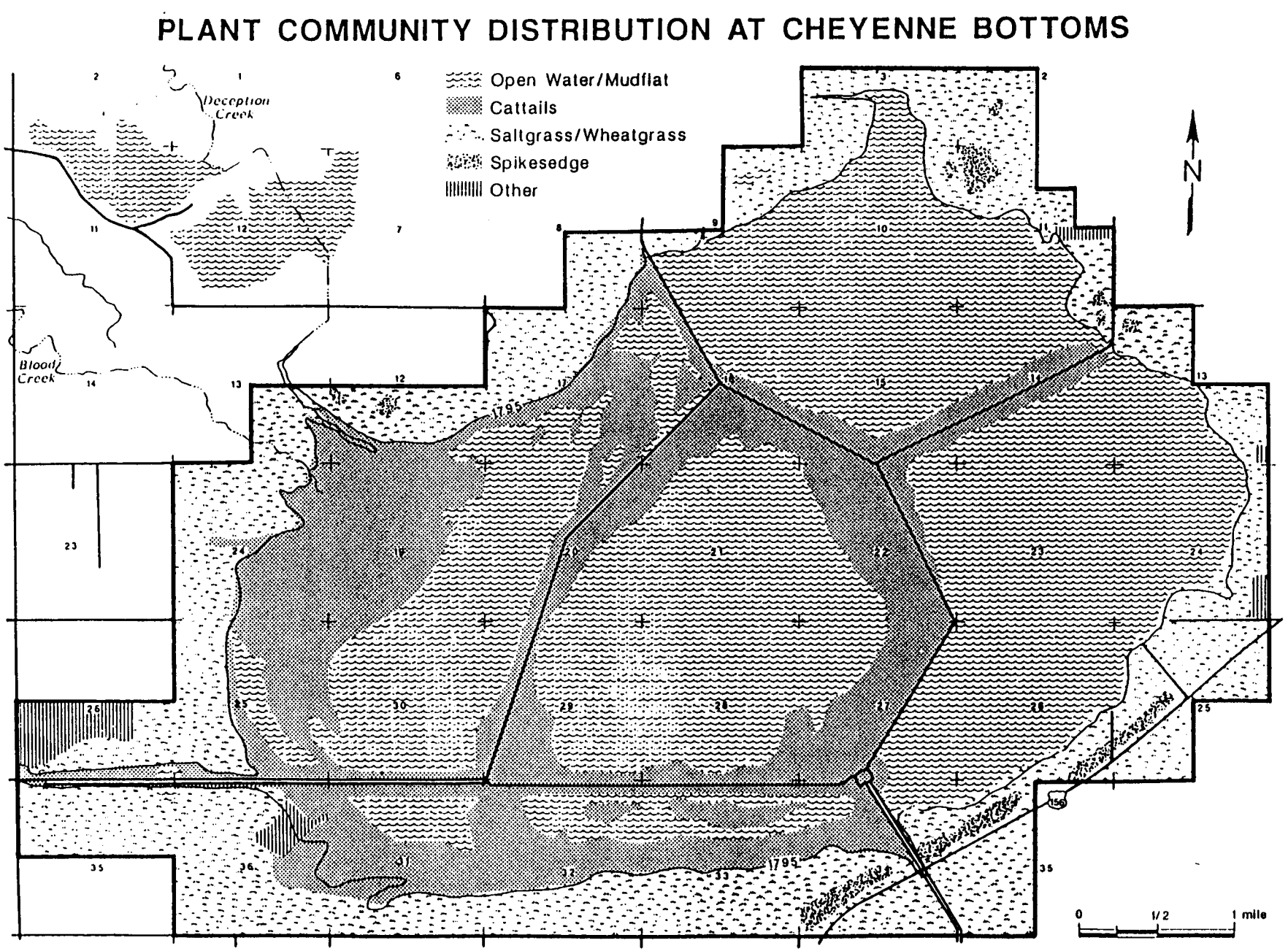

Figure 12.1 Plant community distribution at Cheyenne Bottoms, 1986.

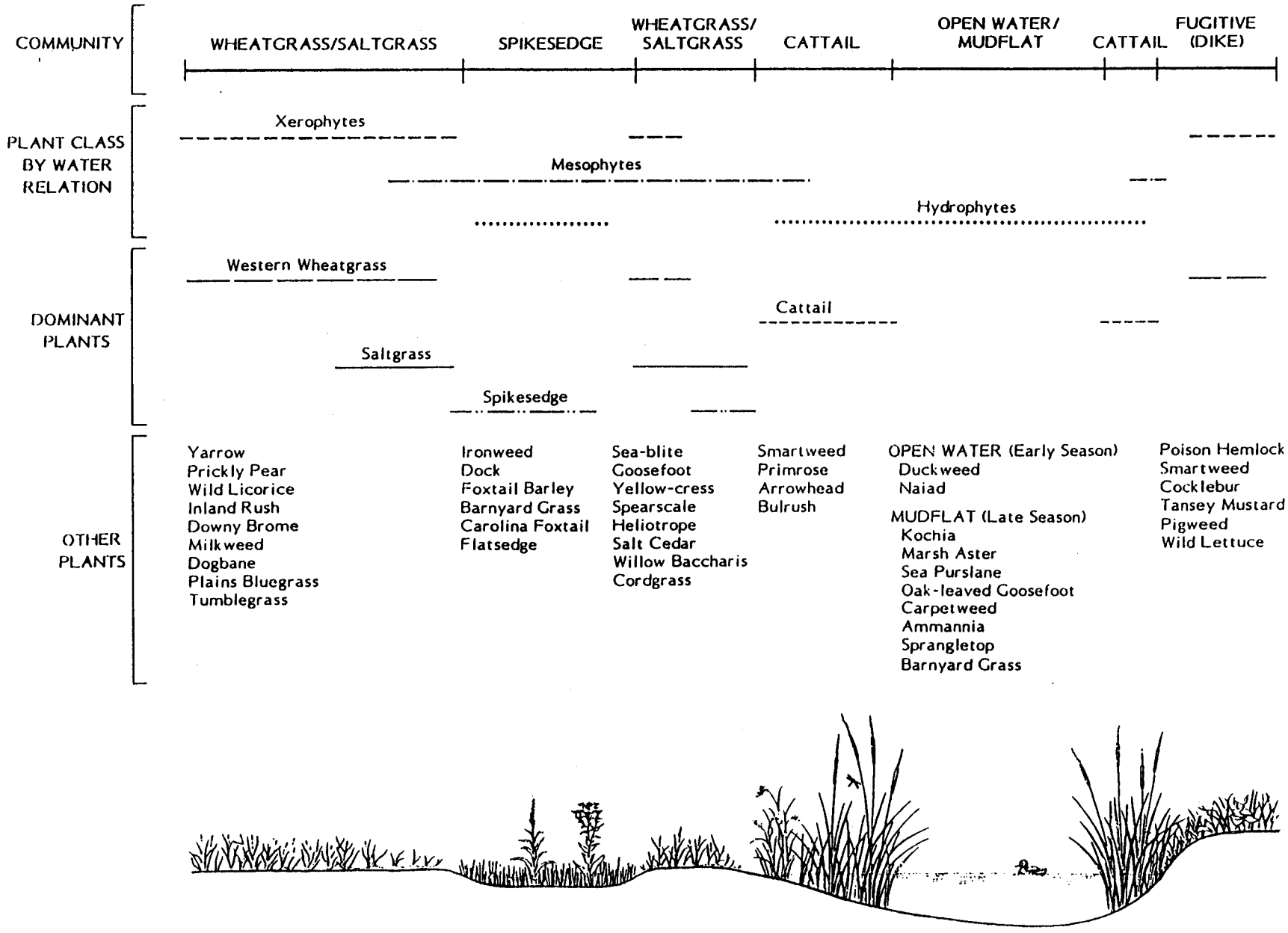

Figure 12.2 Diagrammatic cross section of plant community distribution in Cheyenne Bottoms, 1986.

plants. In essence, submersed and floating-leaved plant life is for practical purposes nonexistent. Submersed plants such as southern naiad (Najas guadalupensis), certain pondweeds (e.g., Potamogeton foliosus), and horned pondweed (Zannichellia palustris) which are so common in the region in areas with stable water regimes, are virtually excluded by the existing conditions at the Bottoms. Unfortunately, the absence of this aquatic plant community impacts waterfowl by not providing habitat for invertebrate communities that might normally attract grazers.

When evaporation causes summer drawdown, the pool areas revert to extensive barren flats. By late June and early July a host of annual plants begin to germinate and gradually cover the flats. By fall the flats support large, dense stands of these annuals. Kochia (Kochia scoparia) and saltmarsh aster (Aster subulatus) are especially common where the ground has been exposed for the longest period. Scattered through the area are specimens of Russian thistle (Salsola iberica), snow-on-the-mountain (Euphorbia marginata), chenopods (Chenopodium spp.), and several pigweeds (e.g., Amaranthus blitoides and A. retroflexus). At the Bottoms, these flats are frequently seeded to Japanese millet (Echinochloa crusgalli var. frumentacea) or wheat to provide additional forage resources for migratory waterfowl in the fall.

In slightly lower areas that have been covered by water for longer periods are found low, annual ground covers, especially an apparently recently introduced species, sea purslane (Sesuvium maritima), and other annuals including sea-blite (Suaeda depressa), carpetweed (Mollugo verticillata), oak-leaved goosefoot (Chenopodium glaucum), and ammannia (Ammannia coccinea and A. robusta). These areas are also especially good sites to find various barnyard grasses (Echinochloa spp.) and heavy stands of sprangletop (Leptochloa fascicularis).

Depressions in this zone that hold additional moisture may support lush growths of a variety of wetland herbs including a number of potentially valuable food resources for waterfowl, e.g., the annual smartweeds (e.g., Polygonum bicorne and P. lapathifolium) and water hemp (Amaranthus rudis). A host of other larger wetland species are also likely to be present, including American burnweed (Erechtites hieracifolia), beggar's tick (Bidens spp.), and sumpweed (Iva annua).

Cattail (Typha) Community

Cattail communities of varying extent are found in all pool areas. They are primarily composed of narrowleaf cattail (Typha angustifolia) and to a far lesser extent common cattail (T. latifolia). In areas where the cattails remain unchecked by natural or mechanical removal, they establish dense stands which exclude open water and terrestrial areas that might otherwise be utilized by area wildlife. Cattail stands are burned, mowed, disked, and plowed in the management area; however, these means of reducing cattail acreage are short-term in their effect and may, in fact, stimulate more vigorous growth in the end.

Cattails are strong perennial herbs spreading vigorously from thick rhizomes. Leaf growth has usually initiated by mid-March, with the plants rapidly gaining height and flowering by mid-June. The plants respond quickly to decreased water availability, their above-ground parts dying back often within days when water loss is excessive. Such occurrences allow for the mechanical removal of the top growth, as earlier mentioned.

During the past 15 years, the cattail population at Cheyenne Bottoms has changed dramatically. Uhler (1929) made no reference to cattails in his report. In the vegetation surveys conducted by Sonnenberg (1961) and Hastings (1970), scant mention was made of cattails. Typha angustifolia was the most

common species of cattail encountered yet as a whole the genus was poorly represented. In 1960, for example, Sonnenberg presented tables of percent basal cover and composition of the vegetation in pools 2 through 5. At that time cattail accounted for less than 1% of Pool 3 and was not listed at all for the remaining pools. Today Pool 3 contains approximately 15% cover by cattail, Pool 2 about 43%, and Pool 5 about 50%. Pool 4 has been dry for some time and like Pool 3 has little cattail coverage, perhaps 5-10%.

The increase of cattail in the Bottoms seems to be to the detriment of the large rushes (Scirpus fluviatilis, S. acutus, and S. heterochaetus). Sonnenberg (1961) and Hastings (1970) both indicated that large areas of the Bottoms were covered by tall rushes, as did Wislizenius in his journal passage in 1839 (Barry, 1972). Yet today the Scirpus (bulrush) community is quite insignificant and is mainly confined to small zones just outside or perhaps slightly higher than the cattails or occurs in small scattered "islands" in the pools. It should be noted, however, that the increase in cattail, particularly Typha angustifolia, is not a phenomenon peculiar to Cheyenne Bottoms. Prior to 1950 this species was virtually unknown in Kansas and much of the eastern Great Plains (Hotchkiss and Dozier, 1949). By 1977 documented records of T. angustifolia had been reported from all areas of the Great Plains (Great Plains Flora Association, 1977), and in Kansas the plant had been discovered in every county. In fact then, this native of the northeast United States and adjacent Canada has for some reason found a new niche in more western areas and spread in a most explosive manner. For better or worse, its presence in the Great Plains is well established and one that must be managed in the future.

As mentioned earlier, cattails suppress other herbaceous growth under nonmanagement conditions. If, however, mechanical removal of the cattails

occurs by mid-summer the open habitats may become covered by perennials such as the docks (Rumex spp.) or a number of annuals, such as smartweeds (Polygonum ssp.), goosefoot (Chenopodium spp.), coreopsis (Coreopsis tinctoria), and sumpweed (Iva annua).

Saltgrass/Wheatgrass Community

Saltgrass/wheatgrass areas are located at the periphery of the refuge on slightly elevated land. The boundary between this area and the lower areas of open-water/mudflat community or cattail community has been clearly marked during the past year by a disked swath which closely follows the 1,795-foot contour in the Bottoms. On the average the lowest areas of the saltgrass/wheatgrass zone hold water for only brief periods at a time. Wheatgrass (Agropyron smithii) dominates in the more xeric areas while saltgrass (Distichlis spicata) can withstand more mesic conditions, at least for brief periods. Both are tolerant of the slightly alkaline conditions existing in the Bottoms. Topographical differences in the landscape are so slight that over a series of years, depending of rainfall, there can be dramatic shifts in the abundance of one species compared to the other.

Wheatgrass is a native, sod-forming, cool-season grass. It initiates spring growth by the end of March or in early April and generally flowers by early June. Fruit maturation occurs shortly thereafter. Saltgrass is a warm-season, sod-forming grass that is native to the region. Vegetative growth is initiated in early April with flowering occurring in late May, although it is not uncommon to find flowering specimens much later in the season and especially in late summer in wetter years. Through the mid-summer, vigorous rhizomatous growth occurs, especially into slightly lower areas where evaporation on the flats has dried the upper surface of the soils. Should

these areas remain water saturated too long into the summer, saltgrass growth is restricted and over time it may be replaced by spikesedge (Eleocharis xyridiformis).

The lower areas of these flats offer an excellent opportunity for the invasive and, too frequently, noxious establishment of salt cedar (Tamarix sp.) and willow baccharis (Baccharis sp.). Neither of these plants is especially common at present, but according to persons familiar with the area in the past 15 to 20 years, both species will increase their population sizes through years of average to subaverage rainfall, until they are again checked by high water levels.

The diversity of plants in the saltgrass/wheatgrass flats is perhaps as varied as in any area of the refuge, except for the fugitive flora of the dikes. Two peak periods of flowering are notable, the first in spring and the second in late summer. Spring flora includes annual brome grasses (especially Bromus tectorum), foxtail barley (Hordeum jubatum), little barley (Hordeum pusillum), yarrow (Achillea millefolium), prickly poppy (Argemone polyanthemos), occasional prickly pear (Opuntia macrorhiza), small stands of wild licorice (Glycerrhiza lepidota) or hemp dogbane (Apocynum cannabinum), and inland rush (Juncus interior). Late-summer flora includes such plants as woolly vervain (Verbena stricta), silver nightshade (Solanum elaeagnifolium), western ragweed (Ambrosia psilostachya), and curlycup gumweed (Grindelia squarrosa).

Small areas barren of vegetation early in the season are scattered across these flats, especially toward the main pool areas. The flora they support in late summer is somewhat similar to that found in the drawdown areas of the pools. There are more halophytes found in these areas than anywhere else in

the Bottoms. Solid stands of halophytic chenopods such as Suaeda and Atriplex, or the grass Poa arida are familiar occurrences.

Spikesedge Community

The spikesedge community is primarily found in shallow depressions about 6-12 inches deep, associated with the wheatgrass/saltgrass areas. They are usually covered by only a few inches of water for several weeks in the spring and are dominated by continuous stands of the spikesedge, Eleocharis xyridiformis.

This particular community type is perhaps underrepresented in figure 12.1. Small depressions with spikesedge communities can be found scattered across much of the saltgrass/wheatgrass zone but are so small that they cannot be mapped at this scale. Uhler (1929) mapped a substantial area of spikesedge flat which essentially ringed the central pool area and created a zone between what is here referred to as the open-water/mudflat area and the saltgrass/wheatgrass area. That area during the past year has been, as was earlier noted, repeatedly disked. The constant disturbance has obviously affected the area to the point that plant-community stability does not currently exist.

Spikesedge begins vegetative growth in late March and early April, blooms, and then sets fruit soon thereafter, often while the ground remains saturated with water.

The soil in these depressions is a fine clay gumbo and surely prohibits the growth of many of the plants that thrive in the surrounding areas. There are, however, a number of perennial herbs with strong taproots that apparently prosper in this environment. By the time the spikesedge has completed flowering, plants of dock (Rumex stenophyllus) have begun to bolt and

flower. Later in the summer heavy stands of ironweed (Vernonia fasciculata) dominate the depressions.

Where these depression areas are extensive, such as the borrow depressions along the southern portion of Pool 5, salt cedar and willow bacharris can evidently make themselves a nuisance.

Other Vegetation

Within the management area a small portion of land is devoted to row crops and an even lesser amount to woodlots, presumably to provide roosts or windbreaks.

The dikes in Cheyenne Bottoms represent the only other habitat worthy of mention. In essence, they support a fugitive community, a habitat for numerous plant species that would not otherwise be found in this depression wetland. Roughly 50% of the total flora listed for Cheyenne Bottoms in appendix 12.1 has been found at one time or another along the dikes. A large portion of these plants are quite transient and while their presence has been appropriately documented, one would be hard pressed to find these same species at the Bottoms again.

These introduced species range from abundant and well established plants like poison hemlock (Conium maculatum) to infrequently documented plants such as butter-and-eggs (Linaria vulgaris) or Texas blueweed (Helianthus ciliaris). The roadsides and upper slopes of the dikes harbor plants that are generally indicative of xeric habitats while lower on the slopes more mesic species are found, especially along the water line. The dike-water interface actually provides an interesting diversity of species and while it may provide little in the way of food resources for area wildlife, it does represent valuable shelter areas.

SALT TOLERANCE OF SELECTED MARSH PLANTS

Past vegetation analyses at Cheyenne Bottoms have not assessed the relation of salinity levels in the area to plant-community composition. Presumably, this is because salinity levels in the Bottoms are low in comparison to other central Great Plains areas well known for their saline conditions, such as the Big Salt Marsh in Stafford County, Kansas (Ungar, 1961, 1964, 1965), or the Great Salt Plains in Alfalfa County, Oklahoma (Ungar, 1968).

Studies of salt tolerance rarely approach the subject from the standpoint of determining the range of salinity under which a specified plant can grow and the problems associated with increased or decreased salinity. Instead the approach commonly employed is to examine a plant community in situ and determine the parameters under which it exists. These data provide reference points at which it is known that life can be sustained. However, they do not provide the actual tolerance range under which the plants grow, or address the effects of salinity on biomass production, maturation, etc. These pitfalls realized, table 12.1 presents soil salt-content levels in which various plants have been reported to grow. These figures provide a rough approximation of salinity levels under which some of the plants found at Cheyenne Bottoms can survive. Table 12.1 was compiled entirely from literature pertinent to the central Great Plains and represents no new data.

Salinity concentrations in the surface soils are important for the establishment of the plants in table 12.1 in a somewhat unusual way. Nonsalt-tolerant species are eliminated or suppressed, and so competition for resources is in effect reduced such that poor competitors that happen to be salt tolerant are found in the saline areas. Conversely, the lack of these halophytes in nonsaline habitats is a result of their inability to compete

with the more diverse flora of the salt-free areas (Ungar, 1967; Ungar et al., 1969). This raises the question of whether or not any of these plants could be considered obligate halophytes.

Table 12.1--Ranges of soil salt content in which species have been reported from areas of the central Great Plains. Soil samples taken from 0 to 10-cm and 40 to 50-cm depths and expressed as percentage-total salts on a dry soil-weight basis. Data from Ungar 1965 (a) and 1966 (b).

SPECIES	SOIL SALT CONTENT(% dry wt.) Soil Depth	
	0-10 cm (mean)	40-50 cm (mean)
Agropyron smithii[ab]	0.00-0.07 (0.06)	---
Aster subulatusa	0.00-0.94	0.00-0.65
Atriplex argente[ab]	0.23-0.80 (0.61)	0.27-0.53 (0.35)
Atriplex subspicata[b]	0.18-1.30 (0.55)	0.16-0.90 (0.63)
Baccharis salicina[b]	0.02-0.63 (0.19)	0.04-0.13 (0.07)
Distichlis spicata[b]	0.13-3.93 (0.9)	0.05-0.74 (0.42)
Heliotropiuma curassavicum	0.22-1.10	0.28-0.45
Hordeum jubatum[b]	0.07-1.30 (0.45)	0.38-0.90 (0.67)
Kochia scoparia[b]	0.34-1.30 (0.66)	0.84-0.90 (0.87)
Leptochloa fascicularis[b]	0.03-0.49 (0.21)	0.62-0.80 (0.68)
Poa arida[b]	0.07-1.09 (0.39)	0.38-0.78 (0.58)
Polygonum lapathifolium[a]	0.18-0.68	0.03-0.07
Spartina pectinata[a]	0.18-1.00	0.03-0.49
Suaeda depressa[b]	0.37-4.44 (1.35)	0.27-1.21 (0.52)
Tamarix ramosissimus[b]	0.14-3.72 (1.74)	0.03-0.77 (0.40)
Typha angustifolia[a]	0.25-0.52	---
Typha latifolia[a]	0.02-0.52	---

The following are brief comments regarding salinity tolerances for selected species occurring at Cheyenne Bottoms: Agropyron smithii (western wheatgrass), though tolerant of traces of salt, should not be considered an indicator of saline soil (Nielsen, 1953; Ungar, 1965). Because of the elevation of the land where most of the wheatgrass communities are found at Cheyenne Bottoms, increased salinity levels would likely have little effect on its abundance.

Aster subulatus (saltmarsh aster) occurs in a broad range of salinity conditions (up to 1%) and is perhaps more directly tied to moisture relationships. Slight increases in the salinity levels at the Bottoms would probably have minimal effects on population size for the species.

Distichlis spicata (saltgrass) spreads by shallow underground rhizomes that stay less than 10 cm deep in the soil. Their roots, however, penetrate the soil to depths in excess of 50 cm, where salinity is normally less than that near the surface. Ungar (1965) states that saltgrass growth is optimal in areas with shallow water tables and salinities in the range of 0.20-0.94 %, with growth markedly affected by soil salinities in excess of 2%. Such high concentrations do not occur in Cheyenne Bottoms and would not be expected unless a saline water source were tapped to supply water for the area. Thus the status of saltgrass in the Bottoms is not likely to deviate appreciably in the future.

Echinochloa spp. (barnyard grass), either cultivated or wild, is infrequently mentioned with regard to salt tolerance, presumably because of its intolerance of such conditions. Sonnenberg (1961) states that at Cheyenne Bottoms, Japanese millet growth was stunted in areas where pH values were 8.0. These measurements were taken in August in areas that had earlier shown lower readings. Upward capillary movement of salts is the likely cause for these high readings; thus it is assumed that barnyard-grass growth is inhibited as salinity increases. Thus, as long as millet is sown as a food supplement in the area, care should be taken to seed areas that maintain the lowest possible levels of salinity.

Leptochloa fascicularis (bearded sprangeltop) according to Sonnenberg (1961) reacts much like Echinochloa to increased salinity.

Tamarix ramosissimus (salt cedar) is well known for its salt tolerance (Tomanek, 1957; Ungar, 1965). Germination of its seeds is little hindered by salinities of as high as 1% (Tomanek, 1957) and mature plants can tolerate levels in excess of 3.5% (Ungar, 1966).

Typha (cattail) is represented by two species at Cheyenne Bottoms, T. angustifolia and T. latifolia. McMillan (1959) demonstrated that T. angustifolia is more adapted to highly fluctuating water conditions and has a broader range of tolerance for salinity than does T. latifolia. Typha latifolia requires a relatively stable water supply and is not very salt tolerable. The coupling effects of these factors certainly explain why T. angustifolia is the more aggressive species in the Bottoms.

RARE, ENDANGERED, AND UNUSUAL PLANTS

The U. S. Fish and Wildlife Service, Department of the Interior, is responsible for maintaining a list of endangered and threatened plants pursuant to the Endangered Species Act of 1973. Currently no plants are known to occur in Cheyenne Bottoms that are officially listed or proposed for listing. In considering 1) the regional flora and 2) the federally listed plants that do occur in Kansas, it is unlikely that any plants will be found in the Bottoms which are considered federally rare or endangered, except due to chance introductions.

Kansas currently has no laws regarding rare or endangered plants and, in fact, seems quite unconcerned with the matter if compared to nongame fauna. In 1977 McGregor authored "Rare native vascular plants of Kansas." It is noteworthy that this work included approximately 300 taxa and that less than 3% are presently listed or proposed for listing federally. The remainder, as McGregor clearly points out, are plants with ranges peripheral to Kansas,

hence their scarcity is not especially surprising. None of the plants listed by McGregor is known to occur at Cheyenne Bottoms.

NATIONAL WETLANDS INVENTORY

The U.S. Fish and Wildlife Service, Department of the Interior, in accordance with "Classification of wetlands and deepwater habitats of the United States" (FWS/OBS-79/31 December 1979) is in the process of preparing a National Wetlands Inventory. Drafts for the Cheyenne Bottoms were completed in 1986 and place the area in two primary catagories: L2UBGh--Lacustrine (L)/Littoral (2)/Unconsolidated bottom (UB)/Intermittently exposed (G)/Diked (h); and PEMFh--Palustrine (P)/Emergent (EM)/Semipermanently flooded (F)/Diked (h).

The lacustrine area includes the open-water areas of Pool 1 and the palustrine area essentially includes the remainder of the refuge area with the exception of the dikes proper, a few upland wheatgrass areas, and a small amount of cultivated land. For practical management purposes, the National Wetland Inventory classifications are of little value.

ANNOTATED SPECIES LIST

A list of plants documented as now occurring or having occurred in the past at Cheyenne Bottoms appears in appendix 12.1. Included are 261 taxa, representing 158 genera and 57 families. A similar listing by Hastings (1970) included 129 taxa from 88 genera and 33 families. The 100% increase in taxa listed herein is a reflection of the increased field activities of the Kansas Biological Survey and University of Kansas Herbarium in recent years and should not be construed as a biological phenomenon. In addition, many of the plants listed are known from but a single collection, especially those associated with the dike areas. Attempts to relocate many of these have

resulted, or would result, in failure due to the tenuous nature of their existence.

The appendix is arranged alphabetically by family and within family by genus, and so forth. The names employed, both scientific and colloquial, follow the treatment used by Brooks (1986), which is slightly modified from those used by the Great Plains Flora Association in "Flora of the Great Plains" (1986). Synonyms are for the most part included only if they were used in previous publications pertinent to Cheyenne Bottoms; e.g., Sonnenberg (1961) and Hastings (1970). Comments are included where appropriate regarding plant habit, habitat, abundance, phenology, and resource value.

This list was compiled from a combination of field studies in 1985 and 1986, herbarium records, and pertinent literature. An attempt was made to locate specimen documentation for all species mentioned in literature pertinent to Cheyenne Bottoms; however, they were not found in all cases. Herbaria consulted included those housed at the following institutions: Emporia State University (KSTC), Fort Hays State University (FHKSC), Kansas State University (KSC), and the University of Kansas (KANU). In addition, a collection housed at the Cheyenne Bottoms Headquarters (CBOT) was examined.

SUMMARY

The vegetation at Cheyenne Bottoms functions first as an integral part of the total environment that provides food, shelter, and other resources for wildlife, and secondly as an educational, recreational, and research facility. On the basis of plant species present and gross physical parameters, four basic plant-community types were identified.

Open-water/mudflat community dominates the lowest areas of the Bottoms. It is generally water covered for the entire year or may experience dramatic drawdown due to seasonal or prolonged drought.

The Cattail community lies adjacent to most of the open-water/mudflat community in shallow water or soils that remain water saturated for long periods of time. This community is one that has explosively increased its coverage during the past 20 years and one that presents a constant management problem because its growth is so dense as to inhibit other plant life and exclude many kinds of wildlife. This is not, however, a problem unique to Cheyenne Bottoms, for the same phenomenon has occurred across most of the Great Plains since about 1950.

The Wheatgrass/saltgrass community lies beyond the cattail community on slightly elevated ground. The dominance of wheatgrass versus saltgrass is dependent on the lack or availability of water, respectively.

Scattered across the wheatgrass/saltgrass community are shallow depressions classed as spikesedge community. While fairly small in acreage, these actually provide important spring and fall forage areas for waterfowl.

Cheyenne Bottoms is an area that has been intensely managed for the benefit of waterfowl, resulting in the alteration of the natural plant community. As the situation currently stands, the natural plant community cannot support the demand for food resources that are placed upon it and must therefore be supplemented by various means. This requirement coupled with certain management techniques (e.g., disking or burning) and the extremes of water availability, all combine to keep the plant community in a constant state of flux.

Therefore, it is unlikely that any alterations made to the Bottoms for the benefit of the wetland birds would be detrimental to the plant

communities. Quite to the contrary, better control of water levels at the Bottoms would most likely improve the manageability of the plant communities in the future by helping stabilize their composition and distribution, thereby providing a more predictable and manageable natural resource.

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APPENDIX 12.1--Annotated species list for the vascular plants of Cheyenne Bottoms, Barton County, Kansas.

Aceraceae, Maple Family

Acer negundo L., box elder

Tree. Infrequent on dikes or along water courses

Brooks 18087 (KANU)

Aizoaceae, Fig-marigold Family

Sesuvium maritimum L., sea purslane

(=S. verrucosum of reports)

Annual. Common to abundant on drying mud flats in late summer. This plant is normally found along the Atlantic and Gulf coasts from New York to east Texas. Its presence at Cheyenne Bottoms has gone undetected since it was first collected in 1977. This is one of only two stations known for the species in Kansas, the second in Barber County, and two of only three sites currently known from noncoastal states, the other in Alfalfa County, Oklahoma.

Brooks 14468 & McGregor (KANU), Brooks 17541 & Laushman (KANU).

Alismataceae, Water Plantain Family

Echinodorus rostratus (Nutt.) Engelm., erect burhead

Perennial herb. Infrequent on mud flats or in spikesedge depressions in mid-summer.

Hastings 192 (FHKSC)

Sagittaria calycina Engelm., giant arrowhead

(=S. montevidensis)

Perennial herb. Infrequent along edges of pools.

Bio. Sci. FHKSC s.n. (CBOT, FHKSC)

Amaranthaceae, Pigweed Family

Amaranthus albus L., tumble pigweed

Annual. Infrequent in waste areas and along roads in late summer.

Brooks 17550 & Laushman (KANU)

Amaranthus arenicola I. M. Johnst.

(=A. torreyi of reports)

Annual. Sonnenberg (1961) reported but no voucher found.

Amaranthus blitoides S. Wats, prostrate pigweed

(=A. gracaezans)

Annual. Infrequent in disturbed sites and along roads. Specimens occasionally seen in dried pool beds in late summer.

Bio. Sci. FHKSC 25 (CBOT)

Amaranthus hybridus L., slim pigweed

Annual. Hastings (1970) reported but no vouchers found.

Amaranthus retroflexus L., rough pigweed

Annual. Infrequent to scattered along roads or on dried pool beds and other disturbed sites in mid- and late summer.

Bio. Sci. FHKSC s.n. (CBOT)

Amaranthus rudis Sauer, water hemp

(=A. tamariscinus of reports)

Annual. Scattered to common in open, disturbed ground, especially low areas like dried pool beds.

Bio. Sci. FHKSC s.n. (CBOT)

Apiaceae, Parsley Family

Conium maculatum L., poison hemlock

Biennial. Locally common along the dikes. Naturalized from Europe. The entire plant is poisonous.

Brooks 17546 & Laushman (KANU)

Daucus carota L., wild carrot

Biennial. Infrequent along the dikes in spring. Introduced from Europe.

Bio. Sci. FHKSC 114 (CBOT)

Apocynaceae, Dogbane Family

Apocynum cannabinum L., hemp dogbane

(=A. sibericum Jacq.)

Perennial herb. Scattered in colonies along the dikes or sporadically in drier areas of wheatgrass/saltgrass flats.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17557 & Laushman (KANU)

Asclepiadaceae, Milkweed Family

Asclepias latifolia (Torr.) Raf., broadleaf milkweed

Perennial herb. Uncommon on wheatgrass flats in late spring.

Bio. Sci. FHKSC 26 (CBOT)

Asclepias speciosa Torr., showy milkweed

Perennial herb. Locally forming extensive colonies or in small patches, especially in ditches and along dikes in late spring.

Bio. Sci. FHKSC s.n. (CBOT), Stephens 55189 (KANU)

Asclepias sullivantii Engelm., Sullivan's milkweed

Perennial herb. Infrequent along dikes.

Brooks 17560 & Laushman (KANU)

Asclepias syriaca L., common milkweed

Perennial herb. Scattered along dikes and in disturbed areas of wheatgrass/saltgrass flats in late spring.

Hastings 42 (FHKSC)

Asclepias verticillata L., whorled milkweed

Perennial herb. Scattered on wheatgrass/saltgrass flats and along dikes in late spring and early summer.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17530 & Laushman (KANU)

Asclepias viridis Walt., green milkweed

Perennial herb. Infrequent on wheatgrass flats.

Hastings 27 (FHKSC)

Asteraceae, Aster Family

Achillea millefolium L. ssp. lanulosa (Nutt.) Piper, yarrow

Perennial herb. Scattered in spring on wheatgrass flats or occasional on dikes.

Bio. Sci. FHKSC s.n. (CBOT), Sonnenberg 60 (FHKSC)

Ambrosia psilostachya DC., western ragweed

Perennial herb. Local and forming small colonies on wheatgrass flats, along dikes, or in other disturbed sites in late summer.

Sonnenberg 68 (CBOT), Hastings 219 (FHKSC)

Ambrosia trifida L., giant ragweed

Annual. Scattered in disturbed sites, brushy areas, and occasionally at margin of pools (out of water) in late summer.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 234 (FHKSC)

Artemisia ludoviciana Nutt. var. ludoviciana, Louisiana sagewort

Perennial herb. Scattered in colonies on dikes or occasionally on wheatgrass flats in summer.

Hastings 52 (FHKSC)

Aster ericoides L., heath aster

(=A. multiflorus)

Perennial herb. Infrequent along roadsides and about disturbed sites.

Hastings 208 (FHKSC), McGregor 37792 (KANU)

Aster lanceolatus Willd.

Perennial herb. Infrequent and scattered along edges of pools in late summer.

McGregor 37778 (KANU)

Aster subulatus Michx. var. ligulatus Shinners, annual saltmarsh aster

(=A. exilis of reports)

Annual. Abundant in summer on drying alkali flats. Forming dense colonies.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 215 (FHKSC), Stephens 50731 (KANU)

Baccharis salicina T. & G., willow baccharis

Shrub. Scattered on alkali flats. Prefers areas periodically flooded but does not withstand permanent water.

Bio. Sci. FHKSC s.n. (CBOT), Willems 114 (FHKSC)

Bidens frondosa L., devil's beggartick

Annual. Infrequent along exposed margins of pools, wet flats, and along ditches.

McGregor 37822 (KANU)

Bidens comosa (A. Gray) Wieg., leafybract beggartick

(=B. tripartiata)

Annual. Infrerquent at edges of pools on open flats.

Hastings 220 (FHKSC)

Cirsium undulatum (Nutt.) Spreng.

Perennial herb. Scattered in pastures and prairies, occasionally on roadbanks.

Bio. Sci. FHKSC s.n. (CBOT, FHKSC)

Cirsium vulgare (Savi) Ten., bull thistle

Biennial. Infrequent on roadsides and in overgrazed pastures.

Naturalized from Europe.

Brooks 17518 & Laushman (KANU)

Conyza canadensis (L.) Cronq., horsetail

Annual. Scattered to abundant in disturbed sites or along roadbanks.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 216 (FHKSC)

Coreopsis tinctoria Nutt., plains coreopsis

Annual. Abundant in open ditches especially where water may have stood in the early season.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17547 & Laushman (KANU)

Erectites hieracifolia (L.) Raf. ex DC., American burnweed

Annual. Infrequent on low moist flats or along edges of cattail areas.

McGregor 37837 (KANU)

Erigeron strigosus Muhl., daisey fleabane

(=E. racemosus)

Perennial herb. Scattered in disturbed sites, especially pastures and sometimes on saltgrass flats.

Sonnenberg 93 (CBOT)Hastings 24 (FHKSC)

Grindelia squarrosa (Pursh) Dunal var. squarrosa, curlycup gumweed

Biennial. Occasional along roads or other open, disturbed sites.

Sonnenberg 184 (CBOT)

Haplopappus ciliatus (Nutt.) DC., wax goldenweed

(=Prionopsis ciliata)

Annual. Scattered to common in open sandy areas, disturbed sites, and pastures.

Bio. Sci. FHKSC s.n. (CBOT, FHKSC)

Helianthus annuus L., common sunflower

Annual. Scattered in disturbed sites, ditches, ravines, and along roadbanks.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17520 & Laushman (KANU)

Helianthus ciliaris DC., Texas blueweed

Perennial herb. Known from a single large colony located on a dike. Native south of this region and probably introduced here.

McGregor 31130 (KANU)

Helianthus petiolaris Nutt., prairie sunflower

Annual. Common in disturbed sites, ditches, ravines and along roadbanks.

Sonnenberg 147 (CBOT)

Heterotheca latifolia Buckl. var. macgregoris Wagenkn., camphorweed

Annual. Infrequent to locally common in open, sandy, usually disturbed sites.

McGregor 33795 (KANU)

Iva annua L., annual sumpweed

(=I. ciliata)

Annual. Scattered to common along margin of pools, along ditches, and other disturbed, periodically flooded sites.

Hastings 217 (FHKSC)

Kuhnia eupatorioides L. var. corymbulosa T. & G., false boneset

Perennial herb. Infrequent in pastures, prairies, and along roadsides.

Hastings 88 (FHKSC), McGregor 37840 (KANU)

Lactuca canadensis L., Canada lettuce

Biennnial. Scattered in low moist areas, ditches or sides of dikes.

Sonnenberg (1961) reported but no specimen evidence found.

Lactuca ludoviciana (Nutt.) Ridd., Louisiana wild lettuce

Biennial. Scattered in low, moist ground.

Bio. Sci. FHKSC 23 (CBOT), Hastings 221 (FHKSC)

Lactuca serriola L., prickly wild lettuce

(=L. scariola)

Biennial. Common to abundant in disturbed sites and along roadbanks.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17543 & Laushman (KANU)

Pluchea odorata (L.) Cass., camphorweed

(=P. camphorata of reports)

Perennial herb.cattered along margins of pools in moist soil.

Brooks 14465 (KANU)

Pyrrhopappus grandiflorus Nutt., tuber false dandelion

Perennial. Uncommon on dikes.

Bio. Sci. FHKSC s.n. (CBOT)

Ratibida columnifera (Nutt.) Woot. & Standl., upright prairie coneflower

Perennial. Scattered in prairies and pastures or on sandy roadsides.

Bio. Sci. FHKSC s.n. (CBOT)

Solidago canadensis L. var. scabra T. & G., Canada goldenrod

(=S. canadensis var. gilvocanescens)

Perennial herb. Scattered in prairies, pastures, and disturbed sites; often associated with low-lying areas.

Hastings 218 (FHKSC)

Sonchus asper (L.) Hill, sow thistle

Biennial. Locally common or scattered along dikes, in waste areas, or in moist soil along pools.

Brooks 17522 & Laushman (KANU)

Taraxecum officinale Weber, dandelion

Perennial. Disturbed ground.

Bio. Sci. FHKSC s.n. (CBOT)

Thelesperma megapotamicum (Spreng.) O. Ktze., slender greenthread

Perennial herb. Infrequent along sides of dikes, scattered in prairies.

McGregor 37830 (KANU)

Tragopogon dubius (L.) Scop., western salsify

(=T. pratensis of reports)

Biennial. Common in sandy, disturbed sites.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17539 & Laushman (KANU)

Vernonia fasciculata Michx., western ironweed

Perennial. Common to abundant in depressions on spikesedge or wheatgrass flats; occasionally along margins of pools.

Bio. Sci. FHKSC 30 (CBOT)

Xanthium strumarium L., cocklebur

Annual. Common to abundant in low areas, especially along pools and ditches.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 86 (FHKSC)

Boraginaceae, Borage Family

Heliotropium curassavicum L., wild heliotrope

Perennial herb. Scattered to locally abundant in late summer on drying alkali flats. Waterfowl food resource?

Bio. Sci. FHKSC s.n. (CBOT), Brooks 14467 (KANU)

Brassicaceae, Mustard Family

Capsella bursa-pastoris (L.) Medic., shepherd's purse

Annual. Occasional in weedy sites. Introduced from Europe.

Bio. Sci. FHKSC s.n. (CBOT)

Descurania pinnata (Walt.) Britt. var. brachycarpa (Richs.) Fern., tansey mustard

Annual. Scattered or in local, dense populations on roadsides, banks, or in pastures.

Hastings 18 (FHKSC)

Descurania sophia (L.) Webb ex Prantl, flixweed

Annual. Scattered to abundant in disturbed ground in spring.

Bio. Sci. FHKSC s.n. (CBOT), Stephens 55197 (KANU)

Erysimum repandum L., spreading erysimum

Annual. Infrequent weed; introduced from Europe.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 18114 & Kuhn (KANU)

Lepidium densiflorum Schrad., peppergrass

Annual. Scattered along roadsides or other exposed, dry, disturbed sites.

Bio. Sci. FHKSC 29 (CBOT), Brooks 18088 (KANU)

Lepidium oblongum Small, peppergrass

Annual or biennial. Occasional along roadsides, on drying flats, or other disturbed sites.

Brooks 18111 (KANU)

Rorippa palustris (L.) Bess. subsp. glabra (Schulz) Stuckey

Annual. Infrequent to common in summer and fall on mud flats or along edge of water in exposed areas.

Brooks 18084 (KANU)

Rorippa sinuata (Nutt.) Hitchc., spreading yellowcress

Annual. Locally common in low poorly drained sites.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 18113 & Kuhn (KANU)

Thlaspi arvense L., pennycress

Annual. Scattered to locally common in disturbed ground. Introduced from Europe.

Bio. Sci. FHKSC s.n. (CBOT)

Cactaceae, Cactus Family

Opuntia macrorhiza Engelm., prickly-pear cactus

Perennial. Occasional on wheatgrass flats or in prairies or pastures.

Bio. Sci. FHKSC 34 (CBOT)

Cannabaceae, Hemp Family

Cannabis sativa L. var. *spontanea* Vavilov, wild hemp

Annual. Infrequent in disturbed sites.

McGregor 37845 (KANU)

Capparaceae, Caper Family

Polanisia dodecandra (L.) DC. subsp. *trachysperma* (T. & G.) Iltis, clammyweed

(=*P. trachysperma*)

Annual. Scattered in open, sandy sites.

Bio. Sci. FHKSC s.n. (CBOT)

Chenopodiaceae, Goosefoot Family

Atriplex argentea Nutt., silverscale saltbush

Annual. Scattered on alkali flats in late summer and fall.

Bio. Sci. FHKSC 45 (CBOT), Hulbert s.n. (KSC)

Atriplex subspicata (Nutt.) Rydb., spearscale

(=*A. hastata* and *A. patula* of reports)

Annual. Common on drying alkaline flats in late summer.

Brooks 17544 & Laushman (KANU), Rydberg & Imler 1294 (KSC)

Chenopodium berlandieri Moq. var. *zschackei* (Murr.) Murr., pitseed goosefoot

(=*C. album* of reports)

Annual. Common in late summer and fall in disturbed sites, especially in dried pools.

Hastings 76 (FHKSC), Stephens 50751 (KANU)

Chenopodium dessicatum A. Nels., desert goosefoot

Annual. Scattered along dikes, on drying mudflats, or disturbed sites.

Stephens 55194 (KANU)

Chenopodium glaucum L., oak-leaved goosefoot

Annual. Common on drying alkaline flats in late summer.

Brooks 14471 (KANU)

Chenopodium missouriense Aellen, Missouri goosefoot

Annual. Infrequent at edges of pools.

McGregor 37841 (KANU)

Chenopodium pratericola Rydb.

(=C. albescens of reports)

Annual. Infrequent in disturbed sites.

Bio. Sci. FHKSC s.n. (FHKSC)

Chenopodium rubrum L., red goosefoot

Annual. Infrequent in moist to wet areas among cattails and rushes.

Weakly naturalized from Europe.

Brooks 14472 & McGregor (KANU)

Cycloloma atriplicifolium (Spreng.) Coult., winged pigweed

Annual. Infrequent in disturbed, sandy sites.

Bartholomew 1283 (FHKSC)

Kochia scoparia (L.) Schrad.

Annual. Scattered to abundant, often forming dense colonies on alkaline flats, along roadsides, in fields, or other disturbed sites. Naturalized from Eurasia.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17542 & Laushman (KANU)

Salsola collina Pall., Russian thistle

Annual. Scattered along roadside banks, pastures, alkaline flats, or other disturbed sites. Naturalized from Eurasia.

Salsola iberica Senn. & Pau, Russian thistle

(-S. kali of reports)

Annual. Scattered to common along roadside banks, pastures, alkaline flats, or other disturbed sites. Naturalized from Eurasia.

Bio. Sci. FHKSC 41 (CBOT)

Suaeda depressa (Pursh) S. Wats., sea-blite

(=S. calceoliformis)

Annual. Common to abundant on drying alkaline mud flats in summer.

Hastings 227 (FHKSC)

Commelinaceae, Spiderwort Family

Tradescantia bracteata Small, bracted spiderwort

Perennial herb. Scattered in prairies, especially sandy soil.

Hastings 236 (FHKSC)

Convolvulaceae, Morning Glory Family

Calystegia macounii (Greene) Brummitt, hedge bindweed

(=Convolvulus sepium of CB reports)

Perennial herb. Locally common in disturbed sites and fields.

Bio. Sci. FHKSC s.n. (CBOT)

Convolvulus arvensis L., field bindweed

Perennial herb. May form extensive colonies in fields and along roadsides.

Reported by Sonnenberg (1961), but no specimen evidence found.

Cucurbitaceae, Gourd Family

Cucurbita foetidissima H. B. K., buffalo gourd

Perennial. Scattered on exposed, sandy banks, especially along roads or ditches.

Sonnenberg 103 (CBOT)

Cupressaceae, Cypress Family

Juniperus virginiana L., red cedar

Small tree. Occasionally found in pastures, prairies, or ravines.

Brooks 18079 (KANU)

Cuscutaceae, Dodder Family

Cuscuta indecora Choisey, large alfalfa dodder

Annual. Parasitic on a variety of vegetation, infrequent to common.

Bio. Sci. FHKSC 7 (CBOT)

Cyperaceae, Sedge Family

Carex brevior (Dewey) Mack., straw sedge

Perennial herb. Infrequent along ditches.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 18118 & Kuhn (KANU)

Carex gravida Bailey var. *gravida*

(=*C. vulpinoidea* of reports)

Perennial. Locally scattered along ditches and edges of pools.

Hastings 122 (FHKSC), Hastings 16 (FHKSC)

Carex gravida Bailey var. *lunelliana* (Mack.) Herm.

Perennial herb. Locally common along ditches and edges of pools.

Carex laeviconica Dewey, smoothcone sedge

Perennial herb. Locally common to abundant, forming colonies along water courses.

Brooks 18119 & Kuhn (KANU)

Cyperus acuminatus T. & H., tapeleaf sedge

Annual. Locally common to scattered on drying flats in late summer.

Bio. Sci. FHKSC s.n. (CBOT)

Cyperus lupulinus (Spreng.) Marcks subsp. lupulinus

(=C. filiculmis of Kansas reports)

Perennial herb. Scattered to infrequent in low prairies, pastures or alkali flats.

Goodrow s.n. (FHKSC), Hastings 137 (FHKSC)

Cyperus odoratus L., slender flatsedge

Annual. Scattered to locally common in late summer in depressions on flats or wet, disturbed sites.

Hastings 222 (FHKSC), Goodrow s.n. (FHKSC)

Eleocharis acicularis (L.) R. & S., needle spikesedge

Annual. Diminutive plant, but one that ofen carpets wet areas among or bordering cattail/bulrush colonies.

Bio. Sci. FHKSC s.n. (FHKSC)

Eleocharis obtusa (Willd.) Schult. var. ovata (Roth) Drap. & Mohl., blunt spikesedge

(=E. engelmannii)

Annual. Locally common in moist, usually sandy sites.

Reynolds s.n. (KANU)

Eleocharis parvula (R. & S.) Link ex Buff. & Fingerh. var. anachaeta Torr.) Svens.

Annual. Scattered on drying mud flats in mid-summer, especially at edges of Typha beds.

Hastings 197 (FHKSC)

Eleocharis xyridiformis Fern & Brack., spikesedge

(=E. palustris in part)

Perennial herb. Abundant in spring on wet saltgrass flats. The fruit borne in late spring is considered a food resource for ducks.

Sonnenberg 164 (FHKSC), Brooks 17462 (KANU)

Scirpus acutus Muhl. ex Bigelow, bulrush

Perennial herb. Scattered and forming dense colonies in shallow water.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17534 & Laushman (KANU)

Scirpus fluviatilis (Torr.) A. Gray, river bulrush

Perennial herb. Scattered in local dense colonies, either in shallow water or in ditches.

Bio. Sci. FHKSC 48 (CBOT), Brooks 17461 (KANU)

Scirpus heterochaetus Chase, slender bulrush

Perennial herb. Infrequent in dense colonies in shallow water.

Bio. Sci. FHKSC s.n. (CBOT, KANU), M. Stone s.n. (KSC)

Scirpus maritimus L. var. paludosus (A. Nels.) Kukenth., alkali bulrush

Perennial herb. Common on alkali flats with poor drainage; sometimes in very shallow standing water.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17461 (KANU)

Scirpus pungens Vahl, American bulrush

(=S. americanus of reports)

Perennial herb. Widely scattered on saltgrass flats.

Bio. Sci. FHKSC s.n. (CBOT), Sonnenberg 83 (FHKSC)

Elaeagnaceae, Russian Olive Family

Elaeagnus angustifolia L., Russian olive

Small tree. Scattered, especially on low sandy ground. Naturalized from Eurasia.

R. E. Brooks 18080 (KANU), Hastings 142 (FHKSC)

Euphorbiaceae, Spurge Family

Croton texensis (Kl.) Muell. Arg. ex DC., Texas croton

Annual. Infrequent along dikes.

McGregor 37835 (KANU)

Euphorbia dentata Michx., toothed spurge

Annual. Scattered in disturbed sites.

Bio. Sci. FHKSC 10 (CBOT), Hastings 180 (FHKSC)

Euphorbia glyptosperma Engelm., ridge-seed spurge

Annual. Scattered to common in open disturbed sites, espcially roadsides or sometimes drying pool beds.

Hastings 193 (FHKSC)

Euphorbia hexagona Nutt. ex Spreng., six-angled spurge

Annual. Infrequent in exposed, sandy sites.

McGregor 37838 (KANU)

Euphorbia maculata L., spotted spurge

Annual. Scattered in disturbed sites.

Bio. Sci. FHKSC 3 (CBOT), Hastings 239 (FHKSC)

Euphorbia marginata Pursh, snow-on-the-mountain

Annual. Scattered to abundant in pastures or exposed prairie ravines.

Brooks 17556 & Laushman (KANU), Stephens 50733 (KANU)

Euphorbia prostrata Ait.

Annual. Open, often disturbed ground, native of the West Indies.

Bio. Sci. FHKSC 2 (CBOT)

Euphorbia serpens H.B.K., round-leaved spurge

Annual. Scattered to common in open disturbed sites.

Bio. Sci. FHKSC 69 (FHKSC)

Euphorbia spatulata Lam.

Annual. Infrequent in disturbed areas.

Hastings 26 (FHKSC)

Euphorbia stictospora Engelm.

Annual. Scattered in disturbed areas.

Bio. Sci. FHKSC 6 (FHKSC)

Fabaceae, Legume Family

Amorpha canescens Pursh, lead plant

Perennial. Scattered in prairies or infrequently on roadside banks.

Hastings (1970) reported this plant but no specimen evidence has been located.

Amorpha fruticosa L., false indigo

Shrub. Scattered along waterways and occasionally at dike-pool interface.

Stephens 50750 (KANU)

Astragalus lotiflorus Hook., lotus milk-vetch

Perennial. Infrequent on gravelly banks in prairies.

Schwilling s.n. (CBOT)

Astragalus missouriensis Nutt., Missouri milk-vetch

Perennial. Infrequent on gravelly banks in prairies.

Schwilling s.n. (CBOT), Bowman 2 (FHKSC)

Astragalus mollissimus Torr., woolly milk-vetch

Reports were based on specimens of A. missouriensis.

Desmanthus illinoensis (Michx.) MacM., Illinois bundleflower

Perennial. Infrequent on roadbanks or in prairies or pastures.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17565 & Laushman (KANU)

Desmanthus leptolobus T. & G.

Perennial. Infrequent in prairies or pastures.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 240 (FHKSC)

Glycyrrhiza lepidota Pursh, wild licorice

Perennial. Infrequent or in local colonies on dry banks or in pastures.

Sonnenberg 46 (CBOT)

Medicago sativa L., alfalfa

Perennial. Infrequent in pastures or along roads. Adventive or weakly naturalized from Old World.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 183 (FHKSC)

Melilotus alba Desr., white sweetclover

Annual or biennial. Scattered along roadsides, in fields, and waste places. Naturalized from Europe.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17519 & Laushman (KANU)

Melilotus officinalis (L.) Lam., yellow sweetclover

Annual or biennial. Scattered to common along roadsides, in fields, and waste places. Naturalized from Europe.

Bio. Sci. FHKSC s.n. (CBOT)

Vicia americana Muhl. ex Willd. var. minor Hook., C. R. Gunn

Perennial. Infrequent in sandy, exposed pastures or prairies.

Schwilling s.n. (CBOT)

Juncaceae, Rush Family

Juncus interior Wieg., inland rush

(=J. dudleyi of CB reports)

Perennial herb. Scattered to infrequent along edges of pools or on saltgrass flats.

R. E. Brooks 18089 (KANU), Bio. Sci. FHKSC s.n. (CBOT)

Juncus torreyi Cov., Torrey's rush

Perennial herb. Common in ditches or locally at edges of pools.

R. E. Brooks 18083 (KANU)

Juncaginaceae, Arrowgrass Family

Triglochin maritima L., arrowgrass

Perennial herb. Uhler (1929) reported this species as occurring along the south side of the Bottoms, apparently in spikesedge depressions; no specimen evidence has been found.

Lemnaceae, Duckweed Family

Lemna minor L., common duckweed

Perennial. Free floating, commonly found in still water among cattail or rushes.

Brooks 17566 & Laushman (KANU), McGregor 37783 (KANU)

Spirodela polyrrhiza L., giant duckweed

Perennial herb. Free-floating and infrequent to abundant especially in quiet water among emergent vegetation. Available from summer until frost and utilzed as food, perhaps because of the proponderance of microscopic life usually associated with their root zone.

Brooks 17567 & Laushman (KANU)

Lentibulariaceae, Bladderwort Family

Utricularia vulgaris L., common bladderwort

Annual. Infrequent and growing submersed among cattails or reeds, protected from wave action.

Bio. Sci. FHKSC s.n. (CBOT, FHKSC), Sonnenberg 44 (FHKSC)

Liliaceae, Lily Family

Allium perdulce S. V. Fraser

Perennial herb. Infrequent in prairies and pastures.

Schwilling s.n. (CBOT)

Smilacina stellata (L.) Desf., starry false Solomon's seal

Perennial herb. Infrequent in thickets or shaded ravines.

Schwilling s.n. (CBOT)

Linaceae, Flax Family

Linum compactum A. Nels., compact stiffstem flax

Annual. Infrequent in wheatgrass flats.

Rydberg & Imler 1287 (KSC)

Lythraceae, Loosestrife Family

Ammannia coccinea Rottb.

Annual. Local on exposed mud flats.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17549 & Laushman (KANU)

Ammannia robusta Herr. & Regal, purple ammannia

Annual. Locally common on exposed mud flats.

Brooks 17548 & Laushman (KANU)

Lythrum californicum T. & G., California loosestrife

Perennial. Along ditches or other low, poorly drained areas, usually scattered among other vegetation.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17540 & Laushman (KANU)

Malvaceae, Mallow Family

Abutilon theophrasti Medic., velvet-leaf

Annual. Infrequent on dried bed of pool. Naturalized from India.

W. Hoffmann s.n. (KANU)

Callirhoe involucrata (T. & G.) A. Gray, purple poppy mallow

Perennial. Scattered in prairies, pastures, or along roadbanks.

Sonnenberg 92 (CBOT, FHKSC)

Molluginaceae, Carpetweed Family

Mollugo verticillata L., carpetweed

Annual. Abundant in mid and late summer on drying mud flats, fallow ground, and open disturbed sites. Naturalized from tropical America.

Hastings 49 (FHKSC)

Najadaceae, Naiad Family

Najas guadalupensis (Spreng.) Morong., southern naiad

Perennial herb. Infrequent to locally common; submersed in shallow, calm water.

Hoffman s.n. (KANU)

Nyctaginaceae, Four-o'clock Family

Mirabilis nyctaginea (Michx.) MacM., wild four-o'clock

(=Allonia nyctaginea)

Perennial herb. Scattered along roadsides and ditches.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 19 (FHKSC), Stephens 55189 (KANU)

Mirabilis linearis (Pursh) Heimerl, narrowleaf four-o'clock

Perennial herb. Infrequent on wheatgrass flats and roadside banks.

Bio. Sci. FHKSC 33 (CBOT), McGregor 37846 (KANU)

Oleaceae, Olive Family

Fraxinus pennsylvanica Marsh. var. subintegerrima (Vahl) Fern., green ash

Tree. Occasional on dike faces or along water courses.

Stephens 55203 (KANU)

Onagraceae, Primrose Family

Gaura parviflora Dougl., velvet gaura

Biennial. Scattered on roadsides and ditches.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17538 & Laushman (KANU)

Oenothera laciniata Hill, cutleaf evening primrose

Annual. Scattered to locally common in sandy soil of disturbed sites or roadsides.

Oenothera villosa Thunb.

Biennial. Scattered in ditches, along roads, and other occasionally wet areas.

Sonnenberg 190 (CBOT)

Oxalidaceae, Wood Sorrel Family

Oxalis dillenii Jacq., green wood sorrel

(=O. stricta of reports)

Annual. Weedy sites, infrequent.

Bio. Sci. FHKSC 8 (CBOT)

Papaveraceae, Poppy Family

Argemone polyanthemos (Fedde) G. Ownby, prickly poppy

Perennial herb. Occasional in well-drained, prairies or exposed roadbanks.

Hastings 41 (FHKSC)

Pedaliaceae, Pedalium Family

Proboscidea louisianica (Mill.) Thell., devil's claw

Annual. Locally common in cultivated fields or disturbed sites.

Bio. Sci. FHKSC s.n. (CBOT)

Plantaginaceae, Plantain Family

Plantago elongata Pursh

Annual. Infrequent in depressions on wheatgrass/saltgrass flats.

Brooks 18117 & Kuhn (KANU)

Poaceae, Grass Family

Agropyron cristatum (L.) Gaertn., crested wheatgrass

(=A. desertorum of reports)

Perennial. Scattered on roadsides or in revegetated areas. Naturalized from Eurasia.

Hastings 65 (FHKSC)

Agropyron elongatum (Host) Beauv., tall wheatgrass

Perennial. Infrequent along roadsides. Introduced from Eurasia.

Brooks 17563 & Laushman (KANU)

Agropyron smithii Rydb., western wheatgrass

Perennial. Common on roadsides and in pastures.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17533 & Laushman (KANU)

Agrostis hyemalis (Walt.) B.S.P.

Annual. Scattered in wheatgrass and spikesedge flats.

Bio. Sci. FHKSC 36 (CBOT), Bartholomew 1293 (KSC)

Alopecurus carolinianus Walt., Carolina foxtail

Annual. Common on saltgrass flats in spring.

Brooks 17463 (KANU)

Andropogon bladhii Retz., Caucasian bluestem

Perennial. Infrequent along roadsides. Introduced from Eurasia.

Brooks 17532 & Laushman (KANU)

Andropogon gerardii Vit., big bluestem

Perennial. Local and scattered on roadbank and in drained prairies.

Hastings 233 (FHKSC)

Andropogon hallii Hack., sandhill bluestem

Perennial. Local in sandy soil on banks or in pastures.

Brooks 17558 & Laushman (KANU)

Andropogon saccharoides Sw. var. torreyana (Steud.) Gould., silver bluestem

Perennial. Sandy soil of roadbanks and disturbed grasslands.

Bio. Sci. FHKSC s.n. (CBOT), Sonnenberg 97 (FHKSC)

Andropogon scoparius Michx., little bluestem

Perennial. Scattered in prairie pastures, occasionally on wheatgrass flats.

Bio. Sci. FHKSC 151 (CBOT)

Aristida longispica Poir., slimspike threeawn

(=A. intermedia)

Perennial. Local in prairie pastures.

Hastings 231 (FHKSC)

Aristida oligantha Michx., prairie threeawn

Annual. Scattered to locally common in open, abused sites.

McGregor 37823 (KANU)

Bouteloua curtipendula (Michx.) Torr., side-oats grama

Perennial. Scattered to common on roadbanks or in pastures and prairies.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17531 & Laushman (KANU)

Bouteloua gracilis (Willd. ex H.B.K.) Lag. ex Griffiths, blue grama

Perennial. Occasional in prairies, especially on gravelly slopes.

Bio. Sci. FHKSC s.n. (CBOT)

Bromus inermis Leyss., smooth brome

Perennial. Scattered to locally common on banks. Introduced from Europe.

Bromus japonicus Thunb., Japanese brome

Annual. Common in pastures, disturbed sites, and along roads.

Naturalized from Eurasia.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17525 & Laushman (KANU)

Bromus tectorum L., downy brome

Annual. Abundant along roads, in fields and pastures and other disturbed sites. Naturalized from Eurasia.

Bio. Sci. FHKSC s.n. (CBOT)

Buchloe dactyloides (Nutt.) Engelm., buffalo grass

Perennial. Scattered to locally common in dry prairies.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 146 (FHKSC)

Cenchrus longispinus (Hack.) Fern., sandbur

Annual. Common along roads and in other disturbed sandy sites.

Bio. Sci. FHKSC s.n. (CBOT)

Chloris verticillata Nutt., windmill grass

Perennial. Scattered in disturbed sites, including pastures.

Bio. Sci. FHKSC 11 (CBOT, FHKSC)

Cinna arundinacea L., stout woodreed

Perennial. Local in moist soil, especially along ditches or at edges of pools.

Reported by Hastings (1970), but specimen evidence lacking.

Cynodon dactylon (L.) Pers., Bermuda grass

Perennial. Scattered in disturbed areas and some low pastures.

Naturalized from the Old World tropics.

Bio. Sci. FHKSC 20 (CBOT), Hastings 73 (FHKSC)

Digitaria ischaemum (Schreb. ex Schweigg.) Schreb. ex Muhl., smooth crabgrass

Annual. Disturbed, usually sandy sites.

McGregor 37827 (KANU)

Digitaria sanguinalis (L.) Scop., crabgrass

Annual. Local in disturbed sites. Naturalized from Europe.

Sonnenberg (1961) reported, but specimen evidence lacking.

Distichlis spicata (L.) Greene var. stricta (Torr.) Beetle, saltgrass

Perennial. Abundant on poorly drained alkali flats. Saltgrass is a dominant component of the plant community found on alkali flats that are infrequently subjected to flooding.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17459 (KANU)

Echinochloa crusgalli (L.) Beauv. var. crusgalli, barnyard grass

Annual. This native plant is very similar to jungle-rice and in the fall produces large quantities of seed utilized by waterfowl. It occurs on flats that experience flooding in the early season or are poorly drained to the point that species such as saltgrass are excluded.

Rydberg & Imler 1290 (KSC)

Echinochloa crusgalli (L.) Beauv. var. frumentacea (Roxb.) Wright, Japanese millet

Annual. Native to southeastern Asia and widely cultivated in the United States. Seeded in the Bottoms yearly to provide additional food resources for waterfowl.

Bio. Sci. FHKSC 46 (CBOT)

Echinochloa crus-pavonis (H.B.K.) Schult. var. macer (Wieg.) Gould (=E. colona of reports)

Annual. Widely scattered in low moist areas. Where abundant this grass can provide an important food resource for waterfowl in late summer and fall.

Rydberg & Imler 1290 (KSC)

Echinochloa muricata (Beauv.) Fern. var. microstachya Wieg., barnyard grass

Annual. This native is similar to E. crusgalli and is by far the more common species in the area.

Brooks 17562 & Laushman (KANU)

Elymus canadensis L., Canada wild-rye

Perennial. Scattered on roadbanks, along ditches, or in ravines.

Sonnenberg 124 (CBOT), Brooks 17545 & Laushman (KANU)

Elymus virginicus L., Virginia wild-rye.

Perennial. Scattered to common on roadbanks, in ditches, or ravines.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17552 & Laushman (KANU)

Eragrostis cilianensis (All.) E. Mosher, stinkgrass.

Annual. Locally common in disturbed, exposed sites. Naturalized from Europe.

Sonnenberg 51 (CBOT), Brooks 17564 & Laushman (KANU)

Eragrostis pectinacea (Michx.) Nees, Carolina lovegrass

Annual. Common along roadsides or scattered in dried pool beds.

Stephens 50741 (KANU)

Eragrostis reptans (Michx.) Nees, creeping lovegrass

Annual. Locally common in late summer on drying flats, usually sandy soil.

Hastings 210 (FHKSC)

Eragrostis spectabilis (Pursh) Steud., purple lovegrass

Perennial. Occasional along margins of ditches, in prairie pastures, or along roadsides.

Bio. Sci. FHKSC 17 (CBOT), McGregor 37834 (KANU)

Eriochloa contracta Hitchc., prairie cupgrass

Annual. Locally common in moist, open ground. This native produces fruit in the fall such that where common it probably is utilized by waterfowl that feed on such food.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17559 & Laushman (KANU)

Festuca arundinacea Schreb., tall fescue

Perennial. Locally common to scattered. Introduced from Europe.

Hordeum jubatum L., foxtail barley

Annual. Abundant on wet saltgrass flats in spring and along roadsides and ditches.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17465 (KANU)

Hordeum pusillum Nutt., little barley

Annual. Common on waste ground, normally in drier situations than foxtail barley.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 18110 & Kuhn (KANU)

Leptochloa fascicularis (Lam.) A. Gray, bearded sprangletop

(=L. uninerva)

Annual. Local to abundant in fall on drying, usually sandy, flats.

Bio. Sci. FHKSC s.n. (CBOT), Sonnenberg 64 (FHKSC)

Leptoloma cognatum (Schult.) Chase

Perennial. Margins of pools, ditches or along roadsides.

Bio. Sci. FHKSC 37 (CBOT)

Muhlenbergia asperifolia (Nees & Mey.) Parodi, scratchgrass

Perennial. Saltgrass/wheatgrass flats, scattered.

McGregor 37824 (KANU)

Panicum capillare L., common witchgrass

Annual. Local to abundant in disturbed sites.

Hastings 211 (FHKSC), Stephens 50737 (KANU)

Panicum dichotomiflorum Michx., fall panicum

Annual. Scattered in moist ground, especially along ditches in area.

Large stands can provide shelter and a food resource in the late summer and fall.

Goodrow 88 (CBOT), Flowers 354 (FHKSC), Stephens 50743 (KANU)

Panicum hillmanii Chase, Hillman's witchgrass

Annual. Infrequent on roadsides.

McGregor 33509 (KANU)

Panicum virgatum L., switchgrass

Perennial. Scattered in low prairies and along roadsides.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17529 & Laushman (KANU)

Paspalum setaceum Michx. var. stramineum (Nash) Banks, sand paspalum

Perennial. Occasional in sandy pastures or prairies.

Sonnenberg 145 (CBOT)

Phlaris arundinacea L., reed canarygrass

Perennial. Local but sometimes forming extensive, nearly exclusive stands in ditches or low areas.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17528 & Laushman (KANU)

Poa arida Vasey, plains bluegrass

Perennial. Scattered on saltgrass flats in late spring and early summer.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 18120 & Kuhn (KANU)

Polypogon monspeliensis (L.) Desf., rabbitfoot polypogon

Annual. Local and scattered at edges of open ditches, or along margins of marsh or around depressions on salt flats. Naturalized from Europe.

Hastings 68 (FHKSC)

Schedonnardus paniculatus (Nutt.) Trel., tumblegrass

Perennial. Local in disturbed sites including roadsides and pastures.

Bio. Sci. FHKSC s.n. (CBOT), Sonnenberg 81 (FHKSC), Stephens 50741 (KANU)

Setaria geniculata (Lam.) Beauv., knotroot bristlegrass

Perennial. Infrequent along road dikes.

Stephens 50739 (KANU)

Setaria glauca (L.) Beauv., yellow foxtail

(=S. lutescens)

Annual. Common in disturbed areas such as along roads or cultivated areas. Naturalized from Eurasia.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17561 & Laushman (KANU)

Setaria viridis (L.) Beauv., green foxtail

Annual. Common in disturbed, open sites. Naturalized from Europe.

Sonnenberg 173 (CBOT), Hastings 185 (FHKSC), Stephens 50740 (KANU)

Sitanion hystrix (Nutt.) J.G. Sm. var. brevifolius (J.G. Sm.) C. L. Hitchc., squirreltail

Perennial. Scattered in dry prairies.

Sorghum halepense (L.) Pers., Johnsongrass

Perennial. Scattered in ditches, along roads or adjacent to cultivated areas. Naturalized from Eurasia.

Spartina pectinata Link, prairie cordgrass

Perennial. Local in ditches or prairie depressions. May form extensive colonies suitable for waterfowl shelter.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17535 & Laushman (KANU)

Sphenopholis obtusata (Michx.) Scribn., prairie wedgegrass

Annual. Scattered on saltgrass flats or along margins of pools.

Sonnenberg 43 (CBOT)

Sporobolus airoides (Torr.) Torr., alkali sacaton

Perennial. Infrequent on alkali flats.

Bio. Sci. FHKSC 39 (CBOT, FHKSC)

Sporobolus asper (Michx.) Kunth var. asper, rough dropseed

Perennial. Scattered along roadsides or occasional in prairies.

McGregor 37798 (KANU)

Sporobolus cryptandrus (Torr.) A. Gray, sand dropseed

Perennial. Scattered in dry, often disturbed sandy sites, especially pastures and roadsides.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 232 (FHKSC)

Sporobolus neglectus Nash, puffsheath dropseed

Annual. Disturbed sites, especially pastures and roadsides.

Sonnenberg 117 (CBOT)

Polygonaceae, Buckwheat Family

Polygonum amphibium L. var. emersum Michx., swamp smartweed

(=P. coccineum)

Perennial. Scattered and forming colonies in low areas especially along dikes or edges of pools; may be in water also.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17537 & Laushman (KANU)

Polygonum arenastrum Jord., prostrate knotweed

Annual. Common weed of open, disturbed sites, especially roadsides and parking areas. Naturalized from Europe.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 152 (FHKSC)

Polygonum bicorne Raf., longstyle smartweed

(=P. longistylum)

Annual. Common in ditches along edges of pools. Where sufficient stands occur this species will provide food in the fall for waterfowl.

Bio. Sci. FHKSC 21 (CBOT), Brooks 17555 & Laushman (KANU)

Polygonum hydropiper L., water pepper smartweed

Annual. Infrequent in moist soil of ditches or margins of pools.

Brooks 17527 & Laushman (KANU)

Polygonum lapathifolium L., pale smartweed

Annual. Scattered to common in damp to wet soils in disturbed areas, ditches, or along canals. Fruit is shed in late summer and sometimes eaten by waterfowl.

Lindstrom 103 (KSC)

Polygonum pensylvanicum L., Pennsylvania smartweed

Annual. Scattered to abundant in low fields, ditches, or other areas with moist soil. Fruit is shed in late summer and sometimes eaten by waterfowl.

Hastings 237 (FHKSC)

Polygonum ramosissimum Michx., bush knotweed

Annual. Common in damp to dry, often alkaline soil of banks, ditches, and other disturbed sites.

Bio. Sci. FHKSC 18 (CBOT), Hastings 223 (FHKSC), Stephens 50748 (KANU)

Rumex altissimus Wood, pale dock

Perennial. Scattered along banks, ditches and occasionally in low areas on saltgrass flats.

Bio. Sci. FHKSC s.n. (CBOT), Hastings 115 (FHKSC), Stephens 55213 (KANU)

Rumex crispus L., curly dock

Perennial. Infrequent in ditches and other low areas. Naturalized from Eurasia.

Hastings 129 (FHKSC)

Rumex stenophyllus Ledeb., narrow-leaved dock

Perennial. Common to abundant in low areas. Naturalized from Eurasia.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17464 (KANU)

Pontederiaceae, Pickerelweed Family

Heteranthera limosa (Sw.) Willd., blue mud plantain

Annual. Infrequent and local. Forming small colonies on open muddy ground or in shallow water.

Schlegel s.n. (FHKSC)

Portulacaceae, Purslane Family

Portulaca oleracea L., common purslane

Annual. Common on drying mud flats and other such disturbed open habitats in mid and late summer. Naturalized from Europe.

Rydber & Imler 1295 (KANU)

Ranunculaceae, Buttercup Family

Anemone caroliniana Walt., Carolina anemone

Perennial. Occasional in prairies or pastures in spring.

Schwilling s.n. (CBOT)

Rosaceae, Rose Family

Prunus virginiana L., choke cherry

Shrub. Infrequently found in thickets along dikes or water courses.

Brooks 18086 (KANU)

Rosa arkansana Porter, prairie rose

Small shrub. Infrequent along roadbanks and in pastures or prairies.

Rubiaceae, Madder Family

Cephalanthos occidentalis L., button bush

Shrub. Occasionally found in ditches or on low flats.

Brooks 17521 & Laushman (KANU

Galium aparine L., catchweed bedstraw

(=G. triflorum of CB reports)

Annual. Infrequent in disturbed areas or along margins of pools.

Brooks 18116 & Kuhn (KANU)

Salicaceae, Willow Family

Populus deltoides Marsh subsp. monilifera (Ait.) Eckenwalder, plains cottonwood

Perennial. Tree of moist ravines or along banks of pools.

Brooks 18123 & Kuhn (KANU)

Salix exigua Nutt. ssp. interior (Rowlee) Cronq., sandbar willow

Shrub forming small to extensive colonies in low areas.

Salix nigra Marsh., black willow

Tree found along water courses or occasionally as a shrub along dikes.

Brooks 18124 & Kuhn (KANU), Lindstrom 117 (KSC)

Salviniaceae, Water Fern Family

Azolla mexicana Presl, mosquito fern

Annual. Periodically abundant in floating, windblown masses, among cattails or rushes, or occasionally stranded on mud in late summer. The plants are incidentally eaten by ducks and other waterfowl.

McGregor 5198 (KANU)

Scrophulariaceae, Figwort Family

Bacopa rotundifolia (Michx.) Wettst., disk water-hyssop

(=Macuillamia rotundifolia)

Annual. Infrequent on usually wet, exposed mud flats.

Sonnenberg 62 (CBOT), Hastings 117 (FHKSC)

Linaria vulgaris P. Mill., butter-and-eggs

Perennial. Side of dike, local.

McGregor (KANU)

Veronica peregrina L. var. xalapensis (H.B.K.) St. John & Warren

Annual. Exposed mud flats, ditches and other moist areas.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 18085 (KANU)

Solanaceae, Nightshade Family

Datura innoxia P. Mill, sacred datura

Annual. Infrequent on dikes, adventive from tropical America.

W. Hoffman s.n. (KANU)

Physalis longifolia Nutt., spearleaf groundcherry

Perennial herb. Scattered on roadbanks and in fields.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17524 & Laushman (KANU)

Physalis pumila Nutt. var. hispida (Waterfall) Hinton

(=P. lanceolata of reports)

Perennial. Scattered on dikes, occasional in pastures.

Stephens 50734 (KANU)

Solanum elaeagnifolium Cav., silverleaf nightshade

Perennial. Occasional along dikes or in pastures.

McGregor 37777 (KANU)

Solanum interius Rydb.

(=S. nigrum of reports)

Annual. Infrequent along ditches, in thickets, or other occasionally disturbed sites.

Hastings 229 (FHKSC)

Solanum rostratum Dun., buffalo bur nightshade

Annual. Scattered in disturbed sites.

Sonnenberg 48 (CBOT), Brooks 17554 & Laushman (KANU)

Sparganiaceae, Bur-reed Family

Sparganium eurycarpum Engelm., giant bur-reed

Perennial. Infrequent on wet ground or in shallow water among other emergent vegetation.

Bio. Sci. FHKSC s.n. (CBOT)

Tamaricaceae, Tamarisk Family

Tamarix ramosissima Ledeb., salt cedar

(=T. gallica, T. pentandra of reports)

Perennial. Shrub propagating by seed and root sprouts to form colonies so dense as to exclude certain wildlife and affect water availability at critical periods.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17526 & Laushman (KANU)

Typhaceae, Cattail Family

Typha angustifolia, narrow-leaf cattail

Perennial herb. Forming extensive colonies along canals and edges of pools. In water to nearly 2 feet deep.

Bio. Sci. FHKSC s.n. (CBOT), Brooks 17536 & Laushman (KANU)

Typha latifolia L., common cattail

Perennial herb. Forming extensive colonies along canals and edges of pools. In water to nearly 2 feet deep.

Bio. Sci. FHKSC s.n. (CBOT)

Ulmaceae, Elm Family

Celtis occidentalis L., hackberry

Tree. Infrequent along fence rows or watercourses.

Stephens 55203 (KANU)

Verbenaceae, Vervain Family

Lippia cuneifolia (Torr.) Steud., wedgeleaf frogfruit

(=Phyla cuneifolia)

Perennial herb. Scattered in colonies in low, exposed areas of pastures, prairies, or along shores of pools.

Hastings 179 (FHKSC)

Lippia lanceolata Michx., lanceleaf frogfruit

Perennial herb. Occasional in moist, broken shade, especially along interface of dikes and pools.

McGregor 37842 (KANU)

Lippia nodiflora (L.) Michx.

Perennial herb. Occasional on mudflats in late summer.

McGregor 37799 (KANU)

Verbena bipinnatifida Nutt., Dakota verbena

Perennial. Scattered in prairies or infrequent along roadsides.

Bio. Sci. FHKSC s.n. (CBOT)

Verbena bracteata Lag. & Rodr., prostrate verbena

Annual. Scattered to common in disturbed sites, especially along roadsides.

Bio. Sci. FHKSC s.n. (CBOT, FHKSC), Stephens 55200 (KANU)

Verbena stricta Vent., woolly verbena

Perennial. Locally common in low pastures or on exposed banks.

Bio. Sci. FHKSC s.n. (CBOT), Sonnenberg 123 (FHKSC)

Vitaceae, Grape Family

Vitis riparia Michx., riverbank grape

Infrequent in brushy areas along water courses.

Stephens 55209 (KANU)

Zygophyllaceae

Tribulus terrestris L., puncture vine

Annual. Scattered on sandy, exposed roadside or other disturbed sites.

Bio. Sci. FHKSC s.n. (CBOT)

CHAPTER 13: INVERTEBRATES

Mark Griffith and Gary Welker

INTRODUCTION

IMPORTANT ASPECTS

When assessing an ecological system, especially one that is capable of being managed, it is imperative that all components of the food web be considered. In a wetland ecosystem, one of the most important elements of the biota is the invertebrate portion. Wetland invertebrates include such organisms as adult insects (both terrestrial and aquatic), insect larvae and nymphs (largely aquatic), zooplankton, other crustaceans, mollusks (snails and clams), and other organisms (e.g., oligochaetes and nematodes). The invertebrate portion of a wetland fauna is typically composed of organisms representative of most trophic roles (i.e. detritivore, herbivore). The invertebrate communities within a wetland lend complexity and diversity to a very dynamic ecosystem.

The invertebrates that occur at Cheyenne Bottoms play an integral role in the functioning and continuation of the Bottoms as a viable wetland ecosystem. Present interests and activities surrounding Cheyenne Bottoms obviously focus on the wetland birds. Cheyenne Bottoms provides critical habitat for both migratory and resident wetland avifauna. Invertebrates provide an important food source for vertebrate omnivores during critical physiological periods (Reid, 1982) such as breeding and migration as well as noncritical dietary maintenance (Kadlec, 1962; Connelly and Chesemore, 1980; Murkin et al., 1982). Since very little information has been collected regarding the invertebrate communities at Cheyenne Bottoms, a preliminary inventory was conducted at various sites throughout the wetland complex to determine the size and structure of the invertebrate communities. The

determination of habitats with maximum invertebrate production and/or highest invertebrate diversity will serve as qualitative/quantitative bases upon which specific management decisions can be founded.

Invertebrates have only recently been recognized to constitute an important part of the diets of wetland birds. The literature addressing invertebrates as a food resource relates mainly to waterfowl (Krull, 1970; Swanson and Meyer, 1977; Taylor, 1978; Connelly and Chesemore, 1980; Kaminski and Prince, 1981; Murkin et al., 1982; Rakstad and Probst, 1982; Nudds and Bowlby, 1984; Armstrong and Nudds, 1985). An abundant supply of invertebrates seems to have an influence on waterfowl use of a wetland habitat. Especially during the breeding season, invertebrates constitute a major portion of waterfowl diet (Swanson and Meyer, 1977; Danell and Sjoberg, 1982; Murkin et al., 1982; Rakstad and Probst, 1982; Nudds and Bowlby, 1984). Immature ducks also rely heavily on invertebrate food resources (Kadlec, 1962; Arner et al., 1974; Rakstad and Probst, 1982). Danell and Sjoberg (1982) indicate that duck production values parallel the changes in value of their main food items during these phases. Arner et al. (1974) focus on the need for animal protein for breeding waterfowl. Aquatic invertebrates typically have a protein content of between 10 and 25% (Krull, 1970).

In addition to the nutritional requirements of breeding waterfowl, the diets of migrating and wintering waterfowl have also been shown to consist of more animal foods than previously thought (Taylor, 1978; Connelly and Chesemore, 1980).

Invertebrates as a food resource must be available in order to be exploited by wetland birds. Three factors essentially determine availability: 1) spatial distribution, 2) temporal succession, and 3) prey-body size. The spatial distribution of invertebrates (where they are found) is addressed in

detail in the following sections that correlate invertebrates and habitat. The temporal succession (how the invertebrate communities change over time) becomes important when considering such seasonal phenomena as migration, reproduction, precipitation, and drought. Due to varying life histories and environmental conditions aquatic invertebrate populations are dynamic over time and typically fluctuate with respect to abundance, biomass, and diversity (Kaminski and Prince, 1981). The various invertebrate populations that Krull (1970) encountered seemed to fluctuate naturally on a weekly basis, leading him to speculate that variability seems to be the rule rather than the exception. However, a general trend seems to indicate a downward seasonal shift in prey size, abundance, and biomass (Mittlebach, 1981; Armstrong and Nudds, 1985).

There is evidence that body-size distributions of aquatic invertebrates correspond to a lognormal curve, and thus these distributions are strongly dominated by small prey (i.e. <2 mm; Mittlebach, 1981). Dabbling ducks seem to partition invertebrate-food resources on the basis of prey size, and these differences in prey sizes utilized are distinct (Nudds and Bowlby, 1984; Armstrong and Nudds, 1985). Prey sizes utilized by dabbling ducks closely correlate with the density of the bill lamellae, which filter the invertebrates from water and sediments.

With respect to the opposite end of the trophic spectrum, aquatic invertebrates play important roles in vegetative decomposition and nutrient processing (Reid, 1982). The abundant vegetative detritus in a wetland situation provides an additional structural component; that is, the microorganisms and periphyton that utilize this detritus form an important source of food for aquatic invertebrates (Swanson and Meyer, 1977; Kaminski and Prince, 1981).

CORRELATION OF INVERTEBRATES AND HABITAT

The structure of a marsh is a product of basin shape, water regimes, cover-water interspersion, and plant species diversity (Weller, 1978). These elements provide for the structural complexity that ultimately translates to the various types of habitat found within a wetland ecosystem. Three general habitat types represent the most important divisions of a wetland aquatic environment: vegetation, bare sediment, and open-water habitats (Mittlebach, 1981).

The correlation of vegetation and associated aquatic fauna has long been recognized and established (see Krecker, 1939),and the literature tends to address this correlation with respect to habitat and invertebrate production. Krull (1970) states that "Ultimate animal abundance is undoubtedly dependent upon the abundance and kind of the various components of the intricate, ecological [vegetation] communities" (p. 717). He goes on to say that macroinvertebrates seem to be many times more abundant in vegetated areas than in nonvegetated areas and that some plants harbor a greater invertebrate biomass, greater numbers, and a greater diversity than do other hydrophytes. Krull (1970) also found that, although seasonal availability of aquatic macroinvertebrates was variable, organismic abundance peaks soon after plants appear in the spring. Voights (1976) indicates a close association between vegetation types and invertebrates present. Wegener et al. (1974) state that there is no doubt that aquatic vegetation plays a major role in invertebrate production. Arner et al. (1974) found that as vegetative associations change throughout the year, so do macroinvertebrate numbers, distributions, and diversity. Reid (1982) indicates that hydrophyte conditions (which tend to be unstable due to fluctuating water levels) influence the invertebrates that are associated with the plants.

The morphological features of marsh vegetation also have an influence on invertebrate communities. The distribution of macroinvertebrates in the littoral zone depends strongly on the colonizable surface area of the macrophytes and on the density of the vegetation (Dvorak and Best, 1982). Hydrophyte leaf shape, structure, and surface area are all related to invertebrate abundance (Reid, 1982). These morphological features seem to correlate with invertebrate population densities according to the levels of protection and "foothold" provided (Krecker, 1939).

Aquatic vegetation seems, then, to serve as a "culture medium" for invertebrate production (Rakstad and Probst, 1982). Although Krecker (1939) indicates that aquatic invertebrates are not as abundant on "unthrifty" (senescent) or decaying plants, Fredrickson and Taylor (1982) suggest that leaf litter from herbaceous plants provides an ideal substrate for invertebrates. Grazer community composition tends to be influenced by changes in periphyton (Reid, 1982). Campbell and Clark (1983) found that small invertebrates tend to be more abundant on leaves with dense growth of filamentous algae than on leaves with sparse algal growth.

Wetland aquatic vegetation can be further subdivided into emergent vegetation, submerged vegetation, and an interspersion of emergents and submerged vegetation in open water. All three of these more specific wetland habitats exhibit peculiar faunal characteristics.

Stands of emergent vegetation (e.g., cattail) seem to influence invertebrate communities. Some invertebrates exhibit a species-specific tendency in their associations with emergent macrophytes (Dvorak and Best, 1982). Kadlec (1962) suggests that emergent vegetation allows an earlier (one week) thaw of ice cover, thereby providing the first suitable invertebrate habitat in the spring. Armstrong and Nudds (1985) found that emergent

vegetation density had a significant positive effect on size of invertebrates, although Rakstad and Probst (1982) indicate that dense stands of emergents severely limit use by waterfowl.

Submerged vegetation also significantly relates to invertebrate communities. Submerged plants with finely dissected or small and densely packed leaves offer both better shelter and a more generous food source (periphyton) for macroinvertebrates than do massive, simply built emergents (Krecker, 1939; Dvorak and Best, 1982). Armstrong and Nudds (1985) indicate that the presence/absence of submerged vegetation accounted for the greatest variance in size of invertebrates, although their category of "submerged" included the submerged portion of emergents. Danell and Sjoberg (1982) suggest that submerged hydrophytes provide a suitable substrate for invertebrate communities because they increase the structural diversity of habitat.

Perhaps the most importantly recognized correlation between invertebrates and habitat is that concerning the interspersed pattern of vegetation and water termed "hemi-marsh" (Weller and Spatcher, 1965). Several studies suggest that breeding dabbling ducks in particular use the 50:50 ratio (of emergent vegetation:open water) of a hemi-marsh as a structural, proximate cue to assess the suitability of invertebrate-food resources (Voights, 1976; Kaminski and Prince, 1981; Murkin et al., 1982; Reid, 1982; Nelson and Kadlec, 1984). These studies generally indicate that the most productive areas, in terms of aquatic invertebrates, tended to be in the hemi-marsh phase, where areas of open water were protected from the wind by stands of emergent vegetation. Danell and Sjoberg (1982) also found that maximum numbers of aquatic invertebrates occurred where beds of submerged vegetation were interspersed with stands of emergent vegetation. Nelson and Kadlec (1984)

suggest that the characteristics of a hemi-marsh provide an important structural component influencing habitat stability due to decomposition of flooded litter accumulations (which provide a highly heterogenous habitat for invertebrate populations). However, Murkin et al. (1982) suggest, that, instead of using the 50:50 ratio of cover to water as a cue to abundant invertebrate resources, it might simply relate to behavioral characteristics of breeding ducks, where the 50:50 ratio provides the optimal ratio of required water to visual isolation. Regardless of the reasons for waterfowl use, a high degree of interspersion is generally considered to yield temporally stable diversities of invertebrates, good abundance and biomass of invertebrates, and sufficient emergent litter, which provides substrate that sustains these high invertebrate populations (Kaminski and Prince, 1981).

The second major habitat type in a marsh environment is bare sediment, both inundated and exposed. Although it appears that the nonvegetated areas of a marsh do not have as diverse an invertebrate community as the vegetated zones (Krull, 1970; Ringger, 1973; Wegener et al., 1974), they nonetheless remain as important habitat for a number of invertebrates. Voigts (1973) suggests a close relationship between the benthos and the phytomacrofauna due to the similar abundance patterns between the two. Murkin et al. (1982) indicate that benthic invertebrates seemed to have the greatest influence on Blue-winged teal and mallard use in the nonvegetative blocks of a manipulated cattail marsh.

Open water is the final major habitat type encountered in a wetland environment. Large, wind-swept, open-water situations are typically characterized by low invertebrate abundance and survival (Nelson and Kadlec, 1984). Zooplankters and surface water hemipterans are often the main invertebrates present in these situations.

MANAGEMENT POTENTIAL

In a wetland environment, life history strategies of wetland invertebrates have been shaped by long-term, regional hydrologic cycles. However, short-term water regimes and physical, chemical, and biotic factors most likely determine actual occurrence, abundance, diversity and availability of invertebrates at any given time (Swanson and Meyer, 1977; Reid, 1982). Marsh invertebrates clearly respond to water and vegetation conditions and seem to have a direct influence on avifauna use and productivity (Arner et al., 1974; Weller, 1978). Therefore, any management decisions (e.g., drawdown, flooding, basin treatment) have marked implications with respect to both invertebrate production and avifauna use and production. If a wetland is managed, for example, principally for waterfowl and shorebirds, it is important to know where and how the invertebrate resources are being utilized as well as what implications might arise due to various management techniques (Reid, 1982).

Management for specific hydrophyte communities seems to be the easiest, most practical means of increasing desirable invertebrate production (Reid, 1982). The simplest, most economical method of manipulating vegetation communities is through extreme water fluctuation (Wegener et al., 1974). Depending on water depths and cover types involved, 1- to 2-year drawdowns at 5- to 10-year intervals are required to maintain what might be perceived as optimal emergent marshes (Harris and Marshall, 1963). Swanson and Meyer (1977) indicate that while drawdowns of short duration (e.g., 3 1/2 months; see Kadlec, 1962) can be detrimental to invertebrates, complete drawdown cycles of 1 to 5 years (see Wegener et al. 1974; Knighton, 1982) provide conditions that support high invertebrate populations following a subsequent rise in water levels. However, Weller (1978) states that several years of

stable water levels of moderate depth are necessary to establish beds of submerged aquatic vegetation.

Although drawdowns are recognized as a viable management technique, Driver (1977) maintains that complete water loss year after year results in a simplified plant community, which in turn results in a simplified chironomid community (see figure 13.1). Nonetheless,in addition to controlling vegetation communities, drawdowns also produce significant changes in soil chemistry, nutrient availability, and consolidation of the substrate (Harris and Marshall, 1963; Wegener et al., 1974). Kadlec (1962) identifies the increase in soil nitrates as the result of aerobic nitrification.

A wetland complex that is capable of being manipulated gives managers options not available in natural systems but also has the potential for adverse implications or ramifications. High usage of a wetland by waterfowl indicates the need for wetland managers to develop habitats that will nurture desirable invertebrate populations (Connelly and Chesemore, 1980). In order to maximize the production of desirable invertebrate communities, it is imperative that there be investigations as to which habitats harbor the greatest quantities of these invertebrates (Krull, 1970). Management options should consider not only numbers of prey items, but also caloric and nutrient value of the prey (Reid, 1982).

Thus, the investigations into the existing invertebrate populations at Cheyenne Bottoms were developed with these considerations in mind. Spatial and temporal abundance, location, availability, and community composition of invertebrates throughout the wetland complex represent the types of information that managers need in order to make decisions if the wetland is to be considered as an ecosystem.

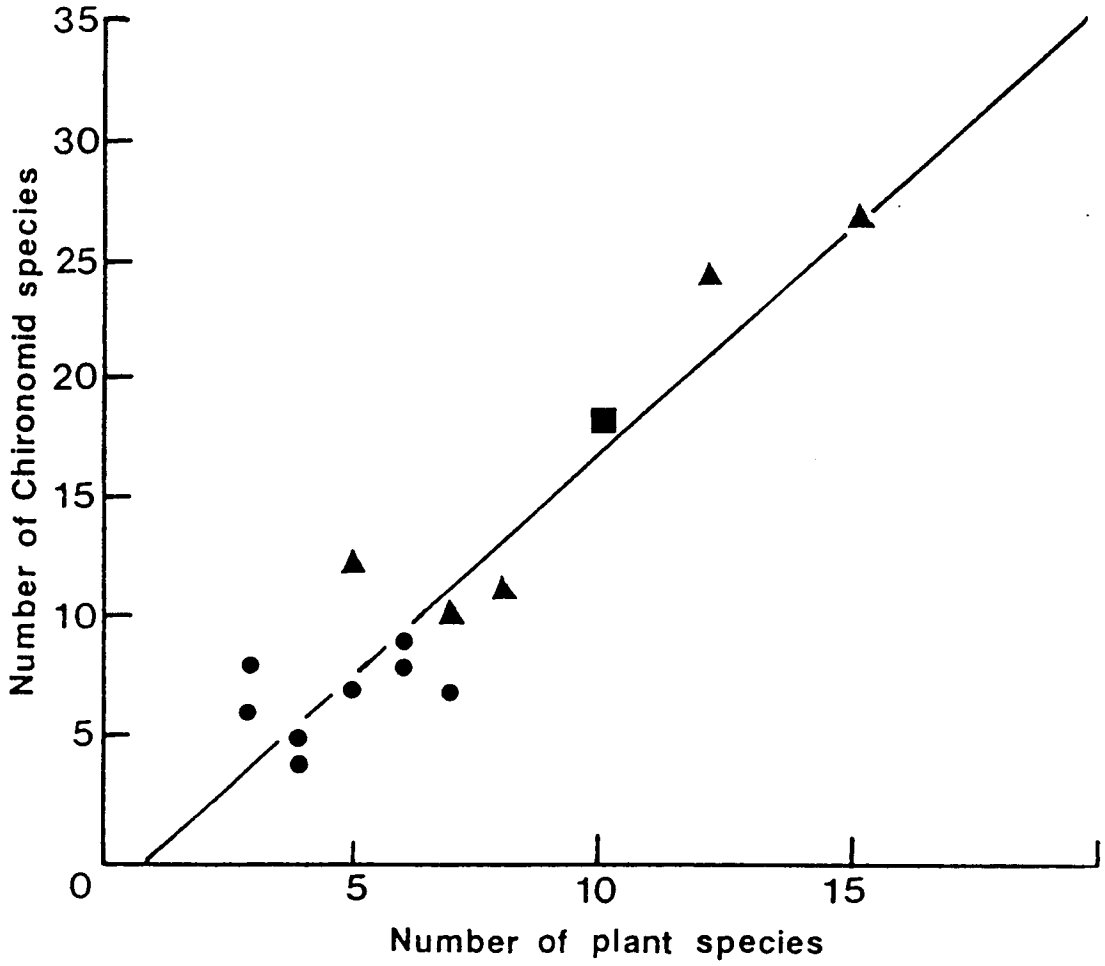

Figure 13.1 - Relationship of Chironomid species diversity to plant species diversity. Circles represent temporary habitat, triangles represent semipermanent habitat, and squares are permanent habitat (Redrawn from Driver 1977).

MATERIALS AND METHODS

SAMPLING REGIME

As outlined in the introduction, the general habitat types of vegetation, bare sediment, and open water represent the three most important structural divisions of a wetland aquatic ecosystem. These elements were thus incorporated into the sampling regime that was developed for the Cheyenne Bottoms invertebrate inventory. The specific situations encountered at Cheyenne Bottoms with respect to these structural elements are essentially a result of the recent history of water-level manipulation in individual pools. Pools 3 and 4 had more terrestrial vegetative associations than the other pools. Six fairly distinct vegetative communities were identified throughout the wetland complex. These identifications were conducted in September 1985 by the consulting wetland ecologist and the project manager. The vegetation types identified as potential habitats to be sampled were:

1. Cattail (Typha spp.)
2. Bulrush (Scirpus ssp.)
3. Aster (Aster spp.)
4. Mixed forbs (e.g. Chenopodium spp., Kochia sp.)
5. Japanese millet (Echinochloa spp.)
6. Wild millet (Echinochloa spp.)

The emergent aquatic vegetation categories (i.e. Typha and Scirpus) were further subdivided into interior sites and exterior sites, due to the size and variable density of the stands. Within these vegetation habitat-sampling sites, three distinct zones or microhabitats were sampled: 1) substrate, 2) submerged vegetation/water column, and 3) emergent portions of the vegetation/water surface.

In addition to these sampling sites, various sites were chosen throughout the wetland that adequately represented open-water situations and mud-flat environments, both inundated and recently exposed. In the open-water

situations, samples were obtained from the substrate and the water-column zones. On the mud flats, core samples of the substrate were taken.

In all, 20 discrete sampling sites were chosen throughout Cheyenne Bottoms. The sampling regime was on a monthly basis (when possible) beginning in March and running through July, although preliminary sampling was conducted in the preceding November (December through February samples were not obtained due to ice cover).

Deviations from the sampling regime were the result of changes in water levels. For example, April was the last sampling date for any of the sites in pools 3 and 4, due to a complete lack of water. Pool 5 fluctuated over the sampling period; at its lowest, Typha sites were moved and Scirpus sites were abandoned. Pool 2 steadily lost water and the mud-flat sites varied accordingly. Figure 13.2 illustrates approximate location of all sampling sites; table 13.1 lists the dates samples were taken at each site.

Another facet of the invertebrate community at Cheyenne Bottoms is represented by the crayfish (Decapoda). Crayfish represent an appreciable food resource for a number of wetland wading birds (Pennak, 1978). Sampling of the crayfish communities was limited both temporally and spatially. Five samples were obtained on one occasion (23 June 1986) when water levels were extremely low. Crayfish populations in pools 2 and 3 were not sampled because of the lack of water.

SAMPLING EQUIPMENT

Five types of samplers were used to obtain the samples for the invertebrate inventory, each one filling the special requirements for sampling an invididual microhabitat:

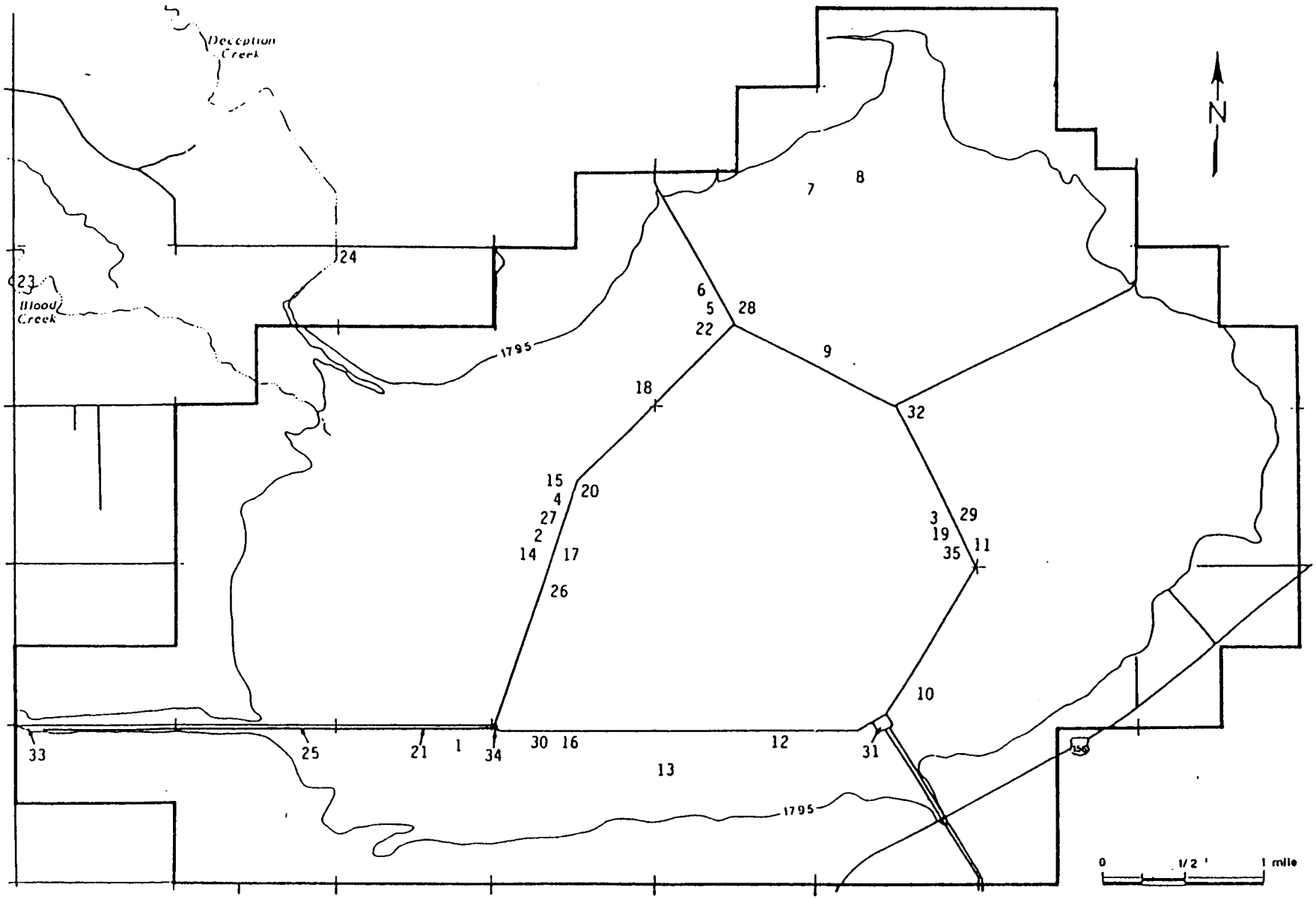

Figure 13.2 - Map of Sampling Sites.

1. Core sampler--samples the benthos in the substrate
2. Macrophyte sampler--samples the emergent vegetation and water column (from the substrate up)
3. Sweep net--samples the submerged aquatic vegetation
4. Plankton net--samples the open-water column
5. Seine (15 ft)--used to obtain the crayfish samples.

Descriptions of the sampling equipment and procedures for their use in the field are detailed in appendix 13.1.

LAB PROCEDURES

Three main types of samples were collected at Cheyenne Bottoms: 1) macrophyte samples, which were dominated by large pieces of vegetation and an abundance of vegetative debris; 2) benthic core samples, containing large amounts of sediment; and 3) sweep net and plankton net samples, that were relatively clean but contained large numbers of organisms. Each type of sample required its own preparation procedure for removing invertebrates from the sample medium. According to sample type all sample were subjected to the following appropriate procedures once they arrived at the lab.

1. Macrophyte samples
   - processing (out of formalin - into 80% ethyl alcohol)
   - cleaning (washing stalks and vegetative debris)
   - initial picking (removing and tallying large rare organism)
   - subsampling (grabbing 200-milliliter subsample)
   - picking (removing and tallying all organisms in subsample)
2. Benthic core samples
   - processing (same as above)
   - elutriation (sediment break-up using surfactant)
   - initial picking (same as above)
   - subsampling (same as above)
   - picking (same as above)
3. Sweep and tow samples
   - processing (same as above)
   - initial picking (same as above)
   - subsampling (same as above)
   - picking (same as above)

Descriptions of the laboratory equipment and procedures for their use are detailed in appendix 13.2.

TABLE 13.1
Sampling Sites for Figure 13.2

Map Site Number	Sample Codes*	Sampling Dates
1	OWP	Nov., Mar., Apr.
2	OWP	Nov., Mar., Apr.
3	OWP	Nov., Mar., Apr.
4	OWB	Nov., Mar., Apr.
5	ETB, ITB	Nov., Mar., Apr.
6	ESB	Nov.
7	JMB, JME	Nov., Mar., Apr.
8	WMB, WME	Nov., Mar., Apr.
9	FMB, EME	Nov., Mar., Apr.
10	AB, AE	Nov., Mar., Apr.
11	SMB	Nov., Mar.
12	ETE/S; ITE/S; ETB; ITB	Mar., Apr., Jul.
13	ESE/S; ISE/S; ESB; ISB	Mar., Apr., Jul.
14	EMB	Apr.
15	OWP	Apr.
16	SMB	Apr., May, Jun.
17	ETE/S; ITE/S; ETB; ITB	May, Jun.
18	EMB	May
19	OWP	May, Jun., Jul.
20	OWP	May, Jun., Jul.
21	OWP	May, Jun., Jul.
22	EMB	Jun., Jul.
23	Water Quality 1	Nov., Apr.
24	Water Quality 2	Nov., Apr.
25	Water Quality 3	Nov., Apr.
26	Water Quality 4	Nov., Apr.
27	Water Quality 5	Nov., Apr.
28	Water Quality 6	Nov., Apr.
29	Water Quality 7	Nov., Apr.
30	Water Quality 8	Nov., Apr.
31	Crayfish 1	Jun.
32	Crayfish 2	Jun.
33	Crayfish 3	Jun.
34	Crayfish 4	Jun.
35	Crayfish 5	Jun.

*OWP; OWB - Open Water Plankton; OW Benthos
ETE/S; ETB - Edge Typha Emergent/Submerged; ET Benthos
ITE/S; ITB - Interior Typha Emergent/Submerged; IT Benthos
ESE/S; ESB - Interior Scirpus Emergent/Submerged; ES Benthos
ISE/S; ISB - Interior Scirpus Emergent/Submerged; IS Benthos
JME; JMB - Japanese Millet Emergent; JM Benthos
WME; WMB - Wild Millet Emergent; WM Benthos
AE; AB - Aster Emergent; A Benthos
SMB; EMB - Submerged Mud Benthos; Exposed MB

METHODOLOGY FOR MEASURING ORGANISMS

Individuals in each invertebrate sample were measured and placed in specific body size catagories. The measurements were taken from only those organisms contained in the vials from which the sample counts were obtained (i.e. generally the sample counts came from subsamples).

The size ranges were determined in accord with both the literature (Nudds and Bowlby, 1984) and the particular circumstances associated with the Cheyenne Bottoms project. The following five size categories were established for the invertebrates (excluding decapods).

1. < 2.5 mm
2. 2.5-5.0 mm
3. 5.1-7.0 mm
4. 7.1-12.0 mm
5. > 12.0 mm

Procedures for measuring invertebrate body sizes are detailed in appendix 13.3.

RATIONALE FOR CLASSIFICATION OF INVERTEBRATES

The invertebrate inventory of the Cheyenne Bottoms project was carried out largely to determine the extent of the food resource base for wetland bird populations (both resident and migratory) occurring at Cheyenne Bottoms. The caloric and protein values of various invertebrates seem to depend on both taxa and organism size (Nudds and Bowlby, 1984). At the outset of the investigation (November 1985), a classification scheme was developed that allowed adequately diverse categories without the problems of detailed taxonomic identification (see Murkin, 1984). The following identification scheme was developed as numerically important groups emerged during the sorting and counting process:

1. Cladocera (water fleas)
2. Copepoda
3. Ostracoda (seed shrimps)
4. Nematoda (round worms)
5. Chironomidae (midges)
6. Oligachaete
7. Miscellaneous

Decapods were not considered under this classification scheme.

NOTES ON CATEGORY SELECTION

- The group "Nematoda" is restricted to nonsegmented, cylindrical, opaque, wormlike organisms that are somewhat pointed on both ends. Any other wormlike organisms that exhibit segmented or flattened bodies (often with discernible head ends) were placed in the "Miscellaneous" category. Large variations in body size seem to be the only difference among organisms within the "Nematoda" category.

- At the outset of the classification-scheme development, "Chironomidae" (midge larvae) appeared to be the only significant family of aquatic Diptera found in the Cheyenne Bottoms samples, often occurring in large numbers at some of the sample sites.

- The "Miscellaneous" category was established for several reasons:

1. It allows researchers the flexibility of quickly categorizing infrequently occurring organisms without exhaustive identification.
2. Should it become necessary to establish a new category, the organisms in previous "misc" categories can be re-examined with a minimum of effort.

This category "miscellaneous" was mainly composed of insect larvae and pupae, gastropods, terrestrial insects, segmented aquatic worms.

Most aquatic worms (Oliqochaeta category) possess long, segmented, slender bodies, usually with setae. Identification is taken no further than this level, due to difficulties encountered at the family level.

RESULTS AND DISCUSSION

IMPORTANT CONSIDERATIONS

When evaluating which groups of invertebrates are the most important at Cheyenne Bottoms (with respect to avian-food resources), it is imperative to bear in mind all of the variables of concern. Not only should there be adequate numbers of invertebrates, they need to be accessible at crucial times during the year. Hence, although the major invertebrate groups of zooplankton and nematodes were quite abundant at various sites and times, their small size restricted their importance as a food resource to all but a few of the more specialized avian foragers.

Both the literature and our limited bird gut analyses (see chapter 16) indicate that the larvae of Chironomidae (Insecta:Diptera) were a dominant food item of great importance to wetland birds found at Cheyenne Bottoms. Chironomid larvae occurred throughout the marsh, with a wide range of both abundance and body sizes (table 13.2 and figure 13.3). The biomass contained in the chironomid larva community (table 13.3) substantially contributes to the nutritional requirements of migrating waterfowl and shorebirds (see Chapter 16). The most productive areas in terms of midge larvae seemed to be those sown to millet and the submerged mud flats. The submerged mud flats exhibited not only large numbers of chironomid larvae but also a relatively even distribution among body-size categories (figures 13.3 and 13.4). These factors combine to produce high levels of biomass as well as provide a diverse size-range of prey items The procedures used to determine biomass are outlined in appendix 13.4.

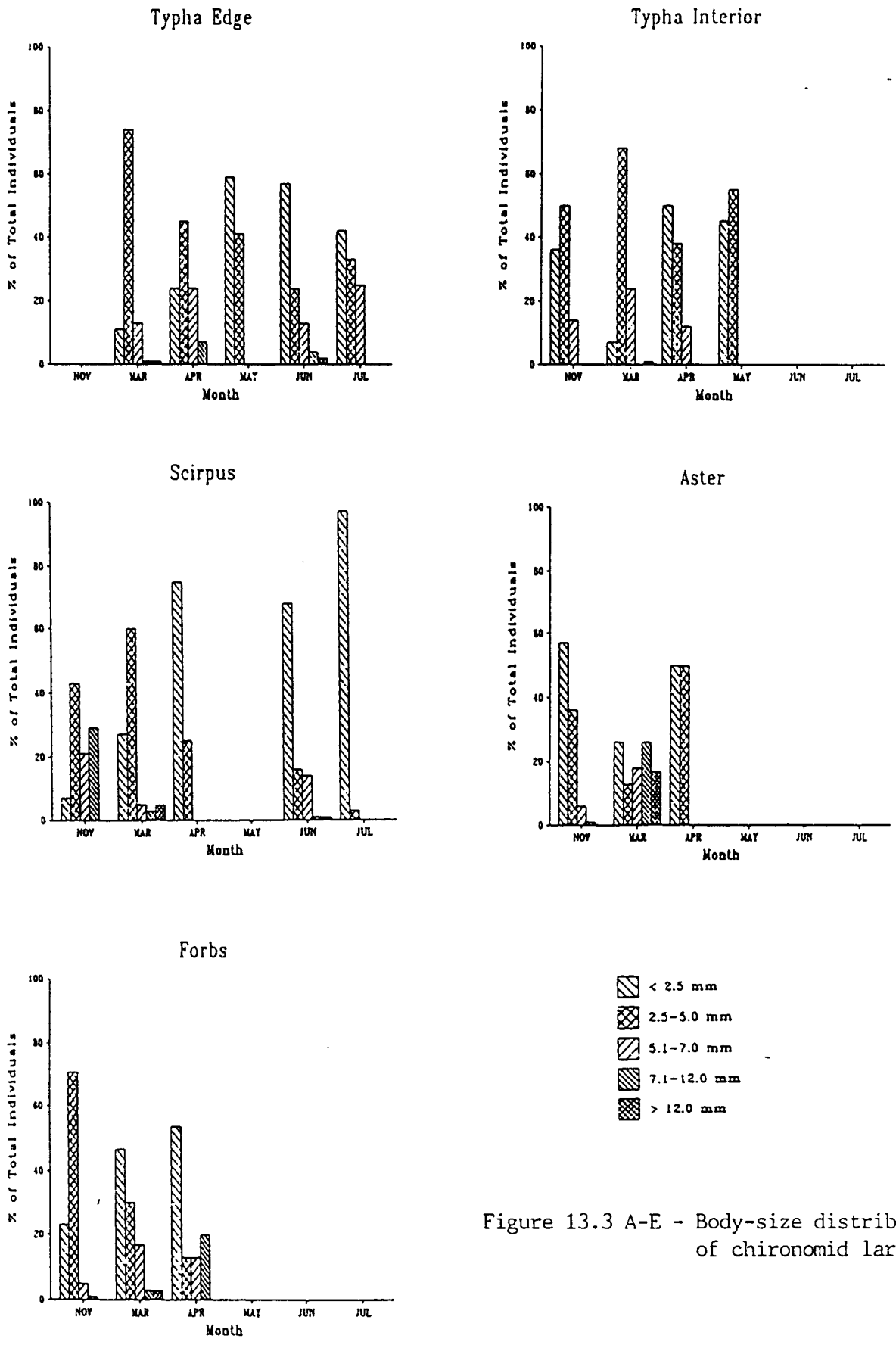

Figure 13.3 A-E - Body-size distributions of chironomid larvae.

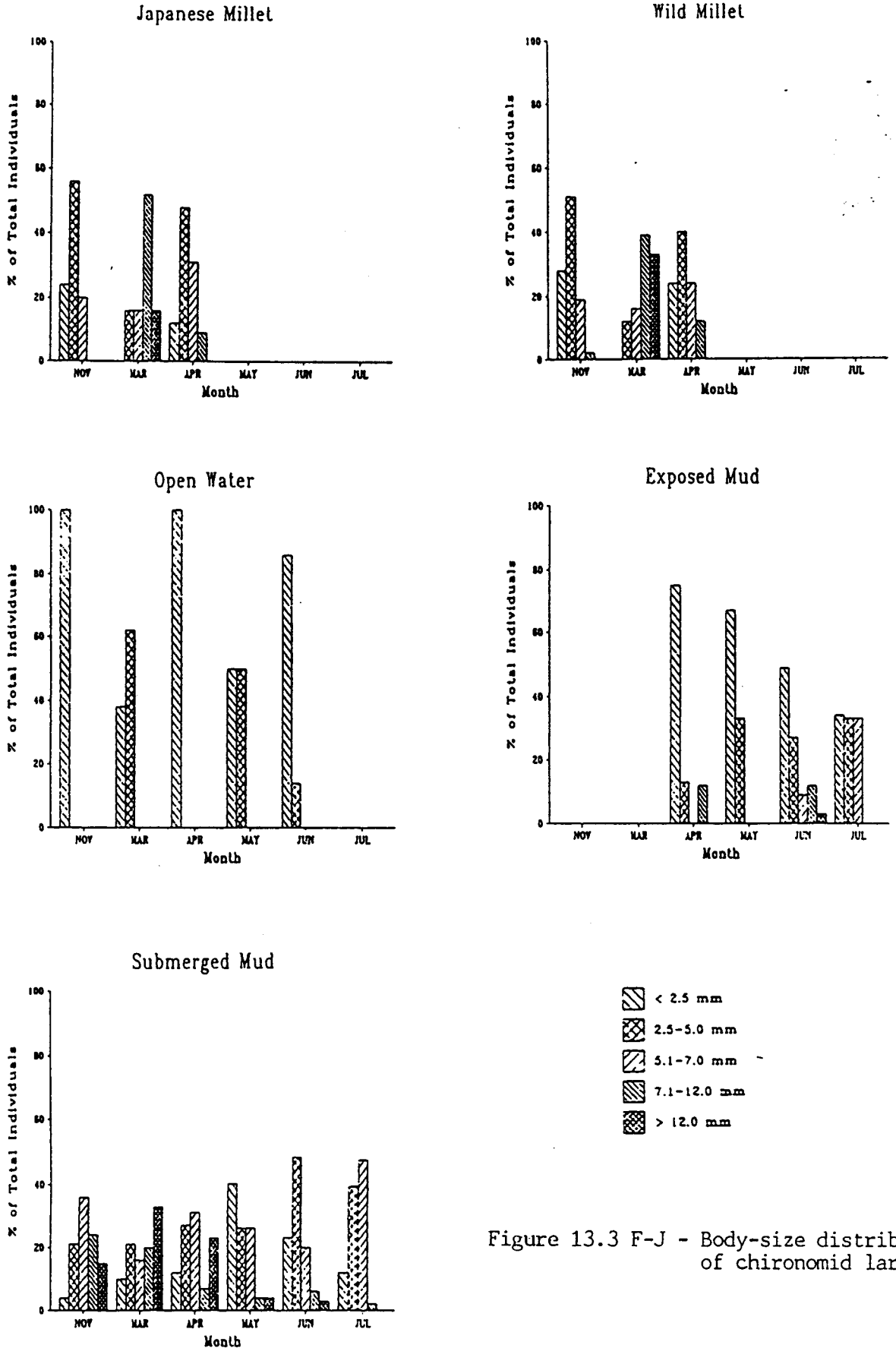

Figure 13.3 F-J - Body-size distributions of chironomid larvae.

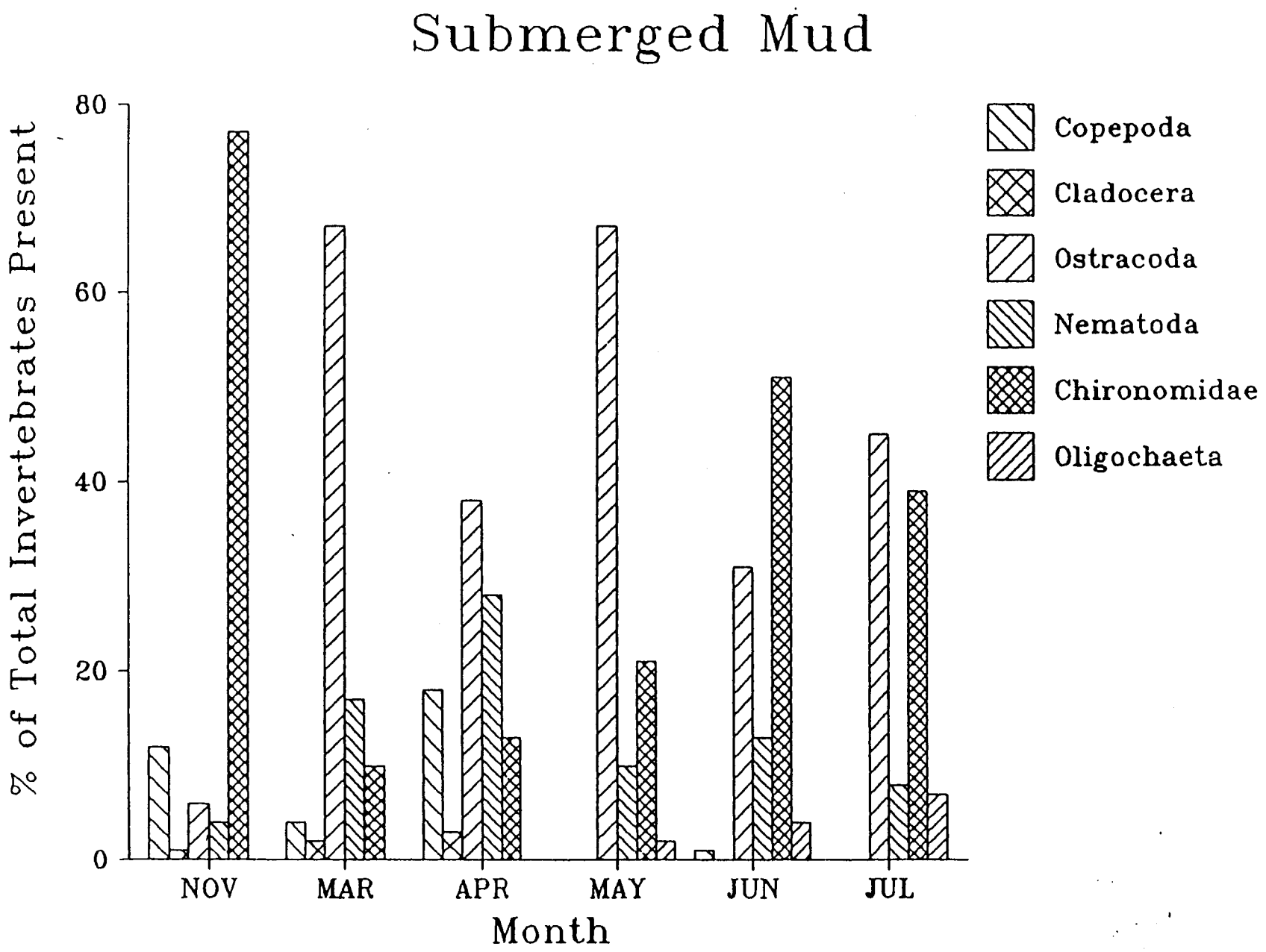

Figure 13.4 - Seasonal organism diversity of submerged mudflat.

Table 13.2--Total number of chironomid larvae per site per square meter of substrate (benthic/nonbenthic). Dashed line indicates no samples were taken.

	Month					
Site	Nov	March	April	May	June	July
Typha, edge	0	6,071	4,128	243	11,171	726
	-	18,676	1,715	940	13,568	1,245
Typha, interior	2,732	2,384	1,214	971	--	--
	--	4,726	76	1,804	--	--
Scirpus, edge	637	12,870	--	--	8,257	243
	--	9,728	--	--	339	224
Scirpus, interior	--	6,311	0	--	--	--
	--	508	51	--	--	--
Aster	2,295	3,885	485	--	--	--
	51	36	--	--	--	--
Forb mix	468	437	727	--	--	--
	258	113	57	--	--	--
Japanese millet	213	3,149	13,114	--	--	--
	15	36	211	--	--	--
Wild millet	7,523	5,100	8,985	--	--	--
	60	40	153	--	--	--
			BENTHOS ONLY			
Open water	5,695	4,963	6,314	--	--	--
Submerged mud	10,838	7,686	4,857	11,657	65,082	20,836
Exposed mud	--	--	1,942	1,700	8,014	255

Table 13.3--Chironomid larvae biomass in kilograms for each habitat type on a monthly basis. Dashed line indicates no samples were taken.

	Nov	March	April	May	June	July
ITE/S	2,661	4,306	20.64	683.2	?	?
ETE/S	?	148	22	--	15	0.2
Scirpus	--	--	--	--	--	--
Aster	595	8,463	25	--	--	--
Forb mix	236	363	287	--	--	--
Jap. millet	76	7,204	7,287	--	--	--
Wild millet	1,216	6,652	621	--	--	--
Mud flats	85,140	74,795	30,169	17,745	93,923	28,500
Exposed mud flats	--	--	800	100	1,122	23
TOTAL	89,379	101,931	93,232	18,528	95,060	28,523

In addition to numbers and biomass, a diverse invertebrate community is important when considering invertebrates as a food resource. Differing physical characteristics and foraging behaviors of wetland birds result in a wide spectrum of invertebrates being consumed. The stands of emergent vegetation, especially Typha, displayed the best combination of high productivity and high diversity (tables 13.2 and 13.4). The interface of Typha and open water appears particularly well suited to support large populations of invertebrates that are both important and available food resources.

Table 13.4--Taxon richness per sampling site for each month sampled. Dashed line indicates no samples were taken.

Site	Nov	March	April	May	June	July
OWP	9	9	8	7	10	12
OWB	7	5	6	--	--	--
ETE/S	--	19	18	15	14	9
ETB	9	5	9	7	10	7
ITE/S	--	13	10	20	--	--
ITB	13	8	8	8	--	--
ESE/S	--	8	--	--	13	10
ESB	10	11	--	--	6	7
ISE/S	--	13	11	--	--	--
ISB	--	7	6	--	--	--
JMB	15	5	8	--	--	--
JME	13	10	10	--	--	--
WMB	7	6	8	--	--	--
WME	11	10	8	--	--	--
FMB	6	7	5	--	--	--
FME	16	11	12	--	--	--
AB	10	7	4	--	--	--
AE	18	7	--	--	--	--
SMB	8	6	6	8	8	8
EMB	--	--	5	7	8	5

The literature repeatedly cites structural diversity as being one of the most important elements influencing both invertebrate production and wetland-bird use. Management schemes, then, should be oriented toward enhancing the structural diversity of Cheyenne Bottoms. Such approaches might include:

- rotating the treatment and status of any given area or pool;
- ensuring adequate mud-flat environments;
- creating hemi-marsh situations of interspersed open water and vegetation.

In addition, hemi-marsh conditions and mud flats would provide a heterogeneous environment, and promote better ecological stability of Cheyenne Bottoms.

CONSIDERATIONS NOT ADDRESSED

Some aquatic invertebrates that occurred frequently and sometimes in great numbers were not considered as important food resources for various reasons. Nematodes or oligochaetes were often found to be the most abundant component at a particular site, but were deemed as unimportant as prey items, largely based upon the literature and upon gut-content analyses of birds taken while actively feeding at Cheyenne Bottoms. The zooplankton commonly found at the marsh, although ubiquitous, are extremely small and most likely contribute very little to the biomass of upper trophic level organisms.

While the aquatic invertebrate studies focused on invertebrate communities as they relate to wetland energetics and avian food resources, the occurrence of one of the terrestrial marsh species merits mention. This species is Simyra henrici, a whitish moth of moderate size. This moth belongs to the largest family of moths found in North America (Noctuidae), which contains such species as the army worm and corn earworm moths. The caterpillars of this marsh moth have recently occurred in such densities as to

cause noticeable and sometimes severe damage to cattail leaves (Typha spp.). The observed outbreaks of these caterpillars have resulted in hundreds of acres of damaged cattails, some of which appeared to be heavily stressed by the feeding activities of these larvae. Because of limited resources, no quantitative estimates were made during the study period on damaged cattail acreages. During 1985, most of the caterpillar population was parasitized by the braconid wasp, Rogas sp. This parasitoid undoubtedly inflicts some mortality on the caterpilar population. A more complete understanding of the relationships that exist between the caterpillar, parasitoid, and Typha would help quantify the impact of caterpillar feeding on the cattail community.

PROBLEMS OF INTERPRETATION

The major problems of interpretation arise from the dynamic nature of a wetland ecosystem. The sampling regime was constantly affected by changes in water levels. In fact, not a single sampling site remained unaffected throughout the sampling period; sites were frequently moved and some were completely abandoned when no alternatives were available. Extreme fluctuations of other environmental parameters might also confound any interpretations. Ice cover in November 1985 prohibited sampling at various sites. High wind velocities at several times during the spring (1986) had a pronounced effect on water distribution throughout the marsh.

Life histories of the wetland invertebrates, the limited sampling regime, and a the coarse resolution in taxonomic identification also present problems of interpretation. The rapid life cycle of many aquatic invertebrates and the rather long periods between sampling dates may have caused some of the fluctuations that were noted in biomass estimates, especially for chironomid larvae. Emergence of adults can also completely alter the population profile. Trophic levels of chironomid larvae are difficult to determine,

since identification to species level is necessary. Time and financial constraints did not permit such detailed examination.

An integral phenomenon of a wetland system is the re-inundation of previously exposed areas. The relatively short period of study precluded the investigation of seasonal re-flooding.

The final problem to be considered is the possibility of experimental error. As noted earlier, the sampling regime itself (on a monthly basis) could be a source of error, given the highly variable and dynamic nature of invertebrate populations. Intrinsic problems are associated with sampling natural populations and also with using subsampling techniques. The study's resource constraints resulted in a relatively cursory investigation that left many ecological inquiries untouched. Human error was kept to a minimum and consistency was provided by following techniques:

- standard field and laboratory procedures and methods were drafted and distributed to all workers
- a training period was provided all invertebrate project members
- specific job duties were assigned all personnel and supervision was provided at all levels
- frequent consultation and discussion sessions between workers and supervisors
- spot quality-control checks were performed.

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components of the water budget during dry, wet, and average years with regard to precipitation. In addition, the water-budget simulation was used to obtain surface runoff estimates in the area as a function of precipitation amounts. The available weather data in the area since the 1950's were examined (figure 6.5) to find above- and below-average precipitation years. The water-budget results for a below-average, average, and above-average water year are shown in table 6.4 for the Blood Creek subwatershed, and in table 6.5 for the Deception Creek subwatershed. Two vegetation covers were assumed to be the predominant types in these subbasins, winter wheat (small grains) and native grasses (pasture). Thus, for example, during the 1984 water year the Deception Creek subbasin received 23.90 inches of precipitation (table 6.5), and using grasses or pasture as the native vegetation cover, 23.44 inches were estimated as being lost to evapotranspiration and 0.84 inches to surface runoff (which is a gain for the Cheyenne Bottoms). Deep drainage during this period is estimated to be 4.67 inches. All these water losses resulted in an estimated soil-moisture deficit of 5.09 inches (table 6.5). It could be readily recognized from these tables that actual (not potential) evapotranspiration is of the same order of magnitude as precipitation. Following natural precipitation and actual evapotranspiration, the largest component of the water balance in the area is the soil-water deficit, indicating that the water resources of the two subbasins are not meeting the natural water demands. It should be noted that seeming "anomalies" in some components of the hydrologic balance, such as the apparent higher deep-drainage values during the average water year, compared to the above-average one, are the results of the pattern and timing of precipitation events. Thus, if the highest precipitation amounts fell during the summer months, they will contribute minimal amounts to deep drainage as compared to spring rains.

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APPENDIX 13.1-SAMPLING EQUIPMENT AND PROCEDURES

CORE SAMPLER

The core sampler was constructed of a section of PVC pipe approximately 80 cm in length with an inside diameter of about 10 cm. One end of the pipe was capped and just below this a wooden dowel was added as a handle (about 35 cm in length, 2.5 cm in diameter). This was accommodated by drilling the appropriately-sized holes through the pipe, installing the perpendicular handle and then cementing in place. A hole was then added to the cap to accommodate a rubber stopper (about 2.5 cm in diameter). Next, the open end of the pipe was filed to an edge to facilitate entry into most substrates. Lastly, the outside length of the pipe was marked in 10 cm increments from the open end. This allowed the operator to record the water column depth and determine how far into the substrate the sampler has entered.

At the sampling site, the rubber stopper is removed and the sampler is lowered vertically into the water until lightly resting on the bottom sediment. A depth reading is then ascertained from the markings on the side of the sampler. The sampler is then forced straight down into the substrate to a depth of approximately 5 cm. The rubber stopper is replaced into the hole and the sampler is twisted and rotated in place to facilitate sample removal. Depending on the consistency of the sediment, the operator sometimes needs to reach down and place their hand across the open end of the sampler as it is being lifted free of the substrate in order to ensure that the sample remains within the sampler. The open end of the sampler is quickly placed into a pre-marked sample bag and the sample allowed to fall into the bag by removing the rubber stopper (allowing gravity or air pressure to remove the sample from the pipe). Three replicate samples were taken at each site and

all were double-bagged in ziploc bags, labelled and preserved with formaldehyde.

MACROPHYTE SAMPLER

The macrophyte sampler is a modified version of Gerking's (1957), constructed of a sheet-metal base supporting a Plexiglas column. The metal base included a curved track along which the enclosure system travels. The column was 70 centimeters tall, open at the top, and had a large window in one side, covered with a .5-mm wire mesh. The macrophyte sampler would enclose a 750-square-centimeter area of vegetated substrate. The sampler was designed to sample only erect emergent vegetation (Typha and Scirpus). The sampling technique remained same regardless of genus or whether the sampling was done in the interior of a macrophyte stand or along the vegetation/open water interface.

The densities of the vegetation were variable, both between interior and exterior Typha and between Typha and Scirpus. The Scirpus colonies were small and exhibited little variation in density between interior and exterior areas. Average Scirpus density was about 8 to 10 stalks per 750 square centimeters. Exterior Typha (at the interface of the Typha stand and open water) density was about 10 to 12 stalks per 750 square centimeters. Interior Typha (approximately 2 meters in from the edge) density averaged about 15 to 18 stalks per 750 square centimeters.

Once an appropriate and representative macrophyte stand had been chosen, the operator randomly chose a representative sampling point within the particular sampling site (i.e. exterior or interior site). The sampling point was approached on foot as quietly and rapidly as possible, with the sampler held aloft. When the site was reached, the sampler was quickly lowered over the macrophytes and rested on the bottom substrate. Since the sampling regime

included the dormant season, a saw-type apparatus was used to cut through the woody Typha stalks. The saw travels along a track, parallel to the substrate surface, shearing the stalks off at substrate/water interface. As the saw is being operated by one person, another person manually operates the enclosure system, which consists of a modified Plexiglas sheet that travels along the curved track, effectively enclosing the macrophyte stalks and water column within the sampler.

Once the sample is enclosed, the macrophytes are clipped off approximately 30 centimeters above the water level. These portions of the plants are discarded. The remaining portions of the macrophyte stalks (i.e. from the cut at the substrate surface to the cut 30 cm above the water level) are then lifted out of the sampler, clipped into small sections, and placed directly into a plastic Ziploc sample bag that had been pre-labeled with appropriate field code, replicate number, and date. The enclosed water column remaining in the sampler is then poured off into a sieved (500-micron) bucket. The inside of the sampler is thoroughly rinsed (using water poured in through the mesh window) and added to the sieve bucket. The material and organisms retained in the sieve bucket are rinsed into the sample bag containing the macrophyte stalks, treated with a formaldehyde solution, sealed, and double bagged.

Three replicates are taken at each sampling site.

SWEEP NET SAMPLING

The sweep net has a rectangular opening (about 12.5 cm x 18.5 cm = 231.25 sq.cm). Once a representative sampling site is chosen, individual sweeps are taken at three randomly chosen points, making sure the sweeps include sufficient proportions of the vegetation being surveyed. Each sampling point is approached as quickly and quietly as possible, the sweep net is lowered

into the water (long axis horizontal) until the lower bar of the frame touched the bottom. The frame of the net is then forced through the vegetation for a total sweep length of approximately 1 meter, at the end of which the net is raised out of the water. The net is held vertically above the water (with the frame at the top) and water is splashed up onto the outside of the net, rinsing all material down into a sieved PVC tube. The PVC tube is then removed and emptied into a sample bag, making sure all material retained therein are rinsed into the bag. The sample is then treated with a formaldehyde solution and double-bagged.

PLANKTON NET TOW SAMPLING

The plankton net has a circular opening approximately 24 centimeters in diameter. The collecting chamber at the net's apex consists of a short section of PVC pipe (approximately 7 cm in length, 5 cm o.d.) and a small funnel glued to the trailing end of the pipe, terminating with a short section (about 8 cm) of clamped surgical tubing.

Once a sampling site has been chosen, the net is cast out (to the side of the user), allowed to sink to the bottom of the water column, and a 2-meter horizontal or vertical tow was taken depending on water depth. The net is then held vertically above the water (with the frame at the top) and water is splashed up onto the outside of the net, rinsing all material down into the collecting chamber. The end of the surgical tubing is then placed inside a sample bag, unclamped, and the contents of the collecting chamber are allowed to drain into the bag. The surgical tubing is then reclamped, and the net is again splashed with water to ensure complete removal of all organisms. This second rinse is then added to the same sample bag, treated with a formaldehyde solution; and double-bagged.

Only one plankton tow was taken at each sampling site.

SEINE SAMPLING

The crayfish communities were sampled using a 15-foot seine. Five representative sites were chosen around the marsh.

Seine hauls of from 60 to 250 feet were taken, depending on success rate and conditions at the site. Hauling a 15-foot seine with a significant amount of bow covers an area approximately 10 feet wide. Therefore, a 60-foot haul covers an area of substrate of about 600 square feet.

Captured crayfish were preserved in a formaldehyde solution, labeled, and returned to the lab for counting, measuring, and sexing.

Abundance and sex distributions of crayfish are illustrated in figure 13.5.

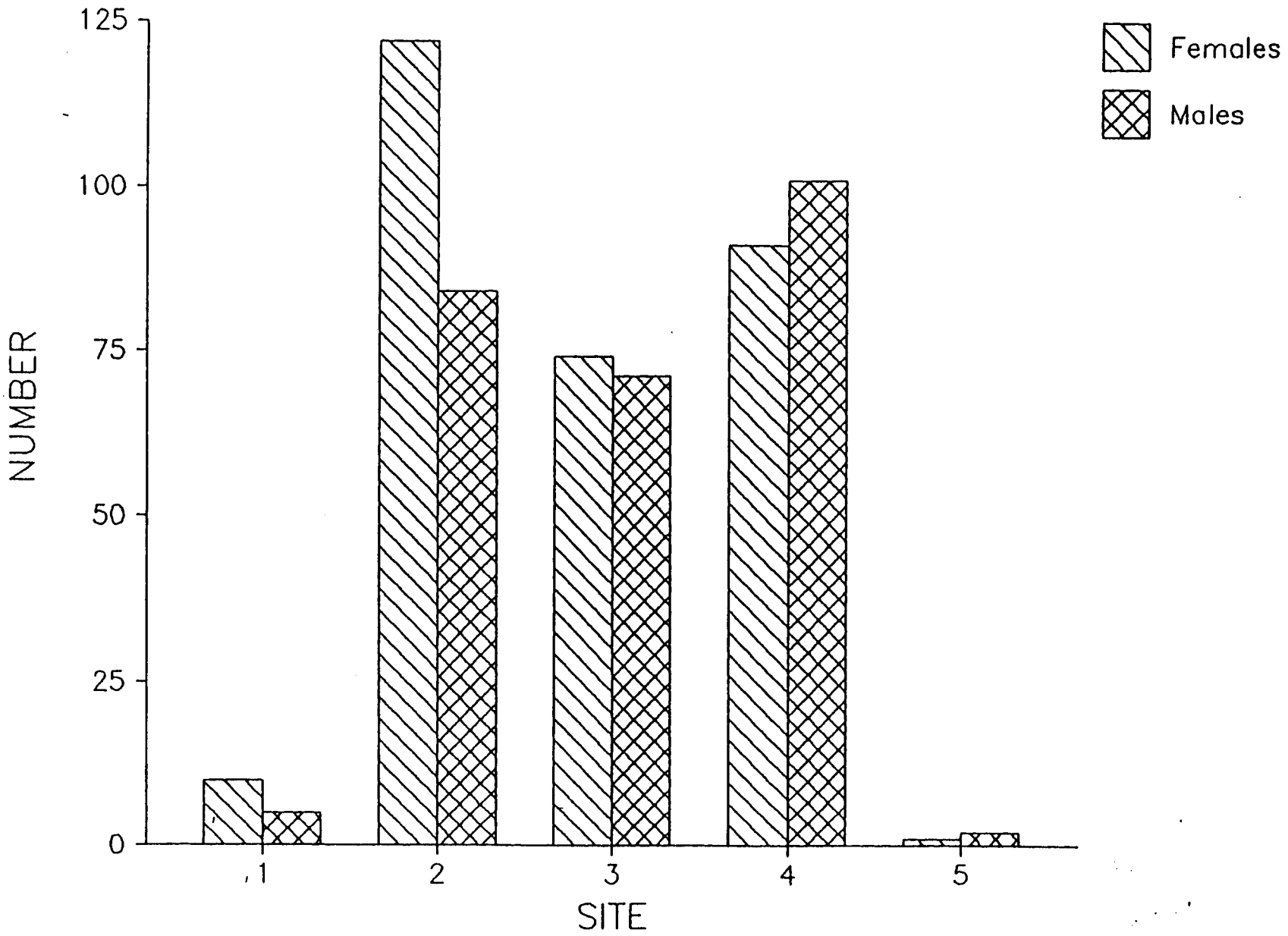

Figure 13.5 - Abundance and sex distribution of crayfish.

APPENDIX 13.2-LABORATORY EQUIPMENT AND PROCEDURES

PROCESSING

Processing the samples in the laboratory entails thoroughly rinsing the samples with water to remove any remaining formaldehyde and storing the washed samples in 80% ethanol. Processing was done as soon as possible once the samples arrived from the field.

The following sampling procedures were observed in the laboratory:

- the outside bag was removed and set aside
- the sample bag is opened and poured into a sieved (500-micron) bucket. The sample bag was thoroughly rinsed into the sieved bucket.
- depending on the amount of sediment in the sample (which, in the core samples, was extensive), the sieving bucket was swirled and sloshed over larger buckets 3/4 full of water, in an effort to remove both any remaining formaldehyde and as much of the silt as possible. Owing to the cohesive nature of the substrate sediment at Cheyenne Bottoms, it was impossible at this point to remove all of the sediment.
- once the sample appears to be as "clean" the sieving bucket is drained of all water and the retained material is thoroughly rinsed back into its sample bag using 80% ethanol. Enough 80% ethanol was added to the bag to ensure adequate coverage of the sample material.
- the sample was again double-bagged and set aside.

ELUTRIATION

The substrate sediment at Cheyenne Bottoms tends to be very cohesive, hence washing and rinsing with clean water alone had little effect. An elutriation device was constructed that allowed a sample with a large amount of sediment to be subjected to both physical- and chemical-breakdown

processes. This elutriator is a modified version of the apparatus constructed by Worswick and Barbour (1974).

The device consists of a funnel at the base of a cylinder, with a sieve-mesh window (350 microns) part way up the side of the cylinder. Water and/or air can be introduced at various rates through a sieve mesh at the base (apex) of the funnel. Initially, after the apparatus had been hooked up, a sample is poured from its bag into the cylinder. The bag is thoroughly rinsed into the cylinder. About 150 milliliters of a surfactant solution (50 grams Cascade/liter of water) is added to the sample and air only is introduced through the apex hose. The air flow was adjusted to produce a vigorous, bubbling action. The sample was then allowed to bubble in this manner for approximately 20 minutes. Water was then also introduced through the apex hose at a volume sufficient to raise the level up to and out of the mesh "window." Care had to be taken not to let the cylinder overflow, because the mesh tended to get clog allowing the water level to continue to rise. Therefore, the mesh was cleaned by backwashing with a forced stream of water or by tapping the mesh. This procedure was continued until the water coming through the mesh was clear. The water inflow was then discontinued and the level in the cylinder was allowed to recede. The entire process was then repeated as necessary up to a maximum of three times (total).

After the final elutriation process, the apex hose was removed and the cylinder was allowed to drain by gravity, with occasionally rinsing of the sides of the cylinder. After draining the cylinder was removed from the funnel and the material retained in the funnel was thoroughly rinsed back into the sample bag, covered with sufficient 80% ethanol, and double-bagged.

CLEANING MACROPHYTE SAMPLES

The vast amounts of vegetative debris contained in the macrophyte samples, along with the fact that some invertebrates retain a "tenacious grip" on vegetation (Ringger, 1973), made it necessary to include a special procedure to separate invertebrates from the stalks and debris. This procedure consists of agitation and sifting as follows:

1. Empty and rinse contents of sample bag into large (5-gallon) bucket.
2. Using a sink sprayer on highest setting the bucket was partial filled and the contains agitated in the process.
3. A wooden paddle was then used to agitate the sample for 60 seconds.
4. The entire contents of the large bucket was emptied into a sieved (500-micron) bucket.
5. Individual pieces of macrophyte stalk were spray rinsed and the dislodged debris was wash back into the sieve bucket.
6. Discard each piece after it has been sprayed and examined.
7. After all individual pieces of stalk have been removed, the sieve bucket should contain miscellaneous bits of tangled vegetative debris and organisms.
8. Small portions of the retained vegetative debris were then laid out evenly, inside a 1/4-inch (hailscreen) sieve bucket contained within a large (5-gallon) bucket.
9. The debris on the hailscreen was sprayed (and washed) for 30 seconds.
10. The hailscreen material was added another bucket and saved until the entire sample has been treated; steps 8 and 9 were then repeated once on this saved debris.

11. After the second cleaning, the debris was placed in a shallow tray containing water and examined for any large organisms that might still be entangled in the debris. Then discarded.
12. The material that passed through the hailscreen in step 9 was consolidated and saved.

INITIAL PICKING/SUBSAMPLING

The large number of samples and the abundance of invertebrates in some samples, demanded that a subsampling procedure must be employed (see Murkin, 1984). However, in order to accurately represent the invertebrate biomass composition, large rare organisms were removed and tallied prior to subsampling.

Once the large rare organisms have been removed from the sample and tallied, the sample was ready to be subsampled. The apparatus used to perform the subsampling procedure was fashioned after that used by Wrona et al. (1982) for the same purpose. The subsampler consists of an 1-Liter Imhoff settling cone fitted with an air stone at the bottom and connected to a compressed air supply. After a particular sample was properly processed (i.e. benthic samples elutriated, macrophyte samples cleaned and initially picked), it was placed in the Imhoff cone and water is added to bring the total volume up to 1 liter. Air was then introduced through the air stone at the bottom of the cone and the sample was allowed to agitate for 5 minutes. After mixing, a subsample of 200 milliliters was taken. The 200-milliliter subsampler was constructed of a section of PVC pipe (21 cm in length, 3.5 cm in width) open on both ends, with a rod passing through the length of the pipe. A rubber stopper was affixed to one end of the rod and a loop-handle was at the other, with approximately 30 centimeters between the stopper and the handle. By pulling the stopper onto the end of the subsampler a 200 mm subsample was

secured. After the subsample was removed the remaining solution was preserved, labeled and stored.

Subsampling validity using this apparatus depends on random mixing of the macroinvertebrates. Wrona et al. (1982) demonstrated the consistency and accuracy of the apparatus. Although our subsampler grabbed 20% of the volume of the Imhoff cone, we consistently grabbed about 17.5% of the organisms. This was verified using a rarefaction technique on eight successive 200-milliliter grabs. The organisms in each subsample grab were counted and the numbers plotted on semi-log graph paper against expected values.

PICKING INVERTEBRATES

Although hand picking invertebrates from the samples is extremely laborious and time consuming, it remains as the only valid form of representation of the invertebrate populations within the sample (Voigts, 1976).

Once a sample was cleaned of debris and sediment and had been initially picked and subsampled if necessary, it was ready to have all of the remaining organisms removed and tallied. Organisms were picked from the samples as follows:

- a small amount of a sample was spooned into a small watchglass.
- the watchglass was systematically examined under a binocular dissecting microscope.
- any organism encountered was removed with forceps and placed in a small vial or bean capsule containing 80% ETOH and accordingly counted on a column Jim Gem clicker-counter under the proper category.

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- all organisms of one category were consolidated into one vial containing 80% ETOH, labeled with sample date, site, replicate number, category of organism, number of organisms, and lab-worker initials, and then stoppered and stored with the other vials of that particular sample. These numbers were then recorded on the appropriate record sheet.

APPENDIX 13.3-INVERTEBRATE BODY-SIZE CLASSIFICATION

An overhead projector was directed at a white posterboard, positioned so that a 5:1 enlargement was obtained on the screen, (i.e. a bar 10 mm in length placed on the translucent screen of the projector measures 50 mm on the posterboard). An opaque shield with a 10 cm diameter window cut in it was placed over the translucent screen, thus projecting a 50 cm diameter image onto the posterboard. Lines corresponding to the maximum length (at a 5:1 scale) for each of the first four categories were scribed on the posterboard.

A vial containing counted and classified organisms (e.g., "Nematodes" from OWB #2: March 13, 1986) was emptied into a petri dish and examined under the microscope. Using forceps, the individual organisms were then placed in a four chamber petri dish which was located in the window of the opaque shield (of the projector). During this transfer process, the organisms were again counted to ensure accuracy. Calipers were used to measure each organism being projected, on the posterboard, then the calipers were aligned with the posterboard measurement bars and the correct size category was determined for each organism. A certain degree of subjectivity was involved in the process, since long-bodied invertbrates (e.g., Nematodes and chironomids) were rarely straight. Generally, the organisms within a size category (e.g., 2.5-5 mm) were measured against each other to better ensure consistency within each size division. After each organism was examined, classified by size and recorded the totals were compared to the classification counts, and all corrections were noted. Periodically the lines on the posterboard are checked using calipers which measure within a tenth of a millimeter. The degree of subjectivity in the measuring process was minimized by limiting the number of individuals involved.

APPENDIX 13.4-BIOMASS DETERMINATION

An estimation of biomass was essential when evaluating the trophic structure of a community. Examination of gut contents of selected shorebirds actively feeding at Cheyenne Bottoms revealed the relative importance of midge larvae as a food resource. In order to determine to what extent chironomid larvae contribute to the energetics of migrating shorebirds and waterfowl, an estimate of chironomid larvae biomass throughout the marsh was necessary. The estimation of biomass was derived from evaluation of the following factors:

- abundance of chironomid larvae (on an areal basis) within the various habitats at Cheyenne Bottoms,
- body-size distributions within these various chironomid larvae communities,
- dry weight determinations of representatives from each body-size category, and
- area measurements of the various habitats where the chironomid larvae communities are found.

Once biomass levels were established, total caloric reserves contained in these larvae were estimated.

The procedures utilized to determine the numerical (abundance) and body-size distributions of chironomid larvae found in the marsh have already been discussed. Dry-weight determinations were made by selecting samples from three spatially and temporally distinct sampling efforts: 1) submerged mud flats (Nov); 2) edge Scirpus (Mar); and 3) edge Typha in June. An average of four representatives from each body-size category were taken from each sample and were placed on oven-dried (1 hour at 105° C), pre-weighed aluminum-foil saucers, then oven-dried for 2 hours at 105° C. Each saucer with dried larvae was then immediately weighed and the weight recorded. Saucer weights were

then subtracted from saucer and larvae weights to yield weight measurements of the larvae. These weights were then averaged among each size class (table 13.5).

Chironomid larvae biomass on an area (per square meter) basis was then estimated. Numbers of chironomid larvae for each sampling effort (table 13.2) were apportioned according to the body-size distribution proportions (figure 13.3) of the same sampling effort. For example, a population estimate of 7686 individuals per square meter was obtained for the submerged mud flat sample taken in March. Of the individuals in that same sample, 10% fell into body-size category #1, 21% in #2, 16% in #3, 20% in #4, and 33% in category #5. The resultant numbers per body-size category were multiplied by their respective average dry-weight values. Table 13.3 shows the ultimate chironomid biomass estimations per square meter per habitat type.

In order to estimate total biomass of chironomid larvae for the entire Cheyenne Bottoms, data from table 13.3 was coupled with area measurements of each habitat type. These area measurements were obtained from the vegetation map using standard polar planimeter techniques. Biomass levels for each habitat type were then extrapolated using the abundance per square meter data for that habitat and multiplied by the total estimated habitat area.

Table 13.5--Oven-dried weights of chironomid larvae (2 hours at 105° C) in grams. Dashed line indicates no samples were taken.

Code/ Date	Foil #	Size cat.	# of organisms	Foil only	+Dry	Organism dry wts	Individual dry wts
ETE/S #1	1-1	1	6	.14634	.14647	.00013	.0000217
6-11-86	1-2	2	5	.15060	.15096	.00036	.000072
	1-3	3	4	.14914	.15068	.00154	.000385
	1-4	4	4	.13086	.13313	.00227	.000568
	1-5	5	3	.13580	.14181	.00601	.0020
ESE/S #2	2-1	1	6	.13373	.13389	.00016	.0000267
3-12-86	2-2	2	5	.13759	.13781	.00022	.000044
	2-3	3	4	.13362	.13453	.00091	.000228
	2-4	4	4	.12516	.12836	.0032	.0008
	2-5	5	4	.14386	.15045	.00659	.00165
SMB #3	--	1	--				
11-20-85	3-2	2	5	.15253	.15284	.00031	.000062
	3-3	3	4	.14728	.14795	.00067	.000168
	3-4	4	4	.13771	.13984	.00213	.00053
	3-5	5	4	.15966	.16340	.00374	.000935
Average		1					.0000242
		2					.0000593
		3					.0002603
		4					.0006237
		5					.0015283

CHAPTER 14: FISHES OF CHEYENNE BOTTOMS AND ASSOCIATED STREAMS

Guy W. Ernsting and Dr. Frank B. Cross

INTRODUCTION

As part of the overall study of Cheyenne Bottoms Wildlife Management Area, a survey of the ichthyofauna of Cheyenne Bottoms and its associated streams was conducted in May and June, 1986. In addition, species composition and distribution data of the fishes of the Arkansas River in Barton and Rice counties collected by Ernsting in 1984, 1985, and 1986 are included as "current information."

The ichthyological study objectives were: 1) to provide a comprehensive survey of the fish fauna of Cheyenne Bottoms and its associated streams (water sources), 2) to assess the food value of fish to other vertebrates of Cheyenne Bottoms, 3) to explore the feasibility of removing carp from the system, and 4) to assess the effects of proposed management alternatives on the fish fauna.

Cheyenne Bottoms has two natural water sources, Blood Creek and Deception Creek, and two artificial water sources, the Arkansas River diversion and the Walnut Creek system diversion.

Where water conditions allowed, the above mentioned streams and the management pools of Cheyenne Bottoms were sampled by seining to determine species diversity, distribution, and relative population densities.

Cheyenne Bottoms historically has been an important stopover point for migrating waterfowl and has been managed for that purpose since its acquisition in 1942 by the Kansas Fish and Game Commission. From the beginning, the area was managed as a waterfowl refuge and public shooting area, with little importance being given to sport fisheries. Cheyenne Bottoms has always provided a limited sport-fisheries resource, with fluctuating water

levels greatly affecting angler success. Stocking of game fish occurred regularly during the late 1950's. From 1954 to 1959, 728,000 channel catfish and 13,200 largemouth bass were stocked in the Bottoms by the Kansas Fish and Game Commission.

HISTORICAL ASPECTS

Historical information concerning species diversity in Cheyenne Bottoms and its associated streams is sparse. Available information is presented in table 14.1. Information concerning the species taken by anglers in the Bottoms pools, canals, and associated streams was obtained from anglers and personnel of the Kansas Fish and Game Commission. Species taken by anglers through the years include channel catfish, flathead catfish, black bullhead, largemouth bass, white crappie, and common carp. Fishing success in the Bottoms proper was always best during and immediately after significant inflows of water, the result of heavy rains or diversions of water from the Arkansas River or Walnut Creek. Common carp, a species not generally desirable to most anglers, has been an important game fish for certain groups of anglers. In addition, "minnows" have been heavily harvested by anglers in the Bottoms for use as bait within the Bottoms and at other areas.

Table 14.1--Historic records of fish species in Cheyenne Bottoms area.

SAMPLE LOCATION SPECIES	I	II	III	IV	V	VI	VII	VIII
Gizzard shad	X			X	X	X		
Common carp	X	X		X	X	X	X	
Speckled chub	X							
Suckermouth minnow	X	X					X	X
Emerald shiner	X							
Red shiner	X	X	X	X	X		X	X
Sand shiner	X	X		X	X	X	X	X
Arkansas R. shiner	X							
Plains minnow	X							
Bluntnose minnow	X			X	X			
Fathead minnow	X		X				X	X
Smallmouth buffalo	X							
River carpsucker	X	X		X	X	X	X	
Channel catfish	X			X	X	X	X	
Golden redhorse	X					X	X	
Black bullhead				X		X		
Flathead catfish					X	X		
Largemouth bass				X	X	X	X	X
Green sunfish		X	X	X	X	X		X
Bluegill				X		X		
Orangespotted sunfish						X	X	
White crappie				X	X	X		
Stoneroller			X	X	X		X	X
Goldfish								X
Mosquitofish		X	X			X	X	X
Plains killifish		X	X			X	X	X
Shorthead redhorse				X	X			
Freshwater drum					X			
TOTALS	14	8	6	14	14	14	12	10

I--1952, Cross et al., Dartmouth, Arkansas River, sec. 32, T. 19 S., R. 12 W.
II--1984, Arruda et al., Dartmouth, Arkansas River, sec. 33, T. 19 S., R. 12 W.
III--1985, Frammyet al., Dartmouth, Arkansas River, sec. 33, T. 19 S., R. 12 W.
IV--1984, Fish Kill Report, Great Bend, Arkansas River, sec. 33, T. 19 S., R. 13 W.
V--1982, Fish Kill Report, Great Bend, Arkansas River, sec. 33, T. 19 S., R. 13 W.
VI--1975, Kansas Fish and Game, Dundee, Arkansas River, sec. 20, T. 20 S., R. 14 W.
VII--1980, Clarke et al., Dundee, Arkansas River, sec. 20, T. 20 S., R. 14 W.
VIII--1983, Cross et al., Dundee, Arkansas River, sec. 22, T. 20 S., R. 14 W.
Prior to 1986 a total of 28 species of fish had been reported from the Arkansas River and Cheyenne Bottoms area.

METHODS AND SAMPLING SITES

Collection equipment used included haul seines of 6 ft X 4 ft X 1/8 inch mesh, 15 ft X 6 ft X 1/4 inch mesh, 30 ft X 6 ft X 3/8 inch mesh, 100 ft X 8 ft X 1 inch mesh, and trammel nets with 1 inch mesh and 8 inch mesh panels X 60 ft long. Voucher specimens are housed at the Museum of Natural History, University of Kansas. Where counts of species were not made, relative abundance was recorded by the terms 'A' abundant, 'C' common, 'F' frequent, 'S' scarce, and 'R' rare in the field notes.

Field work was conducted at a time of relatively low water, so that selection of sample sites was limited to those portions of the streams and the Bottoms which had accessible water. The low-water conditions benefited the survey because fish populations were concentrated in these areas. This situation facilitated diversity data, but certainly biased density and abundance data. Tables 14.2A-14.2D summarize species diversity and abundance of all sample-site locations. Field notes of sample sites are included in appendix 14.1.

Table 14.2A--Diversity and abundance of fish; collection sites 1-10. Sites: 1--Arkansas river, GWE-1-84, 21 April 1984; 2--Arkansas River, GWE-1-85, 27 April 1985; 3--Arkansas River, GWE-2-85, 4 May 1985; 4--Arkansas River, GWE-3-85, 18 May 1985; 5--Arkansas River, GWE-4-85, 18 May 1985; 6--Arkansas River, GWE-5-85, 18 May 1985; 7--Arkansas River, GWE-6-85, 18 May 1985; 8--Arkansas River, GWE-7-85, 21 May 1985; 9--Arkansas River, GWE-8-85, 8 June 1985; and 10--Arkansas River, GWE-1-86, 19 January 1986.

	STATION LOCATION									
SPECIES	1	2	3	4	5	6	7	8	9	10
Suckermouth minnow	F		S		F		S			F
Red shiner	C	A	A	A	A	A	C			C
Sand shiner	A	A	A	A	A	A	A			A
Fathead minnow			S	S	S	S	S			F
Stoneroller			F	F		F			C	C
Quillback					C	C				
Shorthead redhorse									R	
Black bullhead			S					S		
Channel catfish								A		
Plains killifish	A	A	A	S		A	A			A
Mosquitofish		A	A	F		A	A			A
Gizzard shad					R		S			
Common carp								S		
Largemouth bass	R				R					
Green sunfish								F		F
Bluegill								R		
Orangespotted sunfish		R								
Arkansas darter										R

Table 14.2B--Diversity and abundance of fish; collection sites 11-20.
Sites: 11--Arkansas River, GWE-2-86, 19 January 1986; 12--Arkansas River, GWE-3-86, 5 April 1986; 13--Arkansas River, GWE-4-86, 5 April 1986; 14--Arkansas River, GWE-5-86, 13 April 1986; 15--Arkansas River, GWE-6-86, 20 April 1986; 16--Arkansas River, GWE-7-86, 20 April 1986; 17--Arkansas River, GWE-15-86, 5 June 1986; 18--Arkansas River, GWE-16-86, 10 June 1986; 19--Arkansas River, FBC-1-86, 2 June 1986; and 20--Arkansas River, FBC-15-86, 5 June 1986.

	STATION LOCATION									
SPECIES	11	12	13	14	15	16	17	18	19	20
Suckermouth minnow	S	F	S	F						
Red shiner	A	C	A	A		A	A	A	R	A
Sand shiner	A	A	A	A	A	A	A	A		A
Fathead minnow	S	S	S	S	S	F	R		A	S
Stoneroller		S	F	S	F	A	C	S		F
Black bullhead						R	C			
Yellow bullhead							R			
Plains killifish	C	A	C	C	A	F	A	C	R	A
Mosquitofish	A	F	C	C	A	C	A	A	F	A
Common carp									R	
Green sunfish	F	S	S	S		F	C			S
Bluegill							R	A		
Orangespotted sunfish			R							
Arkansas darter			R							

Table 14.2C--Diversity and abundance of fish; collection sites 21-30.
Sites: 21--Deception Creek, GWE-13-86, 31 May 1986; 22--Deception Creek, GWE-14-86, 31 May 1986; 23--Blood Creek, FBC-9-86, 4 June 1986; **--Blood Creek, (No Collection Number), 4 June 1986; 24--Blood Creek, FBC-10-86, 4 June 1986; 25--Blood Creek, FBC-11-86, 4 June 1986l; 26--Dry Walnut Creek, FBC-2-86, 2 June 1986; 27--Wet Walnut Creek, FBC-3-86, 2 June 1986; 28--Wet Walnut Creek, FBC-12-86, 4 June 1986; 29--Wet Walnut Creek, FBC-13-86, 4 June 1986; and 30--Wet Walnut Creek at Diversion Dam, FBC-14-86, 5 June 1986.

	STATION LOCATION										
SPECIES	21	22	23	**	24	25	26	27	28	29	30
Red shiner		A					C	S	C		C
Sand shiner								R			
Fathead minnow	A	A	A	A	A	A	A	A	A	A	A
Black bullhead		A		A			S	S	C		F
Common carp								S	S		A
Largemouth bass								R			
Green sunfish		F			S		F				F
Orangespotted sunfish		C							R		F
White crappie											S

Table 14.2D--Diversity and abundance of fish; collection sites 31-41.
Sites: 31--Inlet Canal, FBC-8-86, 3 June 1986; 32--Inlet Canal, GWE-9-86, 17 May 1986; 33--Pool 5, GWE-10-86, 17 May 1986; 34--Bottoms 'Hub', FBC-4-86, 3 June 1986; 35--Pool 1, FBC-5-86, 3 June 1986; 36--Pools 3 and 4, FBC-6-86, 3 June 1986; 37--Pool 5, FBC-7-86, 3 June 1986; 38--Outlet Canal, GWE-11-86, 17 May 1986; 39--Little Cheyenne Creek, GWE-17-86, 3 May 1986; 40--Little Cheyenne Creek, GWE-12-86, 17 May 1986; and 41--Little Cheyenne Creek, GWE-8-86, 16 May 1986.

	STATION LOCATIONS										
SPECIES	31	32	33	34	35	36	37	38	39	40	41
Red shiner	C	A			S		F		A	A	C
Sand shiner	R	R								A	A
Fathead minnow	A	A		A	A		A	A	A	A	A
Black bullhead	F			A	A					C	
Plains killifish				S		A			R	C	R
Common carp	S		A	C	R		S			R	
Largemouth bass					R						
Green sunfish	F	F		F	F			C		F	
Orangespotted sunfish	F	C		F	F	R	F	A	C	A	C
White crappie	S				S						

RESULTS

Historically, 28 species have been reported from the study area (table 14.1). Eleven of those species were not encountered during the present study. Of those species the speckled chub, emerald shiner, Arkansas River shiner, and plains minnow are probably extirpated from the area. The bluntnose minnow, river carpsucker, and golden redhorse may still occur rarely, though we failed to find them in 1984-86. The goldfish observed in 1983 by Cross et al. (1985) can be considered a rare accidental and may still exist as such. The flathead catfish, while not encountered during this study, is regularly taken by anglers in the Arkansas River and occasionally in the other streams as well, but rarely from the Bottoms.

Three species were encountered in the study area for the first time: quillback, shorthead redhorse, and Arkansas darter. These species occur elsewhere in the Arkansas River drainage and seem to be dispersing into the area surveyed as habitats in the Arkansas River change due to diversion of headwaters and declining water tables upstream.

The present study encountered 20 species (table 14.2A-D): Arkansas River, 19 species; Walnut creeks and Inlet Canal, 9 species; Cheyenne Bottoms pools, 9 species; Little Cheyenne Creek and Outlet Canal, 8 species; Deception Creek, 5 species; and Blood Creek, 3 species.

CHEYENNE BOTTOMS POOLS

Abundance and diversity of species within the Bottoms varies with the depth of water available in a given area. Fathead minnows are the most abundant species, being found in all but one sample site. Black bullhead and common carp are common species. Common carp are thought to be more numerous than our results indicate they are. This is possibly due to the large size of some individuals, making them conspicuous at times of low water. Red shiners

and plains killifish were scarce, except that plains killifish were abundant (and the only species present with the exception of one individual orangespotted sunfish) in two small shallow pools, one each in Pools 3 and 4. Of the sportfish species, the green sunfish and orangespotted sunfish were frequently encountered, but the largemouth bass and white crappie were rare.

BLOOD CREEK and DECEPTION CREEK

Blood Creek originates in northwestern Barton County and flows into Pool 2. At the time of the survey it consisted of isolated shallow pools. Fathead minnows were abundant and present at all sample sites. Green sunfish were scarce, found at only one sample site. Dead fathead minnows and black bullheads were found in a pool adjacent to the Hoisington sewage-treatment plant; probably the organically rich sediments observed there depleted oxygen at this site.

Deception Creek originates in north-central Barton County and flows into Pool 2. Fish were found in a small isolated pool and in a large spring-fed pool. Fathead minnows were abundant at both sites, with red shiners and black bullheads abundant; green sunfish were frequent and orangespotted sunfish common in the spring-fed pool. Local residents claimed to have regularly taken channel catfish from Deception Creek in the past.

WALNUT CREEKS and INLET CANAL

Walnut Creek originates in west-central Ness County with ephemeral tributaries extending westward into Lane County. Fathead minnows were abundant at all sample sites, while common carp and red shiners were locally abundant. Black bullhead, green sunfish, and orangespotted sunfish were frequently encountered, with sand shiners and largemouth bass rare, and white crappie scarce.

LITTLE CHEYENNE CREEK and OUTLET CANAL

The Little Cheyenne Creek is the natural drainage outlet of Cheyenne Bottoms. It has been channelized for approximately the first 2 miles as it flows away from Cheyenne Bottoms. It then follows a natural course to its confluence with Cow Creek in eastern Barton County. Fathead minnows, sand shiners, and red shiners were abundant throughout the creek. Orangespotted sunfish were locally abundant to common with green sunfish and black bullheads common. Plains killifish were locally common to rare, and common carp were rare.

ARKANSAS RIVER

Abundance and diversity of fish species in the Arkansas River depends upon the quality and amount of water present in the stream. The Arkansas River enters southwestern Barton County from Pawnee County and leaves southeastern Barton County into Rice County. When sufficient flow is available, water is diverted from the river at a diversion dam near Dundee into a canal which flows into the Dry Walnut Creek, to the Walnut Creek, and is then diverted from the Walnut Creek to Cheyenne Bottoms through an inlet canal. The diversion of the Arkansas River has two immediate effects. The first is that flow downstream of the diversion is reduced and at times of low flow is stopped entirely. The second is that species diversity of the Walnut creeks and Cheyenne Bottoms can be influenced by species transported from the Arkansas River, although this influence was not apparent in this study. Twenty samples from 10 sample sites on the Arkansas River in Barton and Rice counties yielded 19 species. The general abundances of species found were: sand shiner, red shiner, plains killifish, and mosquitofish--abundant; channel catfish--locally abundant; bluegill--locally abundant, generally rare; quillback and black bullhead--locally common; suckermouth minnow, stoneroller,

and green sunfish--frequent; fathead minnow, gizzard shad, and common carp--scarce; shorthead redhorse, largemouth bass, orangespotted sunfish, yellow bullhead, and Arkansas darter--rare.

SPECIES ACCOUNTS

The following accounts briefly summarize information about each species encountered in the survey area. Information includes sample station where each species was found, distribution of the species in the survey area and their relative abundance, general habitat requirements (Cross, 1967), size ranges of specimens collected, and the species' importance to the Cheyenne Bottoms ecosystem.

Gizzard Shad--Dorosoma cepedianum (LeSueur)

Stations: 5,7

Distribution/Abundance: Arkansas River--scarce.

Habitat: Large streams and reservoirs.

Importance To Bottoms: Minimal.

Common Carp--Cyprinus carpio Linnaeus

Stations: 8, 19, 27, 28, 30, 31, 33, 34, 35, 37, 40

Distribution/Abundance: Cheyenne Bottoms pools--common, Walnut Creeks and Inlet Canal--common at some sites, Little Cheyenne Creek and Outlet Canal-rare, and Arkansas River--rare.

Habitat: Ubiquitous in lakes and streams with large pools.

Size Range: 14-750 mm. Young of year (1986) occurred at the diversion dams on the Arkansas River (sta. 19) and Walnut Creek diversion structure. Their lengths on 5 June varied from 14 to 37 mm. Juvenile (mainly yearling) carp were taken at stations 27 and 31 in the Walnut Creek section of the diversion canal and were abundant in pools within the "Hub"

area (sta. 34), where their density was estimated to be 20 per 1,000 square feet on June 3. Their lengths varied from 81 to 208 mm, mean 142 mm. Adult carp were observed, captured by us, or caught by anglers in the pools of Cheyenne Bottoms, the adjacent lower segment of the Inlet Canal, and in a pool near the headwaters of Walnut Creek (sta. 28). The largest adult we captured was 750 mm total length. Although no adults were seined from the lower channel of Walnut Creek, they clearly occur there, as evidenced by recently hatched young. Carp were not recorded from Blood or Deception creeks but may invade those channels occasionally.

Importance To Bottoms: Common carp are the predominant large fish in the Bottoms pools, and are caught in significant numbers by anglers. Small carp are seined for bait by anglers, and adults are taken by bow hunters when pools are drained. Carp provide food for birds, reptiles, and mammals. Marvin Schwilling, a former manager of the refuge, associated use of the Bottoms by large numbers of white pelicans with an abundance of carp in the 1960's, when extensive areas of relatively deep, open water were available to them. Under present conditions populations of both carp and pelicans are reduced; however, large carp that become stranded and die during low-water periods provide food for many vertebrate and invertebrate scavengers. Carp have some detrimental effects on the habitat in the Bottoms. Their activity inhibits development of aquatic plants, partly by increasing turbidity, thus reducing light penetration and photosynthesis. Turbidity also increases heat absorption by surface water, increasing evaporation. In years immediately after development of the Bottoms, when water supplies were adequate and deep water persisted in borrow ditches alongside dikes, control of carp was attempted. The control method involved use of rotenone in pools and borrow ditches after

draining and subsequent alternation of draining and filling of pools. These efforts were largely unsuccessful because carp removed were replaced by others introduced from streams (Arkansas River and Walnut creeks) with flows diverted to refill the Bottoms.

Carp now occur so generally in the area--probably including impoundments in the drainage basin--that excluding them from the Bottoms is not feasible. Under current conditions, populations of large carp are limited by frequent drying of most pool areas, leaving little water deep enough to sustain many large carp. The present scarcity of submergent vegetation, as well as turbidity associated with wind and wave action, are attributable more to fluctuations in water level than to carp.

Suckermouth Minnow--Phenacobius mirabilis (Girard)

Stations: 1, 3, 5, 7, 10, 11, 12, 13, 14

Distribution/Abudnance: Arkansas River--frequent.

Habitat: Streams with permanent flow and substrate of sand and gravel, tolerant of fluctuating water levels and high turbidity.

Importance To Bottoms Minimal.

Red Shiner--Notropis lutrensis (Baird & Girard)

Stations: 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 22, 26, 27, 28, 30, 31, 32, 35, 37, 39, 40, 41

Distribution/Abundance: Cheyenne Bottoms Pools--scarce, Blood and Deception Creeks--abundant, Walnut creeks and Inlet Canal--locally abundant, Little Cheyenne Creek and Outlet Canal--abundant, and Arkansas River--abundant.

Habitat: All streams and natural bodies of water, very adaptable.

Size Range: Adults 28-90 mm.

Importance To Bottoms: The red shiner may be important as forage for birds, mammals, reptiles, and other fish. Its scarcity in Bottoms pools at the time of our survey may reflect heavy predation under low-water conditions. It is easily seined and is commonly used for bait by anglers.

Sand Shiner--Notropis stramineus (Cope)

Stations: 1, 2, 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 20, 27, 31, 32, 40, 41

Distribution/Abundance: Walnut creeks and Inlet Canal--rare, Little Cheyenne Creek and Outlet Canal--abundant, and Arkansas River--abundant.

Habitat: Shallow sandy streams.

Size Range: 54.5-60 mm

Importance To Bottoms: Minimal. Although water diverted from the Arkansas River may transport sand shiners to the Bottoms, they are unlikely to persist in the fluctuating pools with soft silt bottoms.

Fathead Minnow--Pimephales promelas (Rafinesque)

Stations: 3, 4, 5, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22, 23, 24, 25, 26, 28, 29, 30, 31, 32, 34, 35, 37, 38, 39, 40, 41

Distribution/Abundance: Cheyenne Bottoms pools--abundant, Blood and Deception Creeks--abundant, Walnut creeks and Inlet Canal--abundant, Little Cheyenne Creek and Outlet Canal--abundant, and Arkansas River--scarce.

Habitat: Pools of intermittent creeks with mud or firm clay bottoms.

Size Range: Young of year 16-28 mm, adults 34-79 mm.

Importance To Bottoms: Along with juvenile carp, the fathead minnow probably is the most important forage fish for birds, mammals, reptiles, and other fish in the Bottoms at the present time. It was by far the most abundant species in our samples from the Bottoms area and its direct tributaries.

Fathead minnows are very hardy, able to withstand high turbidity, intermittent flows, silty substrates, and poor water quality that often accompanies low-flow conditions. The fathead minnow spawns continuously in spring and summer on detritus above the substrate. These qualities make it an important species in Cheyenne Bottoms.

Stoneroller--Campostoma anomalum (Rafinesque)

Stations: 3, 4, 6, 9, 10, 12, 13, 14, 15, 16, 17, 18, 20

Distribution/Abundance: Arkansas River--frequent.

Habitat: Small streams and rivers with sand and gravel bottoms.

Importance To Bottoms: Minimal; intolerant of the habitats there.

Quillback--Carpiodes cyprinus (LeSueur)

Stations: 5, 6

Distribution/Abundance: Arkansas River--locally common.

Habitat: Rivers with sand bottoms, mainly in pools.

Importance To Bottoms: Minimal; apparently intolerant of habitats there, perhaps due to frequent extreme fluctuations in water area.

Shorthead Redhorse--Moxostoma macrolepidotum (LeSueur)

Stations: 9

Distribution/Abundance: Arkansas River--rare.

Habitat: Large streams with sand and gravel bottoms.

Importance To Bottoms: Minimal.

Black Bullhead--Ictalurus melas (Rafinesque)

Stations: 3, 8, 16, 17, 22, 26, 27, 28, 30, 31, 34, 35, 40

Distribution/Abundance: Cheyenne Bottoms pools--common, Blood and Deception Creeks--abundant, Walnut creeks and Inlet Canal--frequent, Little Cheyenne Creek and Outlet Canal--common, and Arkansas River--locally common.

Habitat: Calm backwaters, mouths of creeks, intermittent pools of creeks, tolerant of high turbidity and muddy bottoms.

Size Range: Juveniles (yearlings) 46-128 mm. Common and widespread; adults to 188 mm.

Importance To Bottoms: Because of its abundance, this species probably is important forage for birds, mammals, reptiles, and other fish. It is an important sport fish in the Bottoms and is especially tolerant of the frequent poor water conditions found there.

Yellow Bullhead--Ictalurus natalis (LeSueur)

Stations: 17

Distribution/Abundance: Arkansas River--rare.

Habitat: Clear, permanently flowing streams with rocky or gravel bottoms (in Kansas); occasionally in rivers and lakes.

Importance To Bottoms: Minimal.

Channel Catfish--Ictalurus punctatus (Rafinesque)

Stations: 8

Distribution/Abundance: Arkansas River--locally abundant.

Habitat: Large rivers to small streams, prefer sandy and rocky substrate, but tolerate muddy bottoms and fluctuating turbidity, do not require flowing water.

Importance To Bottoms: Although this species was only collected in the Arkansas River during this study, it is frequently caught by anglers in Cheyenne Bottoms and the other streams. It is an important sport fish and was extensively stocked in the Bottoms during the late 1950's. It is much less tolerant than the black bullhead of extreme drawdowns and poor water quality, which limit channel catfish populations at present.

Plains Killifish--Fundulus zebrinus (Jordan and Gilbert)

Stations: 1, 2, 3, 4, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 34, 36, 39, 40, 41

Distribution/Abundance: Cheyenne Bottoms pools--locally abundant, Little Cheyenne Creek and Outlet Canal--locally common, and Arkansas River--abundant.

Habitat: Shallow streams with sandy bottoms, especially if saline. Tolerates extremes of temperature and flow, but not prolonged intermittency if pools have soft silt substrate.

Size Range: Adults 50-86 mm.

Importance To Bottoms: The species is important forage for birds, mammals, reptiles, and other fish. Although killifish were abundant in two pools, their populations in the Bottoms probably fluctuate and are sustained by influx with water diverted from the Arkansas River (absent from Blood, Deception, and Walnut drainages).

Mosquitofish--Gambusia affinis (Baird and Girard)

Stations: 2, 3, 4, 6, 7, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20,

Distribution/Abundance: Arkansas River--abundant.

Habitat: Calm, shallow pools and backwaters of streams.

Size Range: Adults 19-46 mm.

Importance To Bottoms: Apparently minimal. Absence of mosquitofish from the Bottoms and tributary streams may be due to predation and winterkill under extreme low-water conditions.

Largemouth Bass--Micropterus salmoides (Lacepede)

Stations: 1, 5, 27, 35

Distribution/Abundance: Cheyenne Bottoms pools--rare, Walnut creeks and Inlet Canal--rare, and Arkansas River--rare.

Habitat: Will tolerate moderately turbid water of streams and ponds, with mud or sandy bottoms; requires clear water during growing season because it locates prey by sight.

Size Range: Adults 27.5-260 mm.

Importance To Bottoms: The largemouth bass is an important sport fish, but because of its rarity, it is not significant as such in the Bottoms. It was stocked in large numbers during the late 1950's, but did not survive well in the warm, shallow, turbid water of the pools.

Green Sunfish--Lepomis cyanellus (Rafinesque)

Stations: 8, 10, 11, 12, 13, 14, 16, 17, 20, 22, 24, 26, 30, 31, 32, 34, 35, 38, 40

Distribution/Abundance: Cheyenne Bottoms pools--frequent, Blood Creek--scarce, Deception Creek--common, Walnut creeks and Inlet Canal--frequent, Little Cheyenne Creek and Outlet Canal--common, and Arkansas River--frequent.

Habitat: Tolerate small, muddy creeks and pools.

Size Range: Juveniles and adults 34-140 mm.

Importance To Bottoms: This species provides forage for birds, mammals, and reptiles. It has some importance as a sport fish, readily available to anglers in the Bottoms. It easily tolerates the water conditions of the Bottoms pools.

Bluegill--Lepomis macrochirus (Rafinesque)

Stations: 8, 17, 18

Distribution/Abundance: Arkansas River--locally abundant.

Habitat: Streams, lakes, and ponds, prefers clear water with some aquatic vegetation.

Importance To Bottoms: Minimal.

Orangespotted Sunfish--Lepomis humilis (Girard)

Stations: 2, 13, 22, 28, 30, 31, 32, 34, 35, 36, 37, 38, 39, 40, 41

Distribution/Abundance: Cheyenne Bottoms pools--frequent, Deception Creek--common, Walnut creeks and Inlet Canal--frequent, Little Cheyenne Creek and Outlet Canal--abundant, and Arkansas River--rare.

Habitat: Prefers sandy streams, but tolerates muddy water with extensive water-level fluctuations and muddy bottoms.

Size Range: Juveniles and adults 32-85 mm.

Importance To Bottoms: This species is important as forage for birds, mammals, and reptiles. It is catchable by anglers but has little value because of its small size. It is important to the Bottoms because of its tolerance of water conditions there.

White Crappie--Pomoxis annularis (Rafinesque)

Stations: 30, 31, 35

Distribution/Abundance: Cheyenne Bottoms pools--rare and Walnut creeks and Inlet Canal--scarce.

Habitat: Large streams and rivers, lakes, and ponds.

Size Range: 75-166 mm

Importance To Bottoms: White crappie have been caught in large numbers by anglers in the Bottoms immediately following large inflows of water caused by heavy rains and flooding in the watersheds of its water-supplying streams. These fish are washed out of impoundments and into these streams and end up in the Bottoms where they exist in large numbers until low water conditions in the Bottoms cause them to die off. Because the populations are temporary (not self-sustaining in the Bottoms), this is not an important species to the area.

Arkansas Darter--Etheostoma cragini (Gilbert)

Stations: 10, 13

Distribution/Abundance: Arkansas River--rare.

Habitat: Shallow, clear water from springs or seeps, with little current, overgrown by watercress or other aquatic plants.

Importance To Bottoms: The Arkansas darter is of little significance to Cheyenne Bottoms, but Cheyenne Bottoms may have significance to the darter. The Arkansas darter is presently classified as a Threatened Species in Kansas. If continued diversion or additional diversions of water from the Arkansas River cause the river to cease to flow downstream from the diversion dam, the Arkansas darter may be extirpated from this portion of the river.

Table 14.3--Sample-station localities.

STATION	LOCALITY AND NAME
1	Barton Co.: Arkansas R., Sec. 6, T20S, R11W, 21 April 1984
2	Barton Co.: Arkansas R., Sec. 6, T20S, R11W, 27 April 1985
3	Barton Co.: Arkansas R., Sec. 33, T19S, R12W, 4 May 1985
4	Barton Co.: Arkansas R., Sec. 20, T20S, R14W, 18 May 1985
5	Barton Co.: Arkansas R., Sec. 6, T20S, R11W, 18 May 1985
6	Barton Co.: Arkansas R., NE Sec. 15, T20S, R11W, 18 May 1985
7	Barton Co.: Arkansas R., Sec. 33, T19S, R12W, 18 May 1985
8	Barton Co.: Arkansas R., Sec. 6, T20W, R11W, 21 May 1985
9	Barton Co.: Arkansas R., Sec. 6, T20S, R11W, 8 June 1985
10	Barton Co.: Arkansas R., NE Sec. 15, T20S, R11W, 19 Jan 1986
11	Barton Co.: Arkansas R., Sec. 33, T19S, R12W, 19 Jan 1986
12	Rice Co.: Arkansas R., Sec. 29, T20S, R10W, 5 April 1986
13	Rice Co.: Arkansas R., Sec. 34, T20S, R10W, 5 April 1986
14	Barton Co.: Arkansas R., SE Sec. 13, T20S, R11W, 13 April 1986
15	Barton Co.: Arkansas R., SW Sec. 6, T20S, R13W, 20 April 1986
16	Barton Co.: Arkansas R., SW Sec. 14, T20S, R14W, 20 April 1986
17	Barton Co.: Arkansas R., Sec. 6, T20S, R11W, 5 June 1986
18	Barton Co.: Arkansas R., NW Sec. 5, T20S, R13W, 10 June 1986
19	Barton Co.: Arkansas R., SW Sec. 14, T20S, R14W, 2 June 1986
20	Barton Co.: Arkansas R., Sec. 11, T20S, R11W, 5 June 1986
21	Barton Co.: Deception Creek, SW Sec. 14, T17S, R13W, 31 May 1986
22	Barton Co.: Deception Creek, NW Sec. 25, T17S, R13W, 31 May 1986
23	Barton Co.: Blood Creek, Sec. 10, T18S, R13W, 4 June 1986
24	Barton Co.: Blood Creek, Sec. 35, T17S, R14W, 4 June 1986
25	Barton Co.: Blood Creek, Sec. 14, T17S, R15W, 4 June 1986
26	Barton Co.: Dry Walnut Creek, Sec. 21, T19S, R14W, 2 June 1986
27	Barton Co.: Walnut Creek, Sec. 12, T19S, R14W, 2 June 1986
28	Rush Co.: Walnut Creek, Sec. 16, T18S, R20W, 4 June 1986
29	Ness Co.: Walnut Creek, Sec, 1, T19S, R22W, 4 June 1986
30	Barton Co.: Wet Walnut Creek, Sec. 9, T19S, R13W, 5 June 1986
31	Barton Co.: Inlet Canal, Sec. 33&34, T18S, R13W, 3 June 1986
32	Barton Co.: Inlet Canal. Sec. 34, T18S, R13W, 17 May 1986
33	Barton Co.: Cheyenne Bottoms Pool 5, 17 May 1986
34	Barton Co.: Cheyenne Bottoms Hub Area, 3 June 1986
35	Barton Co.: Cheyenne Bottoms Pool 1 at Inlet, 3 June 1986
36	Barton Co.: Cheyenne Bottoms pools 3 & 4 at pumps, 3 June 1986
37	Barton Co.: Cheyenne Bottoms Pool 5 at Inlet, 3 June 1986
38	Barton Co.: Outlet Canal, Sec. 2, T19S, R12W, 17 May 1986
39	Barton Co.: Little Cheyenne Creek, Sec. 12, T19S, R12W, 3 May 1986
40	Barton Co.: Little Cheyenne Creek, Sec. 2, T19S, R11W, 17 May 1986
41	Barton Co.: Little Cheyenne Creek, Sec. 36, T18S, R11W, 16 May 1986

DISCUSSION

No authoritative record of the fish fauna in Cheyenne Bottoms exists prior to construction of dikes and diversion canals in the 1950's, but several lines of evidence permit reasonable assumptions as to its species composition. The topography, soil type, precipitation pattern, and early descriptive accounts indicate that 1) the amount of surface water varied greatly, seasonally and from year to year; and 2) the quality of habitat for fishes was limited by prolonged concentration of fishes and detritus in isolated, shallow pools with clay and silt substrates, in both Blood and Deception creeks as well as in the Bottoms proper. Habitats of this kind generally support a few species of fishes that have large geographic ranges because of their broad environmental tolerance; it is unlikely that any endemic fishes, rare species, or species with restricted ranges occurred there. The absence of early published records may itself suggest that the fish fauna had low diversity or was of little interest. From the 1880's through the early 1900's, naturalists reported fishes from other streams in central and western Kansas in both the Arkansas and Smoky Hill drainages. Seemingly, collections would have been made and reported from Cheyenne Bottoms also, if a distinctive fauna existed or were expected there. Probably the original (natural) fauna of the basin consisted of the same species prevalent there today, with the exception of the introduced common carp: fathead minnow, red shiner, black bullhead, green sunfish, and orangespotted sunfish. Channel catfish, largemouth bass, and a few other species probably were present but not abundant.

Construction of the diversion canal from the Arkansas River through the lower Walnut Creek drainage to Cheyenne Bottoms provided access for several additional kinds of fishes into the Bottoms, notably the plains killifish, plains minnow, sand shiner, channel catfish, flathead catfish, common carp, white crappie, and other species listed in table 14.1. Dikes and borrow ditches within the management area coupled with farm ponds in the enlarged drainage basin (now including Walnut Creek), increased the area and depth of water available and brought about stocks of game fishes (largemouth bass, crappie, bluegill, channel catfish). The refuge pools sustained a significant fishery while water supplies were adequate to maintain the water levels desired. Enough deep water persisted to allow survival of many large fish, including carp, until the borrow ditches filled with silt from wave action and other erosional causes. The presence of carp contributed to the sport fishery and provided food for piscivorous waterfowl (pelicans, herons, grebes, kingfishers, terns, gulls, mergansers, cormorants, osprey, and other opportunistic birds of prey) but obstructed other management objectives of the area by reducing growth of desirable waterfowl-food plants.

Cheyenne Bottoms was developed primarily as a waterfowl refuge and public shooting area, and its management has been directed toward these purposes. Water levels are lowered during spring and summer to control undesirable vegetation and to facilitate the planting of food crops in pools for waterfowl during their fall migration, when diked areas are flooded again. This method of water-level manipulation (when sufficient water is available) is an effective management tool to provide migrating waterfowl with optimum habitat. However, from a fisheries management standpoint this fluctuation is not desirable.

In order to develop a self-sustaining, exploitable population of game fish, water levels should be at a maximum in spring and early summer when these species are reproducing and making most of their annual growth. Therefore, waterfowl management is not compatible with maintenance of a quality fishery, and the fishery deterioated. Both waterfowl values and fishery potential declined as water supplies diminished due to agricultural diversions of surface flows and groundwater upstream in the Arkansas basin. The lack of consistent flow of divertable water in the Arkansas River has been a serious management problem of the CBWMA for many years. Under present conditions, only a few kinds of fishes survive long confinement to the shallow pools and poor water quality that characterize the basin and its tributary streams through much of each year. The remaining fauna seems adequate to provide a forage base for birds, mammals, and reptiles that depend on small fishes for food, but its sport-fishing value is very limited.

The fathead minnow is the predominant species now. It persists in the Bottoms and in small pools along the channels of intermittent tributaries throughout the basin. Black bullheads remain common, principally as juveniles, in residual pools of the Bottoms, associated canals and control structures, and tributaries. Green sunfish and orangespotted sunfish are less abundant but widely distributed in the basin. All these species are relatively small fishes that probably reproduce successfully and more or less continuously in late spring and summer in the Bottoms, making their populations internally self-sustaining. Common carp occur in all pools of the Bottoms and some of its source streams. Numerous young-of-year and/or juvenile carp were found in the Bottoms, Walnut Creek, and the Inlet Canal in our survey (June 1986), but we believe the population of large adult carp has been reduced severely by frequent, extreme reduction in pool size and depth,

perhaps excepting Pool 1. We doubt that carp now present a serious management problem in the Bottoms, in terms of their impact on water clarity and vegetation useful to waterfowl. Fluctuating pool levels seem far more problematical, due to their shallow depth and water scarcity, than the surviving biomass of carp. In any case, eliminating carp from Cheyenne Bottoms and subsequently preventing its re-entry would be exceedingly difficult, economically impractical, and probably impossible. As the largest fish now available as prey for large fish-eating birds and other wildlife, carp populations as they now exist--composed mainly of juveniles 4 to 8 inches long--may balance out as beneficial to the Bottoms ecosystem.

Fishery values could be restored to the level of the 1950's and 1960's by any means that ensured permanent, deep water in the refuge area. If new sources of water are not obtained, deep pools might be created by excavation to the water table. That solution may entail problems with salinity, intensified over time by evaporation. Most fishes resident in the area tolerate moderate salinity, but this problem should be considered further if salt concentrations greater than 6 parts per thousand are anticipated. Only one native species, the plains killifish, withstands extremely high salinity.

External consequences of water allocations for management of Cheyenne Bottoms also affect fishes and thus merit consideration. Diversion of water from the Arkansas River into the Bottoms has been detrimental to fishes in that stream. Although the scope of the diversions is minor compared with diversions for irrigating croplands, the combined diversions have depleted flows essential to river fishes. The result has been that 4 to 8 species have disappeared from this reach of the Arkansas River, and populations of other species have declined. Some fishes native to the river (found downstream from

the Dundee diversion dam) are regarded as endangered or threatened, whereas none that inhabit Cheyenne Bottoms is so listed.

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APPENDIX 14.1--FIELD NOTES ON FISHES

Field notes are arranged in the same order as they appear in table 14.3, by drainage. Collections made by Ernsting prior to May 1986 are not included.

Station 17 5 June 1986

Kansas: Barton Co.: Arkansas River south of Ellinwood, Sec. 6, T20S, R11W

G.W. Ernsting, F.B. Cross, K.J. Irwin, M.L. Ernsting (GWE-15-86)

4.57 m seine

Red shiner--Abundant

Sand shiner--Abundant

Fathead minnow--Rare

Stoneroller--Common

Black bullhead--Common

Yellow bullhead--Rare

Plains killifish--Abundant

Mosquitofish--Abundant

Green sunfish--Common

Bluegill--Rare

Moderate current over sand-gravel, silty backwaters, with much detritus and vegetation.

Station 18 10 June 1986

Kansas: Barton Co.: Arkansas River 2 miles south, 1.5 miles west of Great Bend NW Sec. 5, T20S, R13W

G.W. Ernsting, M.L. Ernsting (GWE-16-86)

1.82 m seine

Red shiner--Abundant

Sand shiner--Abundsant

Stoneroller--Scarce

Plains killifish--Common

Mosquitofish---Abundant

Bluegill--Abundant

Clear water over silty substrate, much vegetation and detritus, weak current (less than 1 cfs).

Station 19 2 June 1986 4:00-4:30 p.m.

Kansas: Barton Co.: Arkansas River at Cheyenne Bottoms diversion dam near Dundee SW Sec. 14, T20S, R14W

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-1-86)

1.82 m seine

Common carp--Rare

Red shiner--Rare

Fathead minnow--Abundant

Plains killifish--Rare

Mosquitofish--Frequent

Water only in pool below first gate of dam, adjacent to north bank of river, much detritus, no flow, river channel dry.

Station 20 5 June 1986 2:00-3:30 p.m.

Kansas: Barton Co.: Arkansas River 2 miles south, 3 miles east of Ellinwood, Sec. 11, T20S, R11W

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-15-86)

4.57 and 1.82 m seines

Red shiner--Abundant

Sand shiner--Abundant

Fathead minnow--Scarce

Stoneroller--Frequent

Plains killifish--Abundant

Mosquitofish--Abundant

Green sunfish--Scarce

Turbid water over sand and black organic ooze substrate. Moderate flow, much cover, detritus, and vegetation. Depth to 0.71 m, mostly 0.15 m to 0.45 m.

Station 21 31 May 1986

Kansas: Barton Co.: Deception Creek SW Sec. 14, T17S, R13W

G.W. Ernsting, M.E. Eberle, B. Stark, M.L. Ernsting (GWE-13-86)

1.82 m seine

Fathead minnow--Abundant

Clear water over silty substrate, much detritus, no flow. Depth less than 0.15 m, intermittent 100%-shaded pools. Dense riparian growth.

Station 22 31 May 1986

Kansas: Barton Co.: Deception Creek NW Sec. 25, T17S, R13W

G.W. Ernsting, M.E. Eberle, W. Stark, M.L. Ernsting (GWE-14-86)

4.57 m seine

Red shiner--Abundant

Fathead minnow--Abundant

Black bullhead--Abundant

Green sunfish--Frequent

Orangespotted sunfish--Common

Turbid water over silty substrate, minimal flow, much detritus. Deep pool, average 1-1.5 m in depth.

Station 23 4 June 1986

Kansas: Barton Co.: Blood Creek, Sec. 10, T18S, R13W

F.B. Cross, G.W. Ernsting, K.J. Irwin, W. Hoffman (FBC-9-86)

4.57 m seine

Fathead minnow--Abundant

No flow, long large pool, algal bloom. Maximum depth 0.75m. Soft silty substrate.

4 June 1986 12:00-12:30 p.m.

Kansas: Barton Co.: Blood Creek immediately upstream from the Hoisington sewage-treatment plant, Sec. 9, T18S, R13W

F.B. Cross, G.W. Ernsting, K.J. Irwin, W. Hoffman

1.82 m seine

No live fish were found. Dead specimens of Fathead minnows and Black bullhead were plentiful, floating on the surface of the water. Kill was probably recent as dead fish were relatively fresh. Water turbid, no apparent flow. Average depth 0.7m. Firm clay substrate.

Station 24 4 June 1986

Kansas: Barton Co.: Blood Creek, sec. 35, T17S, R14W

F.B. Cross, G.W. Ernsting, K.J. Irwin, W. Hoffman (FBC-10-86)

1.82 m seine

Fathead minnow--Abundant

Green sunfish--Scarce

Much detritus, sand and silty substrate, flow less than 1 cfs, dense riparian growth.

Station 25 4 June 1986

Kansas: Barton Co.: Blood Creek, Sec. 15, T17S, R15W

F.B. Cross, G.W. Ernsting, K.J. Irwin, W. Hoffman (FBC-11-86)

1.82 m seine

Fathead minnow--Abundant

Flow less than 1 cfs, much detritus, silty substrate.

Station 26 2 June 1986

Kansas: Barton Co.: Dry Walnut Creek where diversion canal enters from Arkansas River, Sec. 21, T19S, R14W

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-2-86)

1.82 m seine

Red shiner--Common

Fathead minnow--Abundant

Black bullhead--Scarce

Green sunfish--Frequent

Intermittent pools, no flow, substrate silty with rip rap.

Station 27 2 June 1986

Kansas: Barton Co.: Wet Walnut Creek, segment which conducts Arkansas River diversion water, Sec. 12, T19S, R14W

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-3-86)

1.82 m seine

Common carp--Scarce

Red shiner--Scarce

Sand Shiner--Rare

Fathead minnow--Abundant

Black bullhead--Scarce

Largemouth bass--Rare

Silty substrate with much detritus, slight flow, average depth 0.25 m.

Station 28 4 June 1986 3:00-3:30 p.m.

Kansas: Rush Co.: Wet Walnut Creek, 1 mile north, 1 mile east of Alexander, Sec. 16, T18S, R20W

F.B. Cross, G.W. Ernsting, K.J. Irwin, W. Hoffman (FBC-12-86)

4.57 and 1.82 m seines

Common carp--Scarce

Red shiner--Common

Fathead minnows--Abundant

Black bullhead--Common

Orangespotted sunfish--Rare

No flow, large infrequent intermittent pools with much vegetation and detritus. Maximum depth of pools 0.75 m.

Station 29 4 June 1986 3:40-4:10 p.m.

Kansas: Ness Co.: Wet Walnut Creek 0.5 mile south of Bazine, Sec. 1, T19S, R22W

F.B. Cross, G.W. Ernsting, K.J. Irwin, W. Hoffman (FBC-13-86)

4.57 m seine

Fathead minnows--Abundant (only species present)

No flow, average depth of intermittent pools less than 0.2 m, much detritus and organic matter on silty substrate. Pools shaded by overhead vegetation.

Station 30 5 June 1986 9:20-9:50 a.m.

Kansas: Barton Co.: Wet Walnut Creek at diversion dam, Sec. 9, T19S, R13W

F.B. Cross, G.W. Ernsting, K.J. Irwin, M.L. Ernsting (FBC-14-86)

4.57 m seine

Common carp--Abundant

Red shiners--Common

Fathead minnows--Abundant

Black bullheads--Frequent

Green sunfish--Frequent

Orangespotted sunfish--Frequent

White crappie--Scarce

Seined on upstream side of structure. Water turbid, slight flow, silty substrate.

Station 31 3 June 1986 5:00-6:00 p.m.

Kansas: Barton Co.: Inlet Canal at Drop Structure, Secs. 33 and 34, T18S, R13W

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-8-86)

4.57 m seine

Common carp--Scarce

Red shiner--Common

Sand shiner--Rare

Fathead minnow--Abundant

Black bullhead--Frequent

Green sunfish--Frequent

Orangespotted sunfish--Frequent

White crappie--Scarce

Water turbid, slight flow. Upstream of drop structure, substrate firm clay and silt, downstream from drop structure substrate sand and gravel with rip-rap and organic detritus.

Station 32 17 May 1986

Kansas: Barton Co.: Inlet Canal at Refuge Headquarters, Sec. 34, T18S, R13W

G.W. Ernsting, K. Brunson, W. Hoffman, A.L. Ernsting (GWE-9-86)

4.57 m seine

Red shiner--Abundant

Sand shiner--Rare

Fathead minnow--Abundant

Green sunfish--Frequent

Orangespotted sunfish--Common

Slight flow, water turbid, firm clay substrate, recently scoured.

Station 33 17 May 1986

Kansas: Barton Co.: Cheyenne Bottoms Pool 5 at Inlet Structure

G.W. Ernsting and Kansas Herpetological Society

25.4 m seine

Common carp--Abundant

Standing, turbid water, no flow, average depth 0.3 m, soft silt and organic matter substrate.

Station 34 3 June 1986 9:45-11:00 a.m.

Kansas: Barton Co.: Cheyenne Bottoms "Hub" area at outlet structure

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-4-86)

9.14 and 4.57 m seines

Common carp--Common

Fathead minnow--Abundant

Black bullhead--Abundant

Plains killifish--Scarce

Green sunfish--Frequent

Orangespotted sunfish--Frequent

Water turbid, soft silty organic substrate, much detritus.

Station 35 3 June 1986 11:30 a.m.- 1:00 p.m.

Kansas: Barton Co.: Cheyenne Bottoms Pool 1 at Inlet Canal structure, "Y"

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-5-86)

9.14 m seine

Common carp--Rare (skull only)

Red shiner--Scarce

Fathead minnow--Abundant

Black bullhead--Abundant

Largemouth bass--Rare

Green sunfish--Frequent

Orangespotted sunfish--Frequent

White crappie--Scarce

Water turbid, depth immediatly below inlet structure 2 m, soft silty substrate rich in organic matter.

Station 36 3 June 1986 2:30-3:15 p.m.

Kansas: Barton Co.: Cheyenne Bottoms pools 3 and 4 at "pumps"

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-6-86)

9.14 m seine

Plains killifish--Abundant

Orangespoted sunfish--Rare

Water turbid, average depth 0.15 m, soft silt substrate.

Station 37 3 June 1986 4:00-4:30 p.m.

Kansas: Barton Co.: Cheyenne Bottoms Pool 5 at "Y"

F.B. Cross, G.W. Ernsting, K.J. Irwin (FBC-7-86)

9.14 m seine

Common carp--Scarce

Red shiner--Frequent

Fathead minnow--Abundant

Orangespotted sunfish--Frequent

Water turbid, no flow, average depth 0.35 m, soft silty substrate with much detritus.

Station 38 17 May 1986

Kansas: Barton Co.: Outlet Canal, channelized portion of Little Cheyenne Creek, Sec. 2, T19S, R12W

G.W. Ernsting, K. Brunson, W. Hoffman, A.L. Ernsting (GWE-11-86)

4.57 m seine

Fathead minnow--Abundant

Green sunfish--Common

Orangespotted sunfish--Abundant

Water turbid, no flow, average depth 0.3m, soft silty substrate, much detritus.

Station 39 3 May 1986

Kansas: Barton Co.: Little Cheyenne Creek 3 miles north of Ellinwood, Sec. 12, T19S, R12W

G.W. Ernsting, M.L. Ernsting (GWE-17-86)

4.57 m seine

Red shiner--Abundant

Fathead minnow--Abundant

Plains killifish--Rare

Orangespotted sunfish--Common

Water turbid, no flow, firm clay substrate, litle detritus.

Station 40 17 May 1986

Kansas: Barton Co.: Little Cheyenne Creek 6 miles north, 4 miles east of Ellinwood, Sec. 2, T19S, R11W

G.W. Ernsting, K. Brunson, W. Hoffman, A.L. Ernsting (GWE-12-86)

4.57 m seine

Common carp--Rare

Red shiner--Abundant

Sand shiner--Abundant

Fathead minnow--Abundant

Black bullhead--Common

Plains killifish--Common

Green sunfish--Frequent

Orangespotted sunfish--Abundant

Water turbid, flow 1 to 2 cfs, firm clay substrate, little detritus.

Station 41 16 May 1986

Kansas: Barton Co.: Little Cheyenne Creek 6.5 miles north, 5 miles east of Ellinwood, confluence with Cow Creek, Sec. 36, T18S, R11W

G.W. Ernsting, M.L. Ernsting, A.L. Ernsting (GWE-8-86)

1.82 m seine

Red shiner--Common

Sand shiner--Abundant

Fathead minnow--Abundant

Plains killifish--Rare

Orangespotted sunfish--Common

Water slightly turbid, soft silty substrate, areas of dense vegetation and detritus, flow 2 cfs. Cow Creek with no flow, only intermittent pools.

CHAPTER 15: AMPHIBIANS AND REPTILES OF CHEYENNE BOTTOMS

Kelly J. Irwin and Joseph T. Collins

INTRODUCTION

During May and early June 1986 a field survey of amphibians and reptiles was conducted at Cheyenne Bottoms Wildlife Management Area (CBWMA) in Barton County, Kansas. The survey was conducted continuously from 1 May to 18 May by Kelly J. Irwin (KJI) with visits and assistance from Joseph T. Collins (JTC) on three occasions: 2-4 May, 9-11 May, and 16-18 May. In addition, KJI assisted in the fish survey of this area from 2-6 June and made further observations and collections. Thus, this report contains results made over a span of 23 days involving at least 230 hours of fieldwork.

Objectives of the survey were to 1) determine the number of amphibian and reptilian species resident at CBWMA, 2) determine their relative abundance, 3) determine the general habitats used by individual species at CBWMA, and 4) determine what they eat and what eats them.

Data for objectives 1, 2, and 3 were obtained by direct observation and trapping. Few instances of feeding or predation were observed at CBWMA during the study, so information needed to satisfy objective 4 was obtained from data available for other areas of Kansas (based on Collins, 1982).

HISTORICAL DATA

Prior to this study, little was known of the species composition of amphibians and reptiles at CBWMA. The single previous assessment of a portion of the CBWMA herpetofauna was by Berglund (1967), who reported nine species of snakes from the area (table 15.1). We recorded 11 species during this study, consisting of the nine reported by Berglund (1967) plus two species that he predicted might occur on CBWMA. No other groups (i.e. amphibians, lizards,

turtles) have ever been subjected to intense study at CBWMA. Indeed, only incidental collections of any amphibians and reptiles (based on voucher specimens) have been made prior to this study, and these are summarized in table 15.2. However, some records of casual survey attempts are available and are here presented.

Table 15.1--A comparison of the number of species of snakes reported by Berglund (1967)* from CBWMA, and the number of species found during this study.

Species	Reported by Berglund (1967)	Found during this study (1986)
Coluber constrictor	X	X
Lampropeltis calligaster	X	X
Lampropeltis getulus		X
Nerodia rhombifera	X	X
Nerodia sipedon	X	X
Pituophis melanoleucus	X	X
Regina grahami	X	X
Sistrurus catenatus	X	X
Thamnophis radix	X	X
Thamnophis sirtalis	X	X
Tropidoclonion lineatum		X

*Berglund (1967, table 15.1) mentioned Heterodon nasicus (Western hognose snake) in his report but did not actually observe a specimen at CBWMA.

Table 15.2--Historical collections of amphibians and reptiles from CBWMA made prior to this study and based on voucher specimens in the Museum of Natural History, the University of Kansas, in chronological order (1942-1985).

Species	Date Collected	Collector(s)
Pseudacris clarki	6 August 1942	J. Twente
Sistrurus catenatus	16 May 1954	T. Andrews
Kinosternon flavescens	9 May 1959	C. Prophet
Thamnophis radix	June 1959	R. F. Clarke
Sistrurus catenatus	5 September 1962	J. O. Dick
Lampropeltis getulus	1971	R. Lattis
Chrysemys scripta	11 May 1973	J. T. Collins, et al.
Regina grahami	May 1974	G. W. Ferguson
Acris crepitans	20 September 1975	J. Caldwell, et al.
Rana blairi	20 Septemter 1975	T. D. Schwaner, et al.
Rana catesbeiana	20 September 1975	K. J. Irwin, T. D. Schwaner
Cnemidophorus sexlineatus	20 September 1975	C. Parsons
Chrysemys picta	17 July 1976	L. Miller, et al.
Nerodia rhombifera	17 July 1976	M. Capron
Thamnophis radix	17 July 1976	J. T. Collins, et al.
Lampropeltis getulus	13 September 1981	R. Loraine, H. Guarisco
Ambystoma tigrinum	22 September 1985	W. Hoffman
Regina grahami	23 September 1985	W. Hoffman
Chelydra serpentina	7 November 1985	W. Hoffman

On 11-12 May 1973, George Pisani, Ray Ashton, and one of us (JTC) made a trip to CBWMA and observed the following species: Sistrurus catenatus (12 adults; 9 alive, 3 dead), Thamnophis radix (5 adults; all found dead), Coluber constrictor (3 adults), Thamnophis sirtalis (2 adults), Chrysemys scripta (2 adults; 1 alive, 1 dead), Chelydra serpentina (1 large adult), Kinosternon flavescens (1 dead adult), Chrysemys picta (1 adult), and Pseudacris triseriata (1 adult male heard calling). In total, we collected or observed 29 specimens of nine species of amphibians and reptiles while driving on the CBWMA dike roads (refer to J. T. Collins field notes for 11-12 May 1973).

On 26 May 1973, Corson Hirschfeld and one of us (JTC) visited the CBWMA briefly and observed a single adult Sistrurus catenatus (captured by Stan

Roth) and found the severed head of an adult Chelydra serpentina (refer to J. T. Collins field notes for 26 May 1973).

On 20-21 September 1975, members of the Kansas Herpetological Society assembled at CBWMA and observed the following 12 species (no counts were made of the number of individuals of each species): Acris crepitans, Pseudacris triseriata (chorusing), Rana blairi, Rana catesbeiana, Chelydra serpentina, Chrysemys picta, Cnemidophorus sexlineatus, Nerodia rhombifera, Regina grahami, Thamnophis radix, Thamnophis sirtalis, and Sistrurus catenatus (refer to J. T. Collins field notes for 20-21 September 1975).

On 16-18 July 1976, members of the Kansas Herpetological Society again gathered at CBWMA and observed the following 17 species (where known, the number of specimens of each species observed is given): Scaphiopus bombifrons, Bufo cognatus, Bufo woodhousi, Rana blairi, Rana catesbeiana, Pseudacris triseriata, Chelydra serpentina, Kinosternon flavescens (1 adult), Chrysemys picta (1 large adult female), Lampropeltis getulus (1 adult), Nerodia rhombifera (many observed, including one large female), Nerodia sipedon, Pituophis melanoleucus, Regina grahami, Thamnophis radix (4 adults, 2 of which were unusual red morphs), Thamnophis sirtalis, and Sistrurus catenatus (7 adults). Refer to J. T. Collins field notes for 16-18 July 1976 and to Capron and Perry (1976).

On 29 May 1983 and 31 August 1985, Suzanne Collins and one of us (JTC) briefly visited CBWMA. On each occasion we observed single adult Lampropeltis calligaster (refer to J. T. Collins field notes for those dates).

The above observations plus the report by Berglund (1967), when combined with the historical data presented in table 15.2, provided a list of the herpetofauna of CBWMA as it was known prior to this study. The list included nine species of amphibians (one salamander and eight frogs and toads) and 15

species of reptiles (four turtles, one lizard, and 10 snakes), for a total of 24 species.

COMPOSITION OF THE HERPETOFAUNA

During this study, we observed or collected 22 of the 24 previously recorded species (only Ambystoma tigrinum and Pseudacris clarki were not found) and added three species to the herpetofaunal list of CBWMA (see table 15.3). Our inablility to locate Ambystoma tigrinum may be due to its annual activity cycle. The single previous record for CBWMA was found in the fall; possibly these salamanders are only active at CBWMA during fall and winter, as has been noted for other areas of Kansas (Collins, 1982) and Missouri (Johnson, 1977). Pseudacris clarki is known from CBWMA on the basis of a single voucher specimen (see table 15.2). Our inability to find or hear it cannot be explained; it was not encountered at CBWMA during the study period, a time when it is most active and observable elsewhere in the state. Only future collecting can unquestionably confirm it as a member of the CBWMA herpetofauna. Combining the historical list of 24 species with our discovery of three additional taxa gives a total of 27 amphibian and reptilian species known to occur at CBWMA (see table 15.3).

Table 15.3--A list of the amphibian and reptilian species known to occur at CBWMA based on historical records and observations, and this study.

Species scientific name	Common Name
1. *Ambystoma tigrinum*	Tiger salamander
2. *Scaphiopus bombifrons*	Plains spadefoot
3. *Bufo cognatus*	Great Plains toad
4. *Bufo woodhousi*	Woodhouse's toad
5. *Acris crepitans*	Cricket frog
6. *Pseudacris clarki*	Spotted chorus frog
7. *Pseudacris triseriata*	Western chorus frog
8. *Rana blairi*	Plains leopard frog
9. *Rana catesbeiana*	Bullfrog
10. *Chelydra serpentina*	Common snapping turtle
11. *Kinosternon flavescens*	Yellow mud turtle
12. *Chrysemys picta*	Painted turtle
13. *Chrysemys scripta*	Slider
14. *Trionyx spiniferus**	Spiny softshell
15. *Eumeces obsoletus**	Great Plains skink
16. *Cnemidophorus sexlineatus*	Racerunner
17. *Coluber constrictor*	Racer
18. *Lampropeltis calligaster*	Prairie kingsnake
19. *Lampropeltis getulus*	Common kingsnake
20. *Nerodia rhombifera*	Diamondback water snake
21. *Nerodia sipedon*	Northern water snake
22. *Pituophis melanoleucus*	Bullsnake
23. *Regina grahami*	Graham's crayfish snake
24. *Thamnophis radix*	Plains garter snake
25. *Thamnophis sirtalis*	Red-sided garter snake
26. *Tropidoclonion lineatum**	Lined snake
27. *Sistrurus catenatus*	Massasauga

*indicates a species first recorded from CBWMA during this study.

RELATIVE ABUNDANCE OF THE HERPETOFAUNA

Assessment of the relative abundance of 27 species of amphibians and reptiles during a 23-day survey is difficult. It became obvious to us that comparisons between amphibians and reptiles would be futile. Amphibians are more aquatic, are seasonally active and abundant at night during the spring, and are extremely difficult to catch or observe except at the peak of breeding. Reptiles are more terrestrial, diurnal during spring, reach a peak abundance during spring and early summer, and are easily observed, trapped, or caught by hand. These differences are reflected in the number of specimens observed or caught during this survey--amphibians (27), reptiles (703). This difference, however, may not reflect actual abundance, because a single chorus of amphibians may represent hundreds, or even thousands, of individuals. Because of this, we have not compared the two groups. Instead, we present the two groups separately, ranking the species within each group according to observed abundance (reptiles) or observed abundance plus choruses heard (amphibians). The results are shown in table 15.4 (reptiles) and table 15.5 (amphibians).

Table 15.4--The eighteen species of reptiles known to occur at CBWMA, ranked in order of their observable abundance based on data from this study. The specimens found dead were killed by vehicles or people (probably anglers).

Species	# found dead	# observed alive	Total
Chrysemys picta	2	286	288
Nerodia rhombifera	25	193	218
Regina grahami	22	60	82
Sistrurus catenatus	9	17	26
Thamnophis radix	6	19	25
Thamnophis sirtalis	0	10	10
Nerodia sipedon	3	6	9
Kinosternon flavescens	2	5	7
Coluber constrictor	0	7	7
Cnemidophorus sexlineatus	0	6	6
Chrysemys scripta	0	5	5
Lampropeltis getulus	2	3	5
Trionyx spiniferus	0	5	5
Chelydra serpentina	0	4	4
Pituophis melanoleucus	0	3	3
Eumeces obsoletus	0	1	1
Lampropeltis calligaster	0	1	1
Totals	71	632	703

Table 15.5--The nine species of amphibians known to occur at CBWMA, ranked in order of abundance during this study based on individuals observed or caught and choruses heard.

Species	# observed/caught	# choruses heard
Pseudacris triseriata	9	9
Acris crepitans	1	4
Rana catesbeiana	1	2
Scaphiopus bombifrons	9	1
Bufo cognatus	2	1
Rana blairi	4	0
Bufo woodhousi	1	0
Ambystoma tigrinum*	0	-
Pseudacris clarki*	0	0
Totals	27	17

*these species were not found during the survey but have been documented as occurring at CBWMA (see table 15.2).

Reptiles. Table 15.4 shows clearly that two semi-aquatic species, Chrysemys picta and Nerodia rhombifera, are the most observably abundant reptiles at CBWMA and are probably of biological significance to the rest of the vertebrate fauna in the refuge. Additionally, the semi-aquatic Regina grahami may be nearly as abundant as the previously mentioned species, because it is more difficult to observe and somewhat more secretive. These three species comprised 83% of the reptilian observations made during the survey, and this observable abundance is probably accurate for the entire season (spring, summer, fall) at CBWMA. However, the abundance of these three species of reptiles probably reflects the ease with which they are observed, a condition brought about by lower water levels at CBWMA in recent years. These lower levels concentrate available water and the species dependent on it and may account for the high number of specimens of these three species that we observed. Nonetheless, having the eight semi-aquatic species of reptiles concentrated probably allowed for better comparison with the 10 terrestrial taxa, which have less available habitat per acre at CBWMA.

Terrestrial reptiles known to occur at CBWMA consist of 10 species (compared to only eight semi-aquatic species) but comprised only 85 of 703 observations (12%). Thus, the reptilian fauna at CBWMA is made up primarily of semi-aquatic species (88% of observations), a condition expected given the available habitat.

Amphibians. Table 15.5 shows the comparative abundance of seven of the nine species of amphibians known to occur at CBWMA (five of which are considered to be semi-aquatic). Ambystoma tigrinum and Pseudacris clarki are not discussed here, because they were not found during our survey despite having been previously documented at CBWMA (see table 15.2). In table 15.5, greater weight in assessing abundance was given to choruses heard, because

such choruses usually involve a concentration of individuals and indicate breeding activity. Thus, Pseudacris triseriata and Acris crepitans are probably the most abundant amphibians at CBWMA and are probably the most biologically significant in relation to the rest of the vertebrate fauna inhabiting the refuge. The low number of observations of Rana blairi and Rana catesbeiana, frogs which require stable water levels, was disturbing. Our study period was too early in the season to listen for bullfrog chorusing and too late for the plains leopard frog. Nonetheless, we expected to see more individuals. After our survey was completed, Wayne Hoffman (personal communication, 1986) reported to us that bullfrogs were calling on 23-24 June 1986 at CBWMA. We adjusted table 15.5 to reflect his observations.

The amphibian fauna at CBWMA is probably more abundant than our survey indicated, but based on low numbers of specimens that should be abundant in such habitat, apparently has suffered from fluctuating water levels.

HABITATS AND HABITS OF THE HERPETOFAUNA AT CHEYENNE BOTTOMS

In this part of our report we address where amphibians and reptiles live at CBWMA, what they eat, and what eats them. The brief habitat descriptions given here are based on observations made during the survey and augmented by our knowledge of their habitat preferences elsewhere in Kansas. Some data were taken from Collins (1982). Because virtually no observations on feeding or predation were recorded during our survey, we have relied heavily on our personal knowledge plus information in Collins (1982). In the following accounts, reptiles are presented first, with species in the order of their observed abundance (table 15.4); amphibians are presented second, in the same sequence (table 15.5).

Chrysemys picta (Painted turtle).

Habitat Preferences: This semi-aquatic turtle prefers shallow, soft-bottom ponds, a habitat readily available at CBWMA. Turtles were active during the day, basking on driftwood or floating on the water surface, and were most commonly observed in Pool 1 (172 of 288 observations = 60%), a site which contained the deepest and most stable water level.

Food Preferences: Adult painted turtles feed on both plant and animal matter; adults have a greater preference for plant matter, whereas juveniles are more carnivorous. This turtle is an important scavenger, feeding on dead fishes discarded by anglers. Individuals were observed at CBWMA feeding on dead Nerodia rhombifera. This reptile probably represents little threat to water birds at the refuge.

Potential Predators: For adult turtles, people are the main predators; one adult and one juvenile were found dead at CBWMA. The eggs (4 to 20 per clutch annually) and young of painted turtles are eaten by anything big enough to swallow them, including water birds, small mammals, other turtles, large frogs, fishes, and snakes.

Nerodia rhombifera (Diamondback water snake).

Habitat Preferences: This semi-aquatic snake prefers permanent lakes, swamps, and backwaters of rivers. Berglund (1967) reported it as the most abundant water snake at CBWMA and noted "hundreds were seen during the summer." He often observed them basking atop muskrat dens or in grass along the dike shoreline. The inlet canal at CBWMA, particularly at its east end near Pool 1 (where the deepest and most stable water level was available), provided excellent habitat for this species during our survey, and we found N.

rhombifera the most observably abundant snake in the refuge. These snakes spent much time basking on driftwood or swimming; in the summer they are nocturnal, avoiding daytime heat.

Food Preferences: The diamondback water snake feeds primarily on fishes; larger prey items are eaten as the snake increases in size. This snake is an important scavenger, feeding on dead fishes discarded by anglers. Scavenging efforts by diamondback water snakes, when combined with those of the painted turtle; northern water snake, and slider, undoubtedly contribute greatly to the maintenance of CBWMA.

Potential Predators: Large turtles, raptors, and some small mammals feed on adult diamondback water snakes, but another danger to these reptiles at CBWMA appears to be vehicles and people. Twenty-five of these snakes were found dead--nine adults killed by anglers, and four adults and 12 juveniles killed by cars. Females of this species produce large broods (14 to 62 young per litter annually), and these young snakes undoubtedly provide much fodder for water birds, raptors, small mammals, other reptiles, bullfrogs, and fishes.

Regina grahami (Graham's crayfish snake).

Habitat Preferences: The semi-aquatic Graham's crayfish snake prefers to live near ponds and sluggish streams. Berglund (1967) considered this species common at CBWMA; he observed over 20 during a summer at the refuge. Over half (47 of 82) of our observations of these snakes were made along the inlet canal of CBWMA, a site where the water level was most stable. This is a secretive species, much less visible than the painted turtle and diamondback water snake, and it may be more common than our observations indicated.

Food Preferences: As its name implies, this reptile feeds exclusively on crayfish.

Potential Predators: A major danger to this snake at CBWMA is vehicles, which killed 22 of 82 (27%) individuals observed during our survey. Water birds, raptors, and small mammals eat adult and young Graham's crayfish snakes. Young snakes (9 to 39 per litter annually) are eaten also by turtles, bullfrogs, other snakes, and fishes. One sub-adult Graham's crayfish snake was found in the gut of a common kingsnake (Lampropeltis getulus) at CBWMA.

Sistrurus catenatus (Massasauga)

Habitat Preferences: The only venomous serpent found at CBWMA, this terrestrial creature prefers open areas and is commonly encountered on the dikes of the refuge. Berglund (1967) considered it very common at CBWMA and reported eight observations (6 collected, 2 found dead). Specimens collected by him were found "no more than 100 yards from the nearest water.... in grassland areas." Of 26 individuals observed by us, 11 (42%) were found on dikes along the inlet canal at CBWMA; most were crossing the dike, but a few were basking on grassy slopes.

Food Preferences: The massasauga is an opportunistic predator, feeding on small rodents (abundant on the dikes at CBWMA), frogs, lizards, and other snakes. It may occasionally eat young birds and birds eggs, but this has not been documented.

Potential Predators: Thirty-five percent (9 of 26) of the massasaugas observed during our survey were found dead; one was killed by a human, while eight were run over by vehicles. Water birds, raptors, and small mammals eat adult and young massasaugas. Young (5 to 13 per litter annually) are eaten also by turtles, bullfrogs, other snakes, and fishes.

Thamnophis radix (Plains garter snake)

Habitat Preferences: This terrestrial snake prefers open grassy areas, particularly along the edges of marshes, lakes, and prairie streams. Berglund (1967) considered this snake the most common species at CBWMA and observed "hundreds....during the summer." He reported it most common in grassland areas and along the dikes. During our survey, the plains garter snake was most often seen along the inlet canal while crossing the dike (8 of 25 observations = 32%). Of the 25 snakes observed, one was an unusual red morph previously reported by Collins (1982). This morph apparently is known only from CBWMA but was not noted by Berglund (1967).

Food Preferences: Plains garter snakes eat earthworms, toads, frogs, salamanders, fishes, and small rodents.

Potential Predators: Water birds, raptors, small mammals, turtles, and other snakes eat adult and young plains garter snakes. Young (5 to 60 per litter annually) are eaten also by bullfrogs and fishes. Berglund (1967) commented that the mortality rate was high for this species, due to its sunning on dike roads where it was run over by vehicles. During our survey, 6 of 25 (24%) were found dead--all killed by vehicles.

Thamnophis sirtalis (Red-sided garter snake)

Habitat Preferences: This terrestrial snake inhabits a wide variety of habitats, including marshes, wet meadows, pond margins, woodlands and woodland edge, floodplains, and cultivated fields. Berglund (1967) found only one example of this species at CBWMA. Of the 10 examples found during our survey, four were taken near the junction between pools 1, 2, and 5; three were found near the CBWMA headquarters.

Food Preferences: The red-sided garter snake feeds chiefly on frogs and earthworms, but toads, small rodents, and other small snakes are eaten also.

Studies elsewhere in Kansas (Douglas and Harvey counties) indicated that frogs are the predominant prey item.

Potential Predators: Water birds, raptors, large turtles, small mammals and other snakes feed on adult and young red-sided gartersnakes. The young (7 to 80 per litter annually) are eaten also by bullfrogs and fishes.

Nerodia sipedon (Northern water snake)

Habitat Preferences: The semi-aquatic northern water snake lives in and around any body of water, from small forested rocky streams to large, open marshes and wetlands. Berglund (1967) found only two examples of this snake during a summer at CBWMA and stated that it does "not seem to be as common on the area as the diamond-backed (sic) water snake." We agree. Of the nine northern water snakes observed by us during this survey, seven (77%) were found at the junction of pools 1, 2 and 5, a site where water was deepest and most stable at CBWMA.

Food Preferences: Diener (1957), utilizing data which were taken in part from northern water snakes in Meade County, Kansas, showed that fishes made up over 75% of the diet of this serpent; minnows were the predominant prey fish. This snake is known to eat amphibians also.

Potential Predators: Water birds, raptors, small mammals, large turtles, and other snakes eat both adult and young northern water snakes. The young snakes (8 to 46 per litter annually) are eaten by bullfrogs and large fishes also. Three of the nine examples (33%) of this snake found by us during the survey were dead, two killed by anglers and one by a vehicle.

Kinosternon flavescens (Yellow mud turtle)

Habitat Preferences: The semi-aquatic yellow mud turtle prefers a habitat consisting of quiet water with a mud bottom but can survive long

periods of drought by burrowing into mud. Of the seven examples of this species found by us during the survey, four were taken in or near Pool 2; the remaining three were found on the dike between pools 3 and 4.

Food Preferences: The yellow mud turtle is an omnivore; diet items include insects, crayfish, snails, earthworms, amphibians, dead fishes, and aquatic vegetation.

Potential Predators: Adult yellow mud turtles have few predators, due to their protective shell and the offensive odor they emit when molested. Two of the seven turtles of this species found by us were dead; both had been run over by vehicles. Young yellow mud turtles (1 to 4 eggs per clutch annually) are eaten by water birds, small mammals, large fishes, other turtles, and snakes.

Coluber constrictor (Yellowbelly racer)

Habitat Preferences: This terrestrial snake inhabits open grasslands and prairies. Berglund (1967) collected two examples of this reptile during the course of a summer; both were found in dry grassland areas, about 300 yards from water. The seven yellowbelly racers found by us during this survey were found along dike roads throughout CBWMA. Six of the seven were taken in traps.

Food Preferences: Yellowbelly racers eat lizards, rodents, frogs, other snakes, and insects. They may also feed on young birds and birds eggs.

Potential Predators: Hawks and small mammals are primary predators of adults and young of this snake. The young (8 to 22 eggs per clutch annually) are eaten by water birds and bullfrogs also.

Cnemidophorus sexlineatus (Racerunner)

Habitat Preferences: This terrestrial diurnal lizard prefers hot, dry, open, sandy areas with little leafy vegetation, a habitat available at CBWMA on or along the dike roads. All six examples of the racerunner found by us during this survey were taken along dike roads between 1100 and 1430 hours.

Food Preferences: This lizard eats primarily insects and spiders.

Potential Predators: Snakes, small mammals, and birds are known to eat adult racerunners. Their eggs (2 to 6 per clutch; more than one clutch may be laid annually) are dug up and eaten by snakes and mammals also.

Chrysemys scripta (Slider)

Habitat Preferences: This semi-aquatic turtle prefers lakes and large ponds with soft mud bottoms, a habitat available at CBWMA when all five pools have sufficient water levels. Three of five adults (60%) observed by us during this survey were at the junction of pools 1, 2 and 5, a site which contained the deepest and most stable water level at CBWMA.

Food Preferences: Sliders are omnivores, eating both aquatic plants and animals. Along with aquatic vegetation, they consume insects, tadpoles, snails, crayfish, and fishes. Large adult sliders are potential predators of young ducks, but such predation has not been documented.

Potential Predators: Adult sliders probably have no predators; some may be killed by vehicles while crossing dike roads at CBWMA. Young sliders are eaten by water birds, small mammals, larger turtles, snakes, fishes, and bullfrogs. Slider eggs (4 to 20 per clutch annually) are dug up and consumed by small mammals and snakes.

Lampropeltis getulus (Common kingsnake)

Habitat Preferences: The terrestrial common kingsnake lives in moist open lowlands and prairies in western Kansas, a habitat readily available at CBWMA. Berglund (1967) did not find this serpent at CBWMA during his survey. Five examples (3 adults and 2 juveniles) of this snake were observed by us at CBWMA. Three of the five were found along the inlet canal dike road between pools 2 and 5.

Food Preferences: Common kingsnakes eat rodents, small birds, birds eggs, reptile eggs, lizards, and other snakes. The population of these snakes at CBWMA is low enough that they are probably of little threat to bird life. One common kingsnake found at CBWMA during this survey contained a sub-adult Graham's crayfish snake (Regina grahami) in its gut.

Potential Predators: Raptors, water birds, and small mammals eat adult common kingsnakes. The young are consumed by bullfrogs and other snakes also. Common kingsnake eggs (5 to 17 per clutch annually) are eaten by small mammals and other snakes.

Trionyx spiniferus (Spiny softshell).

Habitat Preferences: This semi-aquatic turtle lives in almost any body of water, but prefers those with soft, mud bottoms surrounded by sand or mud flats. The five examples of this turtle observed by us during this survey were all seen swimming in or basking alongside of the inlet canal, where water levels were fairly stable.

Food Preferences: Spiny softshells are carnivorous, eating insects, worms, crayfish, fishes, tadpoles, and frogs. Large adult females may sometimes eat young birds, but this has not been documented.

Potential Predators: Large adult spiny softshells probably have no predators because of their size and aggressive disposition. Small adults and young are eaten by water birds, small mammals, other turtles, large fishes, and bullfrogs. The eggs (4 to 32 per clutch annually) are consumed by small mammals and snakes also.

Chelydra serpentina (Common snapping turtle)

Habitat Preferences: This semi-aquatic turtle is found in every body of water but prefers lakes, marshes, and ponds with soft mud bottoms, habitat in abundance at CBWMA. Four large adults (straight line upper shell length of 10 inches or more) were observed by us during this survey; all were found in or near the inlet canal between the CBWMA headquarters and the junction between pools 1, 2, and 5, where water levels were deepest and most stable. A specimen taken prior to our survey (see table 15.2) weighed approximately 32 pounds.

Food Preferences: This large reptile is an omnivore, eating whatever it can overpower and swallow. Although known to consume aquatic vegetation, it is predominantly a carnivore and will eat insects, crayfish, worms, clams, snails, fishes, frogs, toads, salamanders, snakes, other turtles, birds, small mammals, and available carrion. Of all reptiles known to occur at CBWMA, this turtle probably represents the only significant threat to adult and young water birds.

Potential Predators: Adult common snapping turtles have no known predators (other than people and their vehicles), because of their large size and aggressive disposition. Young turtles are eaten by water birds, raptors, small mammals, bullfrogs, large fishes, other turtles, and snakes. The eggs of this turtle (25 to 83 eggs per clutch; more than one clutch may be laid

annually) are eaten by small mammals and snakes also. Undoubtedly, the young and eggs of the common snapping turtle contribute much to the diet of other vertebrates at CBWMA.

Pituophis melanoleucus (Bullsnake)

Habitat Preferences: This large terrestrial snake is a resident of open grasslands. Berglund (1967) observed five examples of this reptile at CBWMA during his summer survey; they were found along dike roads and in grassland areas. The three adult specimens collected by us during this survey were all taken on dike roads.

Food Preferences: Bullsnakes feed primarily on rodents, but will also eat gophers and rabbits. They sometimes consume birds and bird eggs also and thus may occasionally prey on the young and eggs of water birds at CBWMA.

Potential Predators: Adult bullsnakes are eaten by raptors and mammals. Young bullsnakes are taken by raptors, small mammals, and other snakes. Bullsnake eggs (5 to 19 per clutch annually) are consumed by small mammals and other snakes.

Eumeces obsoletus (Great Plains skink)

Habitat Preferences: This terrestrial lizard is normally an inhabitant of open, rocky hillsides with little or no vegetation. The habitat at CBWMA is less than optimal for this species and probably accounts for our finding only one adult example during this survey; the single specimen was found in a grassy area near CBWMA headquarters.

Food Preferences: Great Plains skinks eat insects, spiders, and snails. They may consume small rodents and other lizards also.

Potential Predators: Due to its very secretive habits, mortality from predation is probably very low for this lizard. However, snakes, large birds, and small mammals will eat the Great Plains skink. An adult female of this species produces 7 to 17 eggs per clutch annually.

Lampropeltis calligaster (Prairie kingsnake)

Habitat Preferences: This secretive, terrestrial snake prefers a variety of habitats, from rocky hillsides with open woods to prairie grassland and sand prairies. Berglund (1967) found three examples of this serpent at CBWMA during his summer survey; one was found on a dike, and two were taken "in grassland areas, far from water." Only one adult specimen was collected by us during this survey, and it was found at the CBWMA headquarters, not far from standing water.

Food Preferences: Prairie kingsnakes feed primarily on small mammals, lizards, and other small snakes. They may also consume young birds and bird eggs, but this has not been documented.

Potential Predators: Raptors, small mammals, and other snakes eat adult and young prairie kingsnakes. The eggs of this reptile (6 to 17 per clutch annually) are eaten by small mammals and other snakes also.

Tropidoclonion lineatum (Lined snake)

Habitat Preferences: This small terrestrial snake inhabits the hillsides of open prairies and woodland edge. The former habitat is available on the dike slopes at CBWMA. Berglund (1967) did not record this species from the refuge. The single specimen found by us during this survey was taken at night along Pool 5.

Food Preferences: This snake feeds exclusively on earthworms.

Potential Predators: Birds, other snakes, and small mammals eat both adult and young lined snakes. Individual broods of this reptile range from 2 to 12 annually.

AMPHIBIANS

Pseudacris triseriata (Western chorus frog)

Habitat Preferences: Western chorus frogs are semi-aquatic and utilize a wide variety of habitats, including damp meadows, pastures, ponds, lakes, floodplains, moist woods, streams, and roadside ditches. Nine examples of this frog were collected by us during this survey; all were taken while calling at night from roadside pools and ditches. Of more significance, substantial breeding choruses of this frog were heard at night throughout the aquatic portions of CBWMA from 1 May to 2 June, and these creatures were still chorusing on 23 June (Wayne Hoffman, personal communication, 1986) following a 2-inch rain. Provided suitable aquatic situations are available, this frog probably choruses throughout summer.

Food Preferences: Insects and spiders make up the diet of this small frog.

Potential Predators: Water birds, snakes, turtles, fishes, small mammals, and larger frogs probably consume great numbers of this abundant amphibian and its tadpoles. A female western chorus frog produces 100 to 1,500 eggs annually.

Acris crepitans (Cricket frog)

Habitat Preferences: The semi-aquatic cricket frog is the smallest amphibian found at CBWMA and prefers to inhabit the muddy, beachlike edges of small, shallow streams and ponds. It avoids deep waters. Although we collected only a single example of this frog at CBWMA, choruses were heard at

night from 1 May to 5 June at two areas, around Pool 1 and near the CBWMA headquarters. However, Wayne Hoffman (personal communication, 1986) informed us that this amphibian was calling throughout the refuge on 23 June following a 2-inch rain.

Food Preferences: This tiny frog eats small insects and spiders.

Potential Predators: Water birds, snakes, turtles, fishes, small mammals, and larger frogs probably eat great quantities of this frog and its tadpoles. A female cricket frog produces 170 to 400 eggs per mass and may reproduce twice annually.

Rana catesbeiana (Bullfrog)

Habitat Preferences: Bullfrogs are semi-aquatic and have a strong preference for permanent lakes, rivers, streams, and swamps where deep, stable water levels are available. Largest of amphibians (it can weigh nearly 1 1/2 pounds) at CBWMA, this species undergoes heavy population fluctuation during dry periods. The single example observed by us during this study was found on 13 May in the inlet canal at the junction of pools 1, 2, and 5, a site at CBWMA where water is deepest. Although we heard no choruses during our survey, Wayne Hoffman (personal communication, 1986) informed us that bullfrogs were calling at CBWMA on the evening of 23 June and at mid-day on 24 June; both choruses were along the dike road separating pools 3 and 4. This frog may be more abundant than our data indicate because it breeds later than most Kansas amphibians and may have just started chorusing after our survey was completed. Nonetheless, these frogs emerge from winter retreats as early as February and are quite visible. Thus we anticipated seeing more than one adult during our survey. Equally inexplicable was the lack of bullfrog tadpoles in areas of concentrated water; none was seen, indicating a lack of

breeding activity the previous year, because these larvae may spend up to 14 months in water before they metamorphose.

Food Preferences: Bullfrogs eat anything they can overpower and swallow, including insects, young birds, rodents, small snakes, young turtles, and other frogs, particularly young bullfrogs. A study done elsewhere in Kansas showed that young bullfrogs composed 80% (by volume) of the diet of adult bullfrogs. This is the only amphibian at CBWMA that represents a threat to young ducks and shore birds, but it probably eats too few of them to be considered a major predator.

Potential Predators: The bullfrog is classed as a "game species" in Kansas and is hunted by people. In addition, mammals and large turtles eat adult bullfrogs. Young bullfrogs and tadpoles can constitute a significant biomass in any aquatic situation where they occur and are eaten by water birds, mammals, snakes, turtles, fishes, and larger frogs. A female bullfrog can produce up to 40,000 eggs annually.

Scaphiopus bombifrons (Plains spadefoot)

Habitat Preferences: This very secretive terrestrial amphibian lives in areas of loose sand or soil on prairies and open floodplains. It normally lives below ground, emerging only during or after substantial rainfall. During this survey, two examples were collected on 8 May at night on the dike road between pools 3 and 4 (no chorusing was heard). Seven specimens were collected at night on 2 June from a chorus at the southwestern edge of Pool 5, south of CBWMA headquarters.

Food Preferences: This frog feeds exclusively on insects.

Potential Predators: Predators of plains spadefoots are unknown. There is some evidence that skin secretions of adults of this amphibian are distasteful to snakes. Whether this is true and extends to such potential predators as water birds has not been documented. A female plains spadefoot produces up to 2,000 eggs annually.

Bufo cognatus (Great Plains toad)

Habitat Preferences: The terrestrial Great Plains toad inhabits the uplands of mixed-grass and short-grass prairies and open floodplains. We obtained two examples of this amphibian during our survey, one on the dike road between pools 3 and 4 on 8 May, and another south of the CBWMA headquarters on 2 June. The latter was taken at night from a chorus of these creatures.

Food Preferences: This toad feeds on insects.

Potential Predators: Adult and young Great Plains toads are eaten by snakes. Because of their irritating skin secretions, small mammals probably avoid these toads. It is not known whether water birds or fishes will eat either adults or tadpoles of this amphibian. An adult female of this species can produce up to 20,000 eggs annually.

Rana blairi (Plains leopard frog)

Habitat Preferences: This semi-aquatic frog occurs in any aquatic situation but prefers prairie streams and marshes. We found four adults of this amphibian during our survey, two along the western portion of the inlet canal, one at the junction of pools 1, 2 and 5, and one near the pool at CBWMA headquarters. We heard no choruses of this frog but attribute this to the early breeding season of this species. It probably bred prior to the start of our survey (1 May). Nonetheless, we cannot explain the lack of observations during our survey--we thought we would see more individuals.

Food Preferences: Plains leopard frogs eat insects, worms, and snails.

Potential Predators: Small mammals, water birds, snakes, turtles, other frogs, and fishes eat adult and young plains leopard frogs; tadpoles of this amphibian (an adult female can produce up to 6,500 eggs annually) are eaten by these predators also.

Bufo woodhousi (Woodhouse's toad)

Habitat Preferences: This terrestrial toad prefers sandy lowlands, particularly the floodplains of larger streams and rivers. Despite the abundance of this type of habitat at CBWMA, we found only a single adult example of this toad during our survey; it was observed on 3 June along the western portion of the inlet canal. The scarcity of this species at CBWMA is unexplainable; no choruses were heard, although our survey took place during the peak of its breeding season.

Food Preferences: This toad eats insects and spiders.

Potential Predators: As with the Great Plains toad, this species produces a skin secretion which may cause many predators to avoid it. However, snakes do consume adult and young Woodhouse's toads. An adult female of this species can lay up to 25,000 eggs annually.

Ambystoma tigrinum (Tiger salamander).

Habitat Preferences: This terrestrial salamander is found throughout Kansas and emerges from underground retreats to breed from December to March. For breeding, it prefers shallow lakes, ponds, ditches and backwater pools. We did not find this amphibian at CBWMA during our survey; the single specimen known from the area was taken on 22 September 1985 by Wayne Hoffman (see table 15.2). While its presence at CBWMA is documented, this species is probably not abundant there, because no larvae were seen during our survey.

Food Preferences: Tiger salamanders eat insects, earthworms, fishes, tadpoles, frogs, toads, other salamanders, and the young of rodents.

Potential Predators: Large birds, small mammals, snakes, turtles, and fishes eat both adult and larval tiger salamanders. An adult female can lay up to 1,000 eggs annually.

Pseudacris clarki (Spotted chorus frog)

Habitat Preferences: This semi-aquatic frog is primarily an inhabitant of open prairie pools and marshes. We did not find it at CBWMA during our survey, and its presence there is questionable. It is documented from the area, based on a single specimen collected in 1942 (see table 15.2), prior to development of dikes at CBWMA. Possibly the habitat today at CBWMA is not suitable for this frog.

Food Preferences: Food items of this frog are not known; it probably feeds exclusively on small insects.

Potential Predators: Water birds, snakes, turtles, small mammals, fishes, and larger frogs consume this amphibian and its tadpoles. An adult female spotted chorus frog can produce up to 1,000 eggs annually.

Table 15.6--A comparison of semi-aquatic versus terrestrial species of amphibians and reptiles at CBWMA.

Semi-aquatic Species	Terrestrial Species
Acris crepitans	Ambystoma tigrinum*
Pseudacris clarki*	Scaphiopus bombifrons
Pseudacris triseriata	Bufo cognatus
Rana blairi	Bufo woodhousii
Rana catesbeiana	Eumeces obsoletus
Chelydra serpentina	Cnemidophorus sexlineatus
Kinosternon flavescens	Coluber constrictor
Chrysemys picta	Lampropeltis calligaster
Chrysemys scripta	Lampropeltis getulus
Trionyx spiniferus	Pituophis melanoleucus
Nerodia rhombifera	Thamnophis radix
Nerodia sipedon	Thamnophis sirtalis
Regina grahami	Tropidoclonion lineatum
	Sistrurus catenatus

*denotes species not found during our survey at CBWMA, but which have been documented from the area.

Table 15.7--Species of amphibians and reptiles known to occur in and around Barton County, Kansas (based primarily on Collins, 1982) and which may eventually be documented at CBWMA.

Species Scientific Name	Common Name
Gastrophryne olivacea	Plains narrowmouth toad
Terrapene ornata	Ornate box turtle
Trionyx muticus	Smooth softshell
Holbrookia maculata	Lesser earless lizard
Sceloporus undulatus	Eastern fence lizard
Phrynosoma cornutum	Texas horned lizard
Heterodon nasicus	Western hognose snake
Heterodon platirhinos	Eastern hognose snake
Diadophis punctatus	Ringneck snake
Masticophis flagellum	Coachwhip
Elaphe guttata	Great Plains rat snake
Arizona elegans	Glossy snake
Lampropeltis triangulum	Milk snake
Thamnophis proximus	Western ribbon snake
Storeria dekayi	Texas brown snake
Nerodia erythrogaster	Blotched water snake
Crotalus viridis	Prairie rattlesnake

SUMMARY

The amphibian and reptilian fauna of Cheyenne Bottoms Wildlife Management Area, consisting of 27 species, is as follows: 1 salamander, 8 frogs and toads, 5 turtles, 2 lizards, and 11 snakes (see table 15.3). The nine amphibians and 18 reptiles that occur at the marsh comprise two groups, semi-aquatic (13 species) and terrestrial (14 species). These are shown in table 15.6. Based on data in tables 15.4 and 15.5 (combined), the semi-aquatic group of species comprised 633 of 730 (87%) observations of individual specimens. The terrestrial group of species represented only 97 observations (13%). Thus, the herpetofauna at CBWMA, based on observable abundance, is primarily semi-aquatic in nature. Additional species may be discovered at the area (see table 15.7), increasing the number of taxa documented, but we doubt this will significantly alter our conclusion that the CBWMA herpetofauna is predominantly semi-aquatic. Indeed, if optimal water levels at CBWMA are achieved in the future, we would anticipate a reduction in abundance of the terrestrial group accompanied by an increase in abundance of some semi-aquatic forms.

Of the 27 species of amphibians and reptiles known to occur at CBWMA, nine are potential predators on water birds and their young and eggs (see table 15.8). It is our opinion that adult common snapping turtles (Chelydra serpentina) are the only reptilian predators of adult water birds at CBWMA. As table 15.8 clearly illustrates, terrestrial snakes (five species) are the only potential threat to bird eggs at the marsh. All nine potential predators are capable of capturing and eating young water birds (nestlings). These nine species (1 amphibian, 3 turtles, and 5 snakes) made up only 35 of 730 (5%) observations during our survey at CBWMA, and we do not consider them a significant threat to water birds at the refuge.

Table 15.8--Those species of amphibians and reptiles known to occur at CBWMA and which are potential predators on adults, nestlings, and egg clutches of water birds. (SA) = semi-aquatic species, (T) = terrestrial species.

Species	Predators on adult birds	Predators on nestlings	Predators on eggs
Rana catesbeiana (SA)		X	
Chelydra serpentina (SA)	X	X	
Chrysemys scripta (SA)		X	
Trionyx spiniferus (SA)		X	
Coluber constrictor (T)		X	X
Lampropeltis calligaster (T)		X	X
Lampropeltis getulus (T)		X	X
Pituophis melanoleucus (T)		X	X
Sistrurus catenatus (T)		X	X

On the other hand, the herpetofauna of CBWMA does represent a significant source of food for water birds, as well as raptors, small mammals, and fishes. Amphibians, with their enormous egg clutches (up to 40,000 eggs annually by an adult female bullfrog), and the resultant tadpoles and metamorphosed young, must surely constitute a major source of food for other vertebrates at CBWMA. Reptiles at CBWMA are represented by 11 species that lay eggs and seven that are viviparous. Discounting three species (Eumeces obsoletus, Lampropeltis calligaster, and Tropidoclonion lineatum), for which we obtained only one specimen each in our survey, the remaining reptilian taxa documented at CBWMA by us lend themselves to a crude analysis of annual reproductive potential. Of the 700 observations, 629 (90%) were of adult examples of 15 species (18 less the 3 species mentioned above). Assuming that one-third (210 specimens) were females, the reptilian fauna surveyed during the spring of 1986 were capable of producing a minimum of 1,639 young and a maximum of 7,852 young (see table 15.9). Based on this crude, but nonetheless revealing statistic, we feel that reptiles are a most significant aspect of the vertebrate fauna of Cheyenne Bottoms Wildlife Management Area and are important prey items to other animals found there.

Table 15.9--Reproductive potential of 15 species of reptiles at CBWMA, based on the assumption that, of 629 adults observed, one-third (= 210 specimens) were females that reproduced once during the 1986 season. Estimated number of females observed are in parentheses after each species name.

Species	# eggs/young annually	Minimum Reproductive Potential	Maximum Reproductive Potential
Chrysemys picta (95)	4-20	380	1,900
Nerodia rhombifera (64)	14-62	896	3,968
Regina grahami (21)	9-39	189	819
Sistrurus catenatus (4)	5-13	20	52
Thamnophis radix (8)	5-60	40	480
Thamnophis sirtalis (3)	7-80	21	240
Nerodia sipedon (3)	8-46	24	138
Kinosternon flavescens (2)	1-4	2	8
Coluber constrictor (2)	8-22	16	44
Cnemidophorus sexlineatus (2)	2-6	4	12
Chrysemys scripta (2)	4-20	8	40
Lampropeltis getulus (1)	5-17	5	17
Trionyx spiniferus (1)	4-32	4	32
Chelydra serpentina (1)	25-83	25	83
Pituophis melanoleucus (1)	5-19	5	19
Totals		1,639	7,852

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We take pleasure in thanking the many individuals who assisted us during our survey at CBWMA. Wayne Hoffman (Kansas Biological Survey), through his diligence and curiousity about our nonavian subjects, found many interesting records at CBWMA and in the surrounding area. His good humor and helpful suggestions made our task easier. Stan Wood, Charles Swank, Michael Ehlebracht, Gene Bahr, and Dean Steiner, all on the staff of the Kansas Fish and Game Commission at CBWMA, were alert to our need for specimens and brought us any herpetological creatures they encountered during their duties at the marsh. Jeff Whipple (Animal Care Unit, University of Kansas) and Scott Hillard (Pratt) made special trips to CBWMA to help us collect and observe the herpetofauna. To them we are grateful. During fish investigations at CBWMA, Frank Cross (University of Kansas) and Guy Ernsting (Ellinwood) showed

benevolent tolerance as one of us (KJI) collected turtles and engaged in other nonichthyological pursuits. Finally, we thank the officers and members of the Kansas Herpetological Society. Their collections at CBWMA during the last few days of our survey added much to our data base.

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CHAPTER 16: THE BIRDS OF CHEYENNE BOTTOMS

by Wayne Hoffman

INTRODUCTION

Cheyenne Bottoms has been recognized for decades as one of the most important stopover locations in the central flyway for migratory waterfowl. In recent years it has also become known for its importance to migratory shorebirds, and in fact has been described as one of the two most important staging areas for shorebirds in the contiguous United States. This assessment may be overstated, but Cheyenne Bottoms probably is the most heavily used inland site in the country, at least east of the Rocky Mountains. It also supports an important heronry (Ernsting, 1984) and provides migratory stopovers for White Pelicans and Sandhill and Whooping cranes. In winter the marsh is usually frozen, and bird density is greatly reduced. The marsh does support a variety of wintering raptors, including several percent of Kansas' wintering Bald Eagles. Cheyenne Bottoms also supports a major blackbird roost that in 1985-86 numbered over one-half million birds and in previous years has been much larger.

The ornithological investigations in the Cheyenne Bottoms study began in August 1985 and continued through early September 1986. These investigations had four major goals.

The first goal was the identification of those species most important to the managed marsh system. Criteria used for assessing importance were A) status, abundance, and desirability as game birds; B) federal threatened or endangered status; C) dependence on critical habitat supplied by Cheyenne Bottoms; and D) energetic or trophic importance to the marsh ecosystem.

The second goal was to assess the numbers of the important species and their patterns of seasonal use of Cheyenne Bottoms. Third, the habitat

requirements and preferences of the important birds needed to be determined. The final goal was to provide options for modifying and managing the marsh to the benefit of the important species.

This chapter presents the study's results relative to the first three goals. The management options are integrated into the overall study options in Chapter 21. In the present chapter, a methods section is followed by an overview of the avifauna of Cheyenne Bottoms and an assessment of importance for each species. The particularly important groups (shorebirds, waterfowl, other waders, raptors, and blackbirds) are then treated separately.

METHODS

The initial rankings of species importance were done by Leigh Fredrickson and the author in October 1985, and were based on the literature, 2 months of census data, and our professional expertise. Species were ranked on a scale of 1 to 3, with 3 being most important. In October 1986 the exercise was repeated, using the data accumulated during the study to refine the determinations. In this second ranking, species were scored on a scale of 0 to 3 and were ranked separately for each of the four ranking criteria (A-gamebird status and importance, B-endangered species status, C-dependence on Cheyenne Bottoms for critical habitat, and D-energetic role in the marsh ecosystem). In category B, federally endangered species receive scores of 3, and threatened species score 2. Species under consideration for threatened status, or otherwise considered at some risk, score 1. In category D, scores are comparable only within groups (waterfowl, shorebirds, raptors, blackbirds) because the energetic impacts of the different groups occur at different trophic levels. All species receiving a ranking of 3 in one category, or rankings of 2 in at least two categories are considered highly important. A number of species received higher rankings in the second exercise, but most of

the adjustments occurred within the two groups receiving the most attention in the study, the waterfowl and the shorebirds.

Field work in the study concentrated on censusing, studies of habitat preferences, and collection of shorebirds for food-habits studies. Table 16.1 lists the ornithological fieldwork in this study. Censuses of shorebirds were conducted on all trips except those in the winter, when shorebirds were not present. Most shorebird censuses could be conducted from the dike system and from county roads adjacent to the management area. Censuses typically included the Mallard Club area and pastureland north and west of Pool 2 and wet areas south of Pool 5, as well as the management area itself. These road censuses took 1 1/2 to 4 hours to complete, depending on bird abundance and distribution and water conditions. When necessary, areas not accessible by car were walked to complete the census. Most of the shorebirds preferred open, unvegetated areas, so accurate counts could be made at great distances with spotting scopes and binoculars. The birds generally could be counted at greater distances than they could be identified to species, so at times species compositions of the flocks had to be estimated from subsamples that could be approached more closely. The birds counted were recorded on field-outline maps of the pools. Habitat preferences were determined by locating the areas of most frequent occurrence for each species on the maps. Notes of more precise habitat use (i.e. water depth, distance from water's edge) were also taken frequently.

Table 16.1--Schedule of field work.

Month	Days	Purpose
		1985
Aug.	12-14	Gain familiarity with Cheyenne Bottoms, begin bird surveys, meet Stan Wood
Aug.	20-22	Shorebird surveys, pelican census, habitat studies
Aug.	31-2 Sept.	Shorebird surveys, habitat studies
Sept.	11-13	Shorebird surveys, habitat studies
Sept.	22-23	Shorebird surveys, habitat studies
Sept.	29-30	Shorebird surveys, habitat studies
Oct.	14	Shorebird and Waterfowl survey
Oct.	20-21	Shorebird and waterfowl survey, habitat studies
Oct.	25-27	Shorebird, waterfowl, crane census; observe public-use patterns (opening weekend of waterfowl-hunting season)
Nov.	2-3	Shorebird and waterfowl survey; observe public-use patterns
Nov.	7-9	Shorebird and waterfowl survey; observe public-use patterns (opening weekend pheasant season, reopen duck season), shorebird feeding habits.
Nov.	19-21	Waterfowl, raptor surveys
Dec.	8	Waterfowl, raptor surveys
Dec.	17-18	Bird surveys, especially raptors, blackbirds
		1986
Jan.	11-12	Raptor survey, blackbird-roost studies
Feb.	1-2	Raptor and waterfowl surveys, blackbird-roost studies
Feb.	21-23	Raptor and waterfowl surveys, blackbird-roost studies
Mar.	5	Shorebird, crane surveys
Mar.	13-15	Shorebird, waterfowl surveys, habitat use
Mar.	21-22	Shorebird, waterfowl surveys, habitat use
Apr.	2-6	Shorebird, waterfowl surveys, habitat use
Apr.	13-15	Shorebird, waterfowl surveys, habitat use, shorebird feeding-habits studies
Apr.	23-26	Shorebird, waterfowl surveys, habitat use, shorebird feeding-habits studies
May	1-4	Shorebird, waterfowl surveys, habitat use
May	9-12	Shorebird, waterfowl surveys, habitat use, shorebird feeding-habits studies
May	16-18	Shorebird, waterfowl surveys, habitat use
June	2-4	Shorebird, waterfowl survey
June	23-24	Shorebird, waterfowl survey
July	4-5	Shorebird, waterfowl survey
July	17-19	Shorebird, waterfowl survey
Aug.	13-15	Shorebird, waterfowl survey
Sept.	3-5	Shorebird, waterfowl survey

Waterfowl censuses generally were more difficult, because the birds frequented areas with substantial vegetation cover. During hunting season in particular, the censuses were restricted to the dikes and roads to avoid disturbing hunters and to avoid flushing the birds from the refuge areas.

Cranes, pelicans, and gulls were censused mainly in the air as they moved in flocks into or across the marsh. Herons and ibises were censused at dusk as they flew across the marsh to their communal roost. Blackbirds were censused similarly, although they were so numerous that their censuses required more than one person, or more than one night, as explained in the section on blackbird ecology.

Shorebirds were collected for food-habits studies with a 20-gauge shotgun and number 4 and number 6 steel shot. These shot sizes are far from ideal for collecting small birds, but they are the smallest shot sizes available in steel shot. In most cases birds were collected only after they were observed feeding. Collecting was limited to the abundant species most likely to play an important role in the marsh and most likely to be dependent on Cheyenne Bottoms for critical habitat. Immediately after collection the digestive tracts of the birds were removed and preserved in 10% formalin solution. After 2 to 3 days they were washed in water and transferred to 80% ethanol for storage. The birds were donated to the KU Museum of Natural History for preparation as scientific specimens. For analysis the tracts were cut open lengthwise, and the contents were washed into a dish with ethanol. The contents were then sorted and the food items tallied by Robyn Burnham. Warren Bird measured samples of chironomid larvae from certain gut samples.

OVERVIEW OF THE CHEYENNE BOTTOMS AVIFAUNA

A list of the birds known from Cheyenne Bottoms was assembled by Marvin Schwilling of the Kansas Fish and Game Commission and is printed in pamphlet form by Barton County Community College for distribution at Cheyenne Bottoms. The current version of the list contains 320 species, and eight additional species are now known to occur there. A total of 417 extant species are known reliably from Kansas (KOS Checklist of the birds of Kansas, 1985), so a remarkable 79% of the Kansas avifauna has been recorded in this one small area. This high percentage is even more remarkable in light of Cheyenne Bottoms' position in the center of the state.

The avifauna of Cheyenne Bottoms is detailed in table 16.2. The table lists the 320 birds from the current list, plus the eight species added since its assembly. One of these, Clark's Grebe, is probably a regular visitor, but until 1985 was considered a color morph of the Western Grebe (AOU 1985). Another, the Swamp Sparrow, was inadvertently omitted. The others, Roseate Spoonbill, Ruff, Thayer's Gull, Ash-throated Flycatcher, Sage Thrasher, and Henslow's Sparrow, should all be considered rare or accidental visitors. Two hundred seventy-four of the 328 species are migrants (this includes several species--e.g., Canada Goose, Red-tailed Hawk--that have both resident and migrating individuals using Cheyenne Bottoms). One hundred and eight species are known to breed at Cheyenne Bottoms, and at least two others (Swainson's Hawk, Wild Turkey) breed nearby, if not actually on the management area. In contrast, only 62 species regularly winter at Cheyenne Bottoms (an additional 10 or so species of waterfowl may be found at the Bottoms in winter if open water is present). The wintering birds include 11 species of waterfowl that feed in agricultural fields, 16 raptors, and 21 seed-eating birds. Only 30 species, including Giant Canada Geese, five raptors, and 12 seed-eating birds

are known to be permanent residents. Twenty-five species are considered to be accidental at Cheyenne Bottoms, and indeed, most of these are accidental anywhere in Kansas.

Table 16.2--Birds known from Cheyenne Bottoms. Column headings: Migr. = migratory individuals of the species use Cheyenne Bottoms; Br. = known to breed at Cheyenne Bottoms; Wint. = known to winter at Cheyenne Bottoms; Res. = some individuals are resident at or around Cheyenne Bottoms; acc. = accidental at Cheyenne Bottoms; This study = species seen in this study. Rank--A = gamebird importance, B = threatened or endangered, C = depends on Cheyenne Bottoms for critical habitat, and D = important to energetics of the marsh.

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A	B	C	D
Common Loon	x									
Horned Grebe	x					x				
Eared Grebe	x					x				
Western Grebe	x					x				
Clark's Grebe	x					x				
Pied-billed Grebe	x	x				x				1
Double-crested Cormorant	x	x				x			1	1
Olivaceous Cormorant	x					x				
Anhinga					x					
Great Blue Heron	x	x				x				1
Green Heron	x	x				x				
Little Blue Heron	x	x				x			1	1
Cattle Egret	x	x				x				1
Great Egret	x					x				
Snowy Egret	x	x				x			1	1
Louisiana Heron	x	x				x				
Black-crowned Night-heron	x	x				x				1
Yellow-crowned Night-heron	x	x				x				
Least Bittern	x	x				x				
American Bittern	x	x				x				
White Pelican	x	x				x			1	3
Brown Pelican					x					
Wood Stork					x					
White-faced Ibis	x	x				x			2	1
White Ibis					x					
Roseate Spoonbill					x	x				
Tundra Swan	x									
Canada Goose	x	x	x	x		x	3		2	2
Brant	x									
White-fronted Goose	x		x			x	3		1	2
Snow Goose	x					x	1			

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A	B	C	D
Ross' Goose	x						1			
Fulvous Whistling-duck	x						1			
Mallard	x	x	x	?		x	3		2	2
American Black Duck	x	x	x				1			
Mottled Duck	?	x	?	?		x	1	1	3	
Gadwall	x	x	x	?		x	3		2	1
Pintail	x	x	x	?		x	3		2	2
Green-winged Teal	x	x	x	?		x	3		2	3
Blue-winged Teal	x	x	x			x	3		2	2
Cinnamon Teal	x	x				x	1			
Northern Shoveler	x	x	x			x	3		2	3
American Wigeon	x	x	x	?		x	3		1	2
Eurasian Wigeon					x	x	1			
Wood Duck	x	x	?			x	2			1
Ring-necked Duck	x		?			x	1			
Redhead	x	x	?			x	3		2	2
Canvasback	x	x	?			x	2	1	1	1
Greater Scaup	x					x	1			
Lesser Scaup	x		?			x	2		1	1
Common Goldeneye	x		?			x	1			1
Bufflehead	x		?			x	1			1
Oldsquaw	x		?			x	1			
White-winged Scoter	x						1			
Surf Scoter	x						1			
Black Scoter	x						1			
Hooded Merganser	x					x	1			
Common Merganser	x		?			x	1			
Red-breasted Merganser	x						1			
Ruddy Duck	x	x	?			x	2		1	3
Turkey Vulture	x					x				
Mississippi Kite	x	x				x				
Sharp-shinned Hawk	x		x			x				
Cooper's Hawk	x		x			x				
Red-tailed Hawk	x	x	x	x		x				1
Red-shouldered Hawk	x									
Broad-winged Hawk	x					x				
Swainson's Hawk	x	?				x				1
Rough-legged Hawk	x		x			x				1
Ferruginous Hawk	x		x			x		1		
Harris' Hawk	x									
Golden Eagle	x		x							
Bald Eagle	x		x			x		3	2	2
Northern Harrier	x	x	x	?		x			2	2
Osprey	x					x				
Prairie Falcon	x		x			x				
Peregrine Falcon	x		?			x		3	2	1
Gyrfalcon					x					

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A	B	C	D
Merlin	x		x			x				
American Kestrel	x	?	x			x				
Greater Prairie-chicken				x			1			
Bob-white		x	x	x		x	2			
Ring-necked Pheasant		x	x	x		x	3			2
Wild Turkey				x		x	2			
Whooping Crane	x						3	1		
Sandhill Crane	x					x			2	2
King Rail	x	x				x			2	2
Virginia Rail	x	x				x	1		2	2
Sora	x	x				x	1		2	2
Black Rail	x	x				x				
Yellow Rail	x									
Common Moorhen	x	x				x				
American Coot	x	x				x	1		1	1
Semipalmated Plover	x					x			1	2
Piping Plover	x					x		2	2	
Snowy Plover	x	x				x		2	3	1
Killdeer	x	x				x			1	1
Lesser Golden-plover	x					x			1	1
Black-bellied plover	x					x			1	2
Mountain Plover	x									
Ruddy Turnstone	x					x				
Common Snipe	x					x	2		1	2
Long-billed Curlew	x	?				x		1		
Whimbrel	x					x				
Upland Sandpiper	x	x				x				
Solitary Sandpiper	x					x				
Spotted Sandpiper	x					x				
Willet	x	?				x			1	1
Greater Yellowlegs	x					x			2	3
Lesser Yellowlegs	x					x			2	3
Knot	x					x				
Pectoral Sandpiper	x					x			1	1
White-rumped Sandpiper	x					x			3	3
Baird's Sandpiper	x					x			3	3
Least Sandpiper	x					x			2	3
Dunlin	x					x				
Curlew Sandpiper					x					
Semipalmated Sandpiper	x					x			2	3
Western Sandpiper	x					x			1	2
Sanderling	x					x				
Stilt Sandpiper	x					x			3	3
Buff-breasted Sandpiper	x					x				

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A	B	C	D
Ruff					x	x				
Long-billed Dowitcher	x					x			3	3
Short-billed Dowitcher	x					x			1	1
Marbled Godwit	x					x			2	2
Hudsonian Godwit	x					x			2	2
Red Phalarope	x									
Red-necked Phalarope	x					x				
Wilson's Phalarope	x	x				x			3	3
American Avocet	x	x				x			3	3
Black-necked Stilt	x					x				
Parasitic Jaeger	x					x				
Pomarine Jaeger					x					
Long-tailed Jaeger					x					
Black Skimmer					x					
Glaucous Gull	x		?							
Herring Gull	x		x			x				1
Ring-billed Gull	x		x			x				2
California Gull					x	x				
Laughing Gull	x					x				
Franklin's Gull	x					x			2	3
Bonapartes Gull	x					x				
Sabine's Gull	x					x				
Black-headed Gull					x					
Little Gull					x					
Forster's Tern	x	x				x				1
Common Tern	x					x				
Least Tern	x	x				x		3		
Caspian Tern	x					x				
Black Tern	x					x			2	2
Rock Dove		x	x	x		x	1			
Mourning Dove	x	x				x	2			
Ground Dove					x					
Monk Parakeet					x					
Yellow-billed Cuckoo	x	x				x				
Black-billed Cuckoo	x					x				
Barn Owl		x	x	x		x				1
Eastern Screech-owl		x	x	x		x				
Great Horned Owl		x	x	x		x				2
Snowy Owl	x		x							
Burrowing Owl	x	x				x				
Barred Owl				x						
Long-eared Owl	x									
Short-eared Owl	x		x			x			1	1
Whip-poor-will	x									
Poor-will	x									
Common Nighthawk	x	x				x				
Chimney Swift	x	x				x				

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A	B	C	D
Ruby-throated Hummingbird	x									
Rufous Hummingbird	x									
Belted Kingfisher	x	x				x				1
Common Flicker	x	x	x	?		x				
Red-bellied Woodpecker		x	x	x		x				
Red-headed Woodpecker	x	x				x				
Yellow-bellied Sapsucker	x					x				
Hairy Woodpecker		x	x	x		x				
Downy Woodpecker		x	x	x		x				
Eastern Kingbird	x	x				x				
Western Kingbird	x	x				x				
Scissor-tailed Flycatcher	x	x				x				
Great Crested Flycatcher	x	x				x				
Ash-throated Flycatcher	x					x				
Eastern Phoebe	x	x				x				
Say's Phoebe	x					x				
Least Flycatcher	x									
Hammond's Flycatcher	x									
Eastern Wood Peewee	x					x				
Western Wood Peewee	x									
Olive-sided Flycatcher	x									
Horned Lark	x	x	x	?		x				
Violet-green Swallow					x					
Tree Swallow	x	x				x				2
Bank Swallow	x					x				2
Rough-winged Swallow	x					x				1
Barn Swallow	x	x				x		1	2	
Cliff Swallow	x	x				x		1	3	
Purple Martin	x	x				x				
Blue Jay	x	x	x	x		x				
Scrub Jay					x					
Black-billed Magpie				x		x				
Common Crow		x	x	x		x				
Clark's Nutcracker	x									
Black-capped Chickadee		x	x	x		x				
Tufted Titmouse				x						
White-breasted Nuthatch	x		x	x		x				
Red-breasted Nuthatch	x									
Brown Creeper	x									
House Wren	x	x				x				

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A B C D
Winter Wren	x						
Bewick's Wren	x						
Carolina Wren	x						
Marsh Wren	x	x				x	2
Sedge Wren	x						
Rock Wren					x	x	
Northern Mockingbird		x	x	x		x	
Gray Catbird	x	x				x	
Brown Thrasher	x	x				x	
Sage Thrasher					x	x	
American Robin	x	x		?		x	
Wood Thrush	x						
Hermit Thrush	x						
Swainson's Thrush	x						
Gray-cheeked Thrush	x					x	
Veery	x						
Eastern Bluebird	x	x	?			x	
Mountain Bluebird	x						
Townsend's Solitaire	x						
Blue-gray Gnatcatcher	x						
Golden-crowned Kinglet	x					x	
Ruby-crowned Kinglet	x					x	
Water Pipit	x					x	
Sprague's Pipit	x					x	
Bohemian Waxwing	x						
Cedar Waxwing	x						
Loggerhead Shrike	x	x	x	?		x	
Starling	x	x	x	x		x	3
White-eyed Vireo	x						
Bell's Vireo	x	x				x	
Solitary Vireo	x					x	
Red-eyed Vireo	x						
Philadelphia Vireo	x						
Warbling Vireo	x	x				x	
Black-and-white Warbler	x						
Prothonotary Warbler	x						
Tennessee Warbler	x						
Orange-crowned Warbler	x					x	
Nashville Warbler	x						
Yellow Warbler	x	x				x	
Yellow-rumped Warbler	x					x	
Cerulean Warbler	x						
Chestnut-sided Warbler	x						

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A	B	C	D
Bay-breasted Warbler	x									
Black-throated Green Warbler	x									
Blackpoll Warbler	x					x				
Palm Warbler	x									
Ovenbird	x									
Northern Waterthrush	x									
Mourning Warbler	x									
MacGillivray's Warbler	x									
Common Yellowthroat	x	x				x				2
Yellow-breasted Chat	x									
Wilson's Warbler	x					x				
Canada Warbler	x									
American Redstart	x					x				
House Sparrow		x	x	x		x				2
Bobolink	x	x								
Eastern Meadowlark		x	x	x		x				2
Western Meadowlark		x	x	x		x				
Yellow-headed Blackbird	x	x				x			2	3
Red-winged Blackbird	x	x	x	x		x			1	3
Orchard Oriole	x	x				x				
Northern Oriole	x	x				x				
Rusty Blackbird	x					x				
Brewer's Blackbird	x		x			x				
Great-tailed Grackle	?	x	x	x		x			1	1
Common Grackle	x	x	x	x		x			1	3
Brown-headed Cowbird	x	x	x	x		x			1	3
Scarlet Tanager	x									
Summer Tanager	x									
Cardinal		x	x	x		x				
Rose-breasted Grosbeak	x									
Black-headed Grosbeak	x	x								
Blue Grosbeak	x	x				x				
Indigo Bunting	x	x								
Painted Bunting	x	x								
Lazuli Bunting	x									
Dickcissel	x	x				x				
Cassin's Finch	x									

Species	Migr.	Br.	Wint.	Res.	Acc.	This Study	Rank A	B	C	D
Evening Grosbeak	x									
Pine Siskin	x									
American Goldfinch	x					x				
Red Crossbill	x		x			x				
Rufous-sided Towhee	x					x				
Lark Bunting	x	x								
Savannah Sparrow	x					x				
Grasshopper Sparrow	x	x				x				
Baird's Sparrow	x									
Le Conte's Sparrow	x					x				
Sharp-tailed Sparrow					x					
Vesper Sparrow	x					x				
Lark Sparrow	x	x				x				
Cassin's Sparrow	x									
Dark-eyed Junco	x		x			x				
Tree Sparrow	x		x			x				1
Chipping Sparrow	x					x				
Clay-colored Sparrow	x					x				
Field Sparrow	x									
White-crowned Sparrow	x		x			x				
Harris' Sparrow	x		x			x				
White-throated Sparrow	x					x				
Fox Sparrow	x					x				
Lincoln's Sparrow	x					x				
Song Sparrow	x		x			x				
Lapland Longspur	x		x			x				
Chestnut-collared Longspur	x		x							
Snow Bunting	x		x							

SHOREBIRDS

INTRODUCTION

According to the International Shorebird Survey (Manomet Bird Observatory), Cheyenne Bottoms is one of the most important sites in the western hemisphere for migrating shorebirds. Observations in this study have confirmed its importance and have also demonstrated that shorebirds play a critical role in the ecology of Cheyenne Bottoms. Cheyenne Bottoms is far more important for shorebirds in northward (spring) migration than in

southbound (summer and fall) migration, although in some years Cheyenne Bottoms has received very large numbers of birds in fall as well.

Different authors classify shorebirds differently, but the group consists of about 165 species in seven or eight families (Peters, 1934; Johnsgard, 1981), distributed world wide. Thirty-nine, or 24%, of these species have occurred at Cheyenne Bottoms, and the Bottoms is extremely important to at least seven of these. The shorebirds also are important in the ecology of this wetland, for they harvest great quantities of food and function as major predators of aquatic insects in the system.

BIOLOGY OF SHOREBIRDS

Shorebirds as a group have rather unusual life histories, and a review of a few characteristics of these will help in understanding the importance of Cheyenne Bottoms to shorebirds. About 60 of the 165 species breed mainly or exclusively in the arctic and subarctic zones of the northern hemisphere and undertake major seasonal migrations. The remainder have temperate or tropical breeding distributions and correspondingly shorter migrations. The arctic-breeding migrants are particularly important at Cheyenne Bottoms. They experience very short breeding seasons and indeed spend most of their lives on their wintering grounds or in migration. Because they feed in rather specialized (and rare) habitats, they gather in immense numbers in relatively few very important sites and must fly nonstop for extremely long distances between these sites. It is critical, then, that these sites provide adequate food for the birds to build fat reserves for the impending flights. Several species, for example, gather to feed in the fall in New England and the Canadian maritime provinces, then fly nonstop over the Atlantic Ocean to the West Indies or even northern South America. Others migrate from Alaska to Polynesia, stopping only when they reach Hawaii. These northern species have

extremely short nesting seasons available to them in the short arctic summer, so they must pair and begin egg laying within a few days of arriving. Thus females must arrive carrying much of the energy for their eggs, rather than gathering this energy after arriving. The arctic tundra seems to be optimal habitat for raising shorebird young, but oddly the adults seem to exhibit little attachment to it except when nesting. Nonbreeding subadults often remain through the northern summer in their wintering areas, and adults whose nests fail often head south immediately, rather than lingering to migrate with the successful birds. Because of this early southward movement of unsuccessful breeders, southbound migration in shorebirds often begins as early as late June. Successful adults of many species migrate south as soon as their young are independent and several weeks before the young are able to begin the migration. These successful adults may begin appearing on temperate zone stopover areas in mid-July, and the peaks of adult migration for several species occur in August. Because so much of southbound migration in shorebirds occurs in mid-summer, I prefer to call it "southbound" rather than "fall" migration.

Cheyenne Bottoms is a critical migratory stopover and feeding area for several species and may be critical to subpopulations of several others. For Baird's and White-rumped Sandpipers, Long-billed Dowitchers, and Hudsonian Godwits, at least, it may be the last stopping place before flying directly to nesting areas 1,400 to 2,400 miles north. Cheyenne Bottoms apparently hosts most of the world population of White-rumped Sandpipers each spring in mid- to late May. The birds then fly, apparently directly, to their high-arctic nesting areas. Cheyenne Bottoms hosts the largest concentration of Hudsonian Godwits in the United States, although most of the species fly directly across the United States, probably to staging areas in Canada. Baird's Sandpipers

and Long-billed Dowitchers are present in very large numbers each spring and feed for 2 to 3 weeks. Large numbers of these latter two species follow migration paths farther west, so Cheyenne Bottoms may not be as critical to them.

Cheyenne Bottoms also hosts a variety of temperate breeding shorebirds. Killdeer, Snowy Plovers, and Avocets nest regularly at Cheyenne Bottoms. Wilson's Phalaropes nest some years, and Upland Sandpipers probably nest in peripheral areas.

HABITAT PREFERENCES OF SHOREBIRDS AT CHEYENNE BOTTOMS

Habitats used by shorebirds in and around Cheyenne Bottoms can be grouped into six categories; open water, open shallows, vegetated shallows, open mud, open upland, and vegetated upland.

The first three of these are flooded habitats. Open water is here defined as flooded areas lacking emergent vegetation and too deep for the shorebirds to wade. Open shallows are similar, but wadeable. The distinction between these two is fuzzy, for the larger birds can wade in deeper water than the small ones. The distinction is useful, however, because it recognizes the extra habitat available to the few species that regularly swim to feed. Vegetated shallows are wadeable areas with emergent vegetation.

Open mud is recently drained, unvegetated pool-bottom and may be wet or somewhat dry. Vegetated mud is exposed pool bottom with a cover of plants. Open upland habitats around Cheyenne Bottoms are plowed fields and recently burned areas. Vegetated uplands include prairie, pastures, and cropland, although the only vegetated-cropland areas that received extensive use during the study were alfalfa fields.

Particular locations within Cheyenne Bottoms may change rapidly from one habitat type to another as water levels and vegetation conditions fluctuate.

From August 1985 through March 1986, Pool 2 had over 2,000 acres of open-water habitat. As water levels dropped in spring 1986 this became, in turn, open shallows, then open mud, then vegetated mud. April and early May were characterized by warm, dry, and very windy weather, and evaporation rates were high. When wind speeds were high, the remaining water was blown from the upwind (usually southern) end of the pool and stacked up at the downwind end. Thus the areas of open shallows and open mud varied widely from day to day. Pool 2 lost practically all standing water by 12 May, and a few weeks later was aerially seeded with Japanese millet. By mid-July the area was heavily vegetated mud, although periodic rains converted the lowest areas to vegetated shallows. Similar, although less dramatic, changes occurred in pools 3, 4, and 5. During the study only the habitats in Pool 1 remained relatively constant.

Table 16.3 summarizes habitat preferences for the more important shorebird species at Cheyenne Bottoms during the study. In the table, 11 species are highlighted with asterisks. These species are of particular importance, either because they occur in great numbers or because of threatened status. Open mud and open shallows are the most important habitats for a majority of the birds and for nine of the 11 highlighted species. Open shallows were the preferred habitat for 10 species, and open mud was preferred by eight. The birds preferring open shallows tended to be the larger species, with longer legs and bills, while the short-billed plovers and small sandpipers were the primary users of the open mud. When high winds in April and May 1986 blew the water off the mud in portions of Pool 2, great concentrations of shorebirds fed along the upwind edge of the remaining water. Dowitchers, Stilt Sandpipers, godwits, and avocets waded in the shallows, generally within 100 meters of the edge, and the plovers and small

sandpipers thronged on the exposed mud, usually within 200 meters of the edge. On some particularly windy days in early May, the water's edge moved as much as a kilometer through the day in response to changes in wind speed, and the zone of concentrated shorebird activity moved accordingly.

Table 16.3--Habitat preferences of shorebirds at Cheyenne Bottoms. Habitat definitions: OW = open water--water free of emergent vegetation and too deep to be waded by the species in question; OS = open shallows--wadable water free of emergent vegetation; VS = vegetated shallows--wadable water with emergent vegetation; OM = open mud--recently exposed unvegetated pool-bottom; VM = vegetated mud--vegetated exposed pool-bottom; UO = upland open--unvegetated upland (plowed fields); UV = upland vegetated--pasture and prairie. The numbers are habitat rankings for the species; the species' most important habitat receives a ranking of 1, the secondmost-used habitat ranks 2, and so on.

	Habitats						
Species	OW	OS	VS	OM	VM	UO	UV
Semipalmated Plover		2		1			
*Piping Plover		2		1			
*Snowy Plover		2		1			
Killdeer				2		1	3
Lesser Golden-plover				1		3	2
Black-bellied Plover				1		2	3
Common Snipe			2		1		3
Whimbrel		1		2			3
*Long-billed Curlew				2			1
Upland Sandpiper				4	2	3	1
Willet		1	2	3	4		
Greater Yellowlegs	3	2	1	4			
Lesser Yellowlegs		2	1	3			
Pectoral Sandpiper		4	1	5	2		3
*White-rumped Sandpiper		2		1			
*Baird's Sandpiper		2		1			
Least Sandpiper		2	3	1	4		
Dunlin				1			
*Semipalmated Sandpiper		2		1			
*Stilt Sandpiper		1	3	2			
Buff-breasted Sandpiper			3		2		1
Short-billed Dowitcher		1					
*Long-billed Dowitcher		1					
*Marbled Godwit		1		2			
*Hudsonian Godwit		1		2			
*Wilson's Phalarope	1	2	4	3			
Northern Phalarope	1	2	3				
American Avocet	2	1	3	4			

Apparently most of the 18 species preferring open mud or open shallows were eating the same type of prey, larvae of chironomids. These midge larvae attain sizes of up to 30 millimeters and are known as "bloodworms." The 18 shorebird species preferring the open shallows and open mud include nine of the 11 species of special importance at Cheyenne Bottoms. The federally threatened Piping Plover and its close relative the Snowy Plover (under consideration for federal listing as threatened) both feed mainly on the open mud, although both occasionally wade into open shallows. The group of small sandpipers known collectively as "peeps"--the Baird's, White-rumped, Semipalmated, and Least sandpipers together accounted for 59% of the bird-days recorded at Cheyenne Bottoms in spring 1986. The "peeps" all specialize on open mud and use open shallows as their secondary choice. Three other species of particular importance, the Long-billed Dowitcher, Stilt Sandpiper, and Hudsonian Godwit, specialize on open shallows, where they wade and probe for the bloodworm larvae and perhaps other invertebrate prey.

The open-water habitats are important to only four species. Wilson's and Red-necked phalaropes feed extensively while swimming, often whirling about in circles to swirl food items to the surface. American Avocets feed regularly while swimming, although they wade more often. In early fall 1985, when very little open shallows was available, avocets fed principally while swimming, primarily in Pool 2. Greater Yellowlegs also feed while swimming, in the manner of avocets, but do so much less frequently. These four species all fed on prey living in the water column rather than benthic prey.

Vegetated shallows seem to be preferred feeding habitats for Greater and Lesser Yellowlegs, and Pectoral Sandpipers. They also provide secondary habitats for Willets and are used to a lesser extent by seven other species.

The vegetated mud habitats of drained pools seem to be primary habitat only for Common Snipe and are used regularly by only five other species. Upland-open habitats are used by four species and are the preferred habitat, at least in fall, of Killdeer. The vegetated upland habitats are the primary habitats of Upland Sandpipers, Long-billed Curlews,and Buff-breasted Sandpipers and are used to a lesser extent by six other species.

ROLE OF SHOREBIRDS IN THE ECOLOGY OF CHEYENNE BOTTOMS

When shorebirds gather in large numbers on their staging areas, their feeding can greatly affect invertebrate populations (Goss-Custard, 1969, 1977; Schneider, 1978). The great numbers of shorebirds visiting Cheyenne Bottoms in spring must consume an appreciable portion of the invertebrate biomass present. The consumption rates of shorebirds at Cheyenne Bottoms could not be measured directly in this study, but shorebird energetic requirements in general are sufficiently well known that estimates of invertebrate biomass consumed can be made from the census data and from formula derived in more intensive studies elsewhere.

The energetic requirements of shorebirds can be calculated from standard metabolic equations (Lasiewski and Dawson, 1967) and activity data (from Goss-Custard, 1969). Table 16.4 presents, for the numerically most important species at Cheyenne Bottoms, estimates of bird-days at in spring 1986, body weight, daily Basal Metabolic Requirements (BMR), daily Existence Metabolic Requirements (EMR), and caloric requirements of the whole population. BMR are the energy requirements of a resting individual, and EMR are those of individuals involved in normal activities, including feeding, flying, sleeping, and preening. EMR, as calculated here does not include energy requirements for migration or for molt.

Several patterns are evident in table 16.4. As is typical of homeotherms, larger body weight is associated with larger total energy requirements but also with greater efficiency (fewer kilocalories expended per gram body weight). The total energetic requirement of these birds during their spring stopovers (68.6 million kilocalories) is equivalent to the energy requirements of 120 people for one year. Four species-categories dominate the shorebird energy requirements. Dowitchers (mainly Long-billed Dowitchers but a few Short-billed Dowitchers were present) accounted for 44% of the shorebird-energy requirements. The other three species-categories (White-rumped Sandpiper, Baird's Sandpiper, other "peeps") together accounted for a further 38%. These and the eight other species marked with asterisks in the table are thought to feed largely on the larvae of midges (bloodworms). These 12 species-categories together account for over 60 million kilocalories, or 88% of the total existence energy requirements of all the shorebirds. Chironomid larvae have a caloric value of approximately 5.5 kilocalories per gram dry weight (Nudds and Bowlby, 1984), so these shorebirds may have consumed 11,000 kilograms dry weight of these larvae in spring 1986.

Table 16.4--Existence Metabolic Requirements of shorebirds at Cheyenne Bottoms, spring 1986. BMR is Basal Metabolic Requirements, in kilocalories per day; EMR is Existence Metabolic Requirements, in kilocalories per day.

Species	Bird-days	Wt(gm)	BMR	EMR	Popn. EMR
*Semipalmated Plover	5,200	42	7.91	38.8	202,000
*Snowy Plover	2,400	45	8.32	40.8	98,000
*Black-bellied Plover	2,200	210	25.34	124.1	273,000
*Lesser Golden-plover	600	145	19.38	95.0	57,000
Willet	400	287	31.75	155.6	62,000
Greater Yellowlegs	9,900	170	21.75	106.6	1,055,000
Lesser Yellowlegs	18,800	81	12.72	62.3	1,172,000
*Baird's Sandpiper	326,000	39	7.50	36.8	11,982,000
*White-rumped Sand.	200,000	43	8.05	39.4	7,888,000
*Least Sandpiper	42,900	21	4.79	23.5	1,008,000
*Other Sandpipers	200,000	30	6.20	30.4	6,081,000
*Stilt Sandpiper	27,600	57	9.87	48.4	1,335,000
*Dowitchers	396,000	107	15.56	76.2	30,192,000
*Hudsonian Godwit	5,000	255	29.15	142.9	714,000
*Marbled Godwit	1,350	370	38.16	187.0	252,000
Wilson's Phalarope	48,000	57	9.87	48.4	2,321,000
American Avocet	23,400	316	34.04	166.8	3,903,000
Totals	1,309,750				68,595,000
			by chironomid eaters		60,082,000
			/5.5kcal/gram = 10,924,000 grams		
			= 10,924 kilograms dry weight.		

Most of the shorebirds at Cheyenne Bottoms in spring 1986 were migrants en route from wintering areas in Latin America and the southern United States to their nesting areas in the boreal and arctic regions of Canada and Alaska. Their requirements for fat reserves to complete the migration can be calculated from equations of the energetic demands of migratory flight (McNeil and Cadieux, 1972) and from knowledge of the distances to be flown. Table 16.5 provides estimates (for these same 17 species categories) of the populations using Cheyenne Bottoms, the route lengths, flight-metabolic requirements (FM), fat required per bird, and fat required by the whole population.

Two shorebird species categories (Snowy Plover and American Avocet) exhibit rout lengths of zero, indicating that they breed at Cheyenne Bottoms. Flight metabolism (FM), like BMR and EMR, increases with body size, and again, big birds are more efficient, at least within the size range included here. The fat reserves needed per bird depend on the distances to be flown (estimated from range maps) and on flight speeds (adapted from McNeil and Cadieux, 1972). The fat reserves needed in total are almost 2.8 million grams. The four species-categories dominant in metabolic requirements also account for 91% of the migratory fat requirements. These species were not only numerically dominant but also breed farther north and thus have longer flights to make. The dowitchers alone accounted for 44% of the migratory fat requirements. The 12 categories of chironomid-eating species accounted for over 98% of the migratory fat requirements. The five species that apparently do not depend on chironomids all have relatively short migratory distances.

Table 16.5--Potential migratory fat accumulation by shorebirds using Cheyenne Bottoms, spring 1986. FM is flight metabolic requirements, in kilocalories per hour. Species categories marked with an asterisk (*) feed primarily on chironomid larvae at Cheyenne Bottoms.

Species	# indiv.	Route length (mi)	FM (kcal/hr)	Fat/bird (g)	Fat/popn. (g)
*Semipalmated Plover	900	1700	3.51	13	11,700
*Snowy Plover	40	0	3.69	0	0
*Black-bellied Plover	500	1900	11.63	47	23,500
*Lesser Golden-plover	60	1700	8.83	32	1,900
Willet	50	350	14.68	12	600
Greater Yellowlegs	600	1400	9.94	33	19,800
Lesser Yellowlegs	1,000	1450	5.73	19	19,000
*Baird's Sandpiper	38,000	2000	3.32	14	532,000
*White-rumped Sandp.	30,000	2100	3.58	16	480,000
*Least Sandpiper	5,000	1650	2.10	7	35,000
*other sandpipers	30,000	2100	3.58	16	480,000
*Stilt Sandpiper	4,500	1800	4.41	19	85,500
*dowitchers	31,000	2400	7.04	40	1,240,000
*Hudsonian Godwit	750	1400	13.44	44	33,000
*Marbled Godwit	250	550	17.73	22	5,500
Wilson's Phalarope	5,500	350	4.52	4	22,000
American Avocet	1,300	0	15.76	0	0
Totals	149,450				2,792,400
			by chironomid eaters:		2,748,100
			by four dominant species:		2,552,000

The chironomid feeders together would require 2.75 million grams (2,750 kilograms) of fat to complete their migrations. Assuming a 70% assimilation efficiency (Myers et al., 1985), this would require the ingestion of nearly 4,000 kilograms dry weight of chironomid larvae.

These calculations of migratory fat requirements are very tentative, for a number of reasons. First, they assume that the birds arrive at Cheyenne Bottoms without stored fat. If the birds did arrive with some fat, they would not need to eat as much at Cheyenne Bottoms. Second, the calculations also assume that the birds leave Cheyenne Bottoms and fly directly to their nesting areas. Many undoubtedly do this, but some are known to make other stops to the north and could obtain some of the needed reserves there. Third, the

population estimates are very conservative, in that they assume very low turnover rates. The census data are equally consistent with much larger numbers using Cheyenne Bottoms, but with individuals staying for shorter periods. Fourth, females of the arctic-nesting species must arrive on their breeding grounds carrying, as reserves, some of the energy to put into their eggs, so their feeding requirements at Cheyenne Bottoms would be higher than calculated here. Finally, the drying of Pool 2 at Cheyenne Bottoms in mid-May may have caused White-rumped and Stilt sandpipers to leave early, without accumulating the needed reserves of fat. The metabolic requirements (EMR) are based on substantially firmer data and calculations than the migratory-fat calculations.

Considering the 11,000 kilograms required for metabolism and the 4,000 kilograms needed for migratory fat, the shorebirds at Cheyenne Bottoms may have harvested 15,000 kilograms (dry weight) of chironomid larvae in spring 1986. Chironomid larvae contain about 90% water, so the 15,000 kilograms would equal 150,000 kilograms live weight. The high-quality open shorebird habitat at Cheyenne Bottoms in spring 1986 amounted to about 3,000 acres, so these 150,000 kilograms would amount to 50 kilograms (110 pounds) per acre.

SHOREBIRD SPECIES ACCOUNTS

The species accounts begin, where appropriate, with a statement of species status. This statement notes special status under federal law (legal-game species, threatened and endangered species). The status statements also document the few species accounts discussing two closely related species together.

A distribution and abundance section describes the world range, with emphasis on North America, followed by a statement of distribution and abundance in Kansas. Then the species' occurrence in Kansas is described. Four major sources of data are discussed in each account. The first is a paper by Parmalee, Schwilling, and Stephens (1969) on "Charadriiform birds of Cheyenne Bottoms," describing the abundance and seasonality of shorebirds and other charadriiform birds at Cheyenne Bottoms, through 1968. The second is the files of bird records kept at Cheyenne Bottoms since 1962. Files for the years through 1975 were kept by, and remain in the care of, Marvin Schwilling of the Kansas Fish and Game Commission. Files since 1976 have been kept by Stan Wood and are housed at the Cheyenne Bottoms Waterfowl Management Area headquarters. These files are together cited in the species accounts as the "CBWMA files." The third data source is a summary of banding records for Cheyenne Bottoms through 1982, obtained by Kansas Fish and Game Commission personnel from the U.S. Fish and Wildlife Service. Most of the shorebird-banding data are due to the work of Mr. Ed Martinez of Great Bend. The banding summaries are useful sources of information on seasonality of shorebird presence, but must be used with care. The relative abundances of species in the data may reflect differential susceptibility to capture as well as actual abundance. Since banding activity seems to have occurred during the peak migration months, the relative abundance in "off" seasons may not be

accurately represented, especially for particular species. Censuses conducted in this study are also summarized here.

The next section describes habitat use by the species, first in general terms, and then for Cheyenne Bottoms specifically. The final section discusses food preferences of the species. All species have a general section describing food preferences gleaned from the literature. For selected species, observations of feeding and analyses of gut contents of individuals collected in this study are described.

American Avocet (Recurvirostra americana)

American Avocets breed from southern Canada (west of the Great Lakes) south through the Columbia Basin and the Great Basin, the interior valleys of California, and the Great Plains, to southern Texas and central Mexico. They winter from coastal California, south Texas, and Florida south to Central America. In Kansas they are abundant migrants and nest regularly in the western half of the state. Parmalee et al. (1969) called them common to abundant migrants and summer residents at Cheyenne Bottoms, with extreme dates of 13 March to 8 December. They also reported the recovery in Florida of an avocet banded as a chick at the Bottoms. The CBWMA files yield an early date of 8 March and numerous nesting records. The banding records include 384 individuals, banded between April and September, and peaking in June. These include numerous prefledgling young.

In this study avocets were seen on all 1985 surveys in August, September, and October, with a peak of 1090 birds 29 September. In spring they were first seen 3 April and have been present on all surveys since. Numbers peaked at 1,300 May 2 and dropped to 60 birds by 16 May, but rose again to 900 on 3 June. Thirty to 40 pairs attempted to nest in 1986. The main nesting areas were in sparsely vegetated areas of pools 3 and 4, generally near shallow,

standing water. A few nests were located in pools 2 and 5, and at least two were built in the southeastern corner of Pool 1. Apparently all nesting attempts failed, as no young avocets could be found in June or July. Many of the nesting areas were flooded by rains in May and June, and nest predation may have been heavy.

Habitat Use. Avocets mostly feed in open, shallow water. They prefer shallow lakes, marshes with open water, and shallow lagoons. At Cheyenne Bottoms avocets used all five pools, when water levels were suitable. In fall 1985 most avocets used Pool 2. For much of the fall the water was too deep for wading, and the birds fed mainly while swimming. After mid-October, they also used the shallow water of the newly flooded pools 3 and 4. In spring 1986, all pools were used. Use of pools 2, 3, and 4 ended in early May when those pools went dry, but shortly before they went dry, they got heavy use, evidently as prey were concentrated by the falling water levels. After 10 May, pool 5 and the southeastern corner of Pool 1 received the most use.

Food Preferences. American Avocets feed on planktonic invertebrates, small fish, and flying and surface-inhabiting insects. They feed by pecking, sweeping, or filtering animals from the water, by grasping insects sitting on the mud substrate, and by snatching low-flying insects from the air (Hamilton, 1975). At Cheyenne Bottoms they fed primarily by sweeping their bills through the water to capture small fish and planktonic invertebrates. Three avocets were collected in this study. One, collected 14 April, contained fish parts (probably of fathead minnows), a larval odonate, and a few aquatic hemiptera. The other two, collected 25 April, contained 340 and 388 small chironomid larvae, as well as a few parts of other aquatic insects. These two birds were watched for several minutes before collecting and were feeding by

sweeping their bills through the water. The larvae they were obtaining must have been in the water column, perhaps as a result of heavy wave action.

Black-necked Stilt (Himantopus mexicanus)

Black-necked Stilts breed from Oregon, Idaho, Utah, southern Colorado, central Kansas, and from southern New Jersey south through central America and the Antilles to northern Venezuela, Colombia, and Ecuador (AOU, 1983; Blake, 1977). They winter within the breeding range but withdraw from the more northern areas. In Kansas, Black-necked Stilts inhabit the south-central region, about north to Cheyenne Bottoms. Parmalee et al. (1969) called them "Irregular rare transient(s) in spring and casual visitor(s) in summer and early fall." Their observations occurred from 1 April to 24 August. The CBWMA files contain 32 records and provide an early date of 21 March.

In this study five Black-necked Stilts were seen in the Mallard Club area 11 September 1985. In the spring, one was seen on 13 April, three on 2-4 May, and a pair on 10 and 11 May. Although Black-necked Stilts breed regularly at Quivira National Wildlife Refuge to the south, they apparently have not been found nesting at Cheyenne Bottoms. From 2 May to 10 May 1986, a mated pair occupied a territory on a mud bar in the inlet canal approximately 1 mile east of the CBWMA headquarters. They were together constantly and were seen to copulate once. On 10 May water diverted from Wet Walnut Creek reached Cheyenne Bottoms and their mud bar was quickly covered with about 2 feet of water. That afternoon the pair was seen in Pool 4 but then disappeared.

Habitat Use. Black-necked Stilts prefer open shallow water without macrophytes. They seem to be partial to saline, brackish, and alkaline water but also use freshwater. Observations were made in the drying remnants of

pools 2, 4, and 5, and in the inlet canal prior to the spring influx of diverted water.

Food Preferences. Black-necked Stilts feed primarily on planktonic invertebrates, and terrestrial (mudflat) arthropods. They may also take small fish (Johnsgard, 1981).

Lesser Golden Plover (Pluvialis dominica)

Lesser (American) Golden Plovers breed on arctic tundra from Alaska to Baffin Island and winter primarily in South America south of the equator. Currently they are uncommon migrants through Kansas both in spring and fall. A century ago, before they were devastated by market hunting, they were abundant migrants, at least in spring. Parmalee et al. (1969) reported them at Cheyenne Bottoms from 9 April to 9 November, without an obvious break between northward and southward migrations. The CBWMA files include an early date of 8 April.

In this study one flock of 15 birds was observed 29 September. These plovers were present in spring from 3 April to 10 May, with a maximum count of 40 birds 2 to 4 May.

Habitat Use. Golden Plovers commonly feed in over-grazed pastures, mowed hayfields, short-grass prairies, and on lawns. At Cheyenne Bottoms they also regularly fed on the exposed mud of Pool 2. They usually stayed above the waterline, on wet mud, but sometimes foraged on higher, drier, areas.

Food Preferences. Golden Plovers feed on a variety of terrestrial insects, as well as on intertidal and lacustrine invertebrates. In migration terrestrial orthopterans are very important (Johnsgard, 1981). At Cheyenne

Bottoms they fed extensively on the exposed mud of Pool 2, apparently taking chironomid larvae.

Comment. If Lesser Golden Plover populations continue to recover from the devastation they suffered in the last century, numbers using Cheyenne Bottoms should increase dramatically. Cheyenne Bottoms probably will not become critical habitat for them, however, for they do make extensive use of upland habitats.

Black-bellied Plover (Pluvialis squatarola)

Black-bellied Plovers have a circumpolar breeding range on arctic tundra. They winter primarily on seacoasts in tropical and temperate zones worldwide. They are uncommon migrants through Kansas both in spring and fall. Parmalee et al. (1969) reported extreme dates at Cheyenne Bottoms of 9 April to 19 June and 8 August to 9 November. The 21 records in the CBWMA files add little to this picture. In this study Black-bellied Plovers were seen only twice the in fall (two on 31 August, 25 on 20 October). In spring they were present from 2 May to 3 June, with a maximum of over 450 birds on 16 May.

Habitat Use. Black-bellied Plovers use habitats varying from tundra to ocean beaches, salt marshes, plowed fields, and grazed pastures. The unifying variables seem to be moist substrates and low or sparse vegetation. At Cheyenne Bottoms most Black-bellied Plovers observed in this study used the exposed mudflats of pools 2 and 5. They normally remained on the wet or drying mud above the waterline.

Food Preferences. Black-bellied Plovers feed on a variety of beach-dwelling invertebrates, as well as on terrestrial and marsh-inhabiting insects

(Johnsgard, 1981). At Cheyenne Bottoms they fed mainly on the exposed mud in pools 2 and 5, apparently on chironomid larvae.

Killdeer (Charadrius vociferus)

Killdeer are primarily temperate-zone plovers that breed throughout most of North America in open, often disturbed areas. They nest from central Alaska and central Canada south into Mexico (AOU, 1983). They breed throughout Kansas, generally on roadsides, cultivated ground, and other sites where human activity reduces vegetational cover. At Cheyenne Bottoms they are common summer residents, nesting primarily on the dikes. Parmalee et al. (1969) listed as extreme dates 7 March and 11 December. The CBWMA records add an early date of 15 February. A total of 856 Killdeer were included in the banding summaries. They were banded in all months from March to October and peaked in July and August. Numerous nonflying juveniles were included in the total.

In this study Killdeer were found to be common at the Bottoms until late October 1985, and reappearing in mid-March in 1986. Killdeer numbers throughout fall migration and early in spring were much higher on plowed farmland adjacent to the CBWMA than on the management area itself. About 40 pairs attempted to nest on the management area in 1986, mainly on the dikes and on exposed dry mud in pools 3,4, and 5. Downy Killdeer were in evidence throughout Cheyenne Bottoms in May and June, but overall nesting success could not be estimated.

Habitat Use. Killdeer are habitat generalists, and their main requirement is open areas with no more than sparse low vegetation and dry, well-drained sites for nesting. At Cheyenne Bottoms, Killdeer mainly use the dike roads, cultivated fields, and the exposed mud of drained pools.

Food Preferences. Killdeer mainly eat insects, especially beetles (Johnsgard, 1981) but will take other invertebrates, including earthworms. The stomachs of two Killdeer collected at Cheyenne Bottoms contained a variety of beetles, gastropods, and diptera. About two-thirds of the beetles were hydrophylids, and the others were terrestrial species.

Semipalmated Plover (Charadrius semipalmatus)

Semipalmated Plovers breed in sandy, gravely, and mossy tundra areas, from western Alaska to Baffin Island, and south in suitable habitat into British Columbia, to southern Hudson Bay, and to the Canadian Maritime provinces. They winter mainly along seacoasts from California and the Carolinas to central Chile and Patagonia. In Kansas they are uncommon transients both in spring and fall. Parmalee et al. (1969) called them regular, uncommon to common transients at Cheyenne Bottoms, with records from 7 April to 23 May for northbound birds, and 20 July to 30 October for southbound birds. The CBWMA files extend the spring migration period to 22 March to 8 June and provide an early date of 30 June for southbound birds. The banding summaries include 650 captures; 30% from spring migration and 70% from fall.

In this study Semipalmated Plovers were seen 21 August (two birds) and 31 August (four birds), and again 22 September (10 birds). In spring they were seen from 23 April to 10 May, but with a peak of 850 birds 10 May. Apparently all had departed before the 12 May census.

Habitat Use. Semipalmated Plovers prefer rocky, sandy, or muddy beaches, lakeshores, and mudflats. They were most often seen on the exposed mud of pools 2,3, and 5. They rarely waded but instead fed on the exposed mud above the waterline.

Food Preferences. Semipalmated Plovers feed on invertebrates that they glean from the surface of the substrate. Insect larvae and adults are particularly important in inland sites.

Snowy Plover (Charadrius alexandrinus)

The Snowy Plover is under consideration by the U.S. Fish and Wildlife Service for listing as a threatened or endangered species (Federal Register, vol 47, p.58474).

Snowy Plovers breed in North America on seacoasts from southern Washington to Baja California and around the Gulf of Mexico, in the Great Basin in Oregon, California, Nevada, and Utah, and on the Great Plains from Kansas south to New Mexico (AOU, 1983). Elsewhere they have a temperate to tropical distribution, mostly on seashores and saline lagoons, in South America, Eurasia, North Africa, and Indonesia.

At Cheyenne Bottoms Snowy Plovers are uncommon summer residents. Parmalee et al. (1969) gave extreme dates of 31 March to 18 September, and a maximum count of 37 birds. The CBWMA files established an early arrival of 25 March. The banding records include 388 birds, captured in the months April through September, and include many juveniles.

In 1986, 15 to 20 pairs were present and resumed breeding and produced a total of 8 to 10 young. Nests were not located, but from the behavior of the adults the nesting areas could be determined. Snowy Plovers attempted to nest in Pool 3 in the northern basin where the best stands of millet grew in 1985 (two to three pairs produced two young), about 100 meters off the Pool 1/Pool 3 dike (two pairs produced two young), and around some of the blinds in the winter wheat area (three to four pairs produced two to three young). In Pool 4 one or two pairs may have used the areas around blind islands along the Pool 3/Pool 4 dike; alternatively, the birds seen here may have been the same ones

seen in the adjacent areas of Pool 3. Three pairs were regularly seen in Pool 5 and raised two young. Several pairs were seen regularly in Pool 2, but no young were detected there. Water levels and movements probably prevented successful nesting before early May, and after that, the area may not have supported adequate food. Although Cheyenne Bottoms provides much less suitable habitat than Quivira Refuge, appropriate habitat management should maintain a viable breeding population.

Habitat Use. Snowy Plovers prefer unvegetated or sparsely vegetated beaches, salt flats, mud bars, and sand bars. At the Bottoms they mainly use the exposed mud, wet and dry, in the peripheral pools.

Food Preferences. Snowy Plovers feed primarily on insects and insect larvae, although in seacoast situations, small crustaceans, small mollusks, and polychaete worms are important (Johnsgard, 1981). At Cheyenne Bottoms insects, including chironomid larvae, are the preferred food.

Piping Plover (Charadrius melodus)

The U.S. Fish and Wildlife Service (Federal Register, vol.51, p.50726-50733, 1985) recently listed the Piping Plover as a threatened species (the Great Lakes population is listed as endangered).

Piping Plovers breed along the Atlantic coast from North Carolina to the Maritime provinces, on the Great Lakes, and in the northern Great Plains in Alberta, Manitoba, Saskatchewan, Montana, North and South Dakota, Minnesota, Nebraska, and Iowa. The nesting areas closest to Cheyenne Bottoms are along the Platte River in south-central Nebraska. Piping Plovers winter in Florida and along the coast of the Gulf of Mexico (AOU, 1983).

Piping Plovers are rare migrants through Cheyenne Bottoms in spring and fall. Parmalee et al. (1969) reported them from 29 March to 14 May, and the

CBWMA files included 14 sightings from 29 March to 3 May, and 3 June to 3 August. In this study single Piping Plovers were observed 31 August 1985, 13 April, 10-12 May, and 18 August 1986. Two individuals were seen 23 April.

Habitat Use. Piping Plovers, like other small plovers, require extensive areas relatively free of vegetation, adjacent to open water. Their normal habitats include ocean beaches, riverine and lacustrine mud, sand, and gravel bars, and salt pans. Currently Cheyenne Bottoms hosts very few Piping Plovers, but if attempts to improve nesting habitat in the northern Great Plains are effective, use can be expected to increase.

Food Preferences. Piping Plovers feed mainly on insects and other small arthropods picked from the surface of the substrate (Johnsgard, 1981). Apparently they fed on chironomid larvae at Cheyenne Bottoms.

Ruddy Turnstone (Arenaria interpres)

Ruddy Turnstones have a circumpolar breeding distribution, using mainly dry arctic tundra. They winter mostly on seacoasts throughout the tropics and both temperate zones (AOU, 1983). They are uncommon transients through Kansas, stopping mainly on lakeshores and unvegetated areas of marshes. Parmalee et al. (1969) gave migration extremes of 7 May to 6 June and 9 August to 8 October and noted far more birds in spring than in fall. The CBWMA files include 21 reports and extend the earliest spring report to 24 March, and the earliest southbound report to 26 July. In this study no Ruddy Turnstones were seen at Cheyenne Bottoms during fall migration, although one was present at Quivira Refuge 2 September. In spring, two Ruddy Turnstones were observed 10 May.

Habitat Use. Ruddy Turnstones in migration prefer beaches, lakeshores, mudflats, and other vegetation-free at the edge of water. They often flip over shells, pebbles, and other small objects to expose invertebrates hiding beneath them and may prefer pebble-strewn beaches to other habitats.

Food Preferences. Ruddy Turnstones feed mainly on invertebrates picked from the surface of the substrates (or from under small objects). At times they feed heavily on the eggs of terns and other colony-nesting seabirds (e.g., Loftin and Sutton, 1979). They seem to be too rare at Cheyenne Bottoms to have significant trophic impact on nesting birds or on invertebrate populations.

Common Snipe (Gallinago gallinago)

Common Snipe are the only shorebirds legally hunted at Cheyenne Bottoms, although hunting pressure there seems light.

Common Snipe are virtually world-wide in distribution. They breed from arctic wet tundra south in heavily vegetated marshes well into the temperate zone. In the Great Plains snipe breed south to northern Colorado, western Nebraska, and central Iowa (AOU, 1983). In Kansas snipe are abundant transients, with some individuals present in all but the coldest months of the year. Parmalee et al. (1969) considered them common to abundant transients at Cheyenne Bottoms and gave extreme dates of 11 March to 10 June and 4 September to 6 December. The CBWMA files extend the spring arrival to 9 March, and the southbound arrival to 13 July.

In this study snipe were first observed 21 August 1985 and were present throughout the fall. Snipe disappeared from Cheyenne Bottoms about 20 November, when the marsh froze over completely, but three were observed on 18 December along the Arkansas River between Great Bend and Ellinwood, where

shallow open water persisted. In spring 1986 snipe were first observed 13 March and were seen regularly until 23 April. These birds' predilection for heavy vegetation precluded accurate censuses, but numbers encountered for much of October and in early April suggested a population of several hundred to a few thousand birds present.

Habitat Use. Snipe prefer grassy and weedy marshes, with moderately dense vegetation, and exposed wet soil or very shallow water. At Cheyenne Bottoms in fall 1985, snipe concentrated in areas flooded by rainfall, peripheral to the main pools. They were particularly evident northwest of Pool 2 and south of Pool 5.

Food Preferences. Snipe feed by probing in muddy substrates with their long and flexible bills. Foods include insects (adults and larvae), small crustaceans, earthworms, and small snails (Johnsgard, 1981). Stomachs of two Common Snipe collected at Cheyenne Bottoms in November 1985 contained small gastropods, and one also had a single fairy shrimp.

Upland Sandpiper (Bartramia longicauda)

Upland Sandpipers breed in the interior of northern Alaska and from the Canadian prairie provinces south to eastern Oregon, central Colorado, north-central Texas, southern Illinois, and central Virginia. They have a large wintering range in tropical and temperate South America (AOU, 1983). In Kansas, Upland Sandpipers are widespread and common breeding birds wherever their preferred prairie habitat remains. Parmalee et al. (1969) considered them "regular, uncommon transient(s) and rare summer resident(s)," and mentioned the possibility of breeding in the peripheral areas of the CBWMA. They listed extreme dates of 9 April to 7 September. The CBWMA files provide an early date of 2 April.

In this study, Upland Sandpipers were seen in sparsely vegetated areas of Pool 3 on 20 August, 31 August, and 11 September 1985, and were common in recently mowed alfalfa fields near Cheyenne Bottoms in late August. In spring 1986 they appeared in peripheral areas and northwest of Pool 2 on 14 April and were present in these areas (and possibly nesting) through early June. In late June the exposed soils of pools 2, 3, and 5 were seeded with Japanese millet, and on 18-19 July at least 20 Upland Sandpipers were seen in these plantings.

Habitat Use. Prairie is the preferred habitat of Upland Sandpipers, and tall-grass prairies may be preferred over short-grass prairies. These birds also use some agricultural land, especially hayfields and alfalfa fields. At Cheyenne Bottoms most of the sightings were in peripheral pastureland.

Food Preferences. Upland Sandpipers feed mainly on insects and other invertebrates and obtain much of their food by gleaning from foliage. The only feeding observations at Cheyenne Bottoms were of birds picking objects (insects?) from the foliage of annual plants in drained areas of pool 3.

Long-billed Curlew (Numenius americanus)

The Long-billed Curlew is under consideration by the U.S. Fish and Wildlife Service for listing as a threatened or endangered species (Federal Register, vol. 47, p.58454).

Long-billed Curlews breed on the Great Plains, in the intermountain valleys of the Rocky Mountains, in the Great Basin, and in the Columbia Basin, from southern British Columbia, Alberta, Saskatchewan, and Manitoba south to northeastern California, central Nevada and Utah, southern Colorado, and northern Texas; and east to western Nebraska and southwestern Kansas. They winter, mainly coastally, in southern California, Mexico, and Central America,

and along the Atlantic and Gulf coasts from South Carolina to southern Texas (AOU, 1983). In Kansas, Long-billed Curlews breed sparingly in the southwestern portion of the state, and an occasional migrants elsewhere. Parmalee et al. (1969) called them uncommon transients at Cheyenne Bottoms and discussed two possible nesting attempts near the waterfowl-management area. They listed extreme dates of 29 March and 25 September. The CBWMA files include an earlier record (23 March). In this study single Long-billed Curlews were seen 23 April and 12 May, and a flock of 13 was present on 4 July.

Habitat Use. Long-billed Curlews breed in short-grass and mixed-grass prairies, grazed pastureland, and grassy shrub-steppe habitats (Johnsgard, 1981). The unifying factor seems to be complete grass coverage but with grass short enough for standing birds to visually survey their surroundings. In migration and winter, they frequent a variety of marsh, lagoon, and beach habitats. At Cheyenne Bottoms, two sightings were in pastureland, and the group of 13 was resting on the mud of Pool 5.

Food Preferences. Long-billed Curlews eat a variety of invertebrate prey. On upland habitats they often feed by grasping visually located insects; in wetland habitats they generally probe for burrowing invertebrates.

Whimbrel (Numenius phaeopus)

Whimbrels have a circumpolar breeding distribution on arctic tundra, and they winter in tropical and warm-temperate coastal areas world-wide. In Kansas, Whimbrels are uncommon to rare transients. Parmalee et al. (1969) reported migration dates of 24 April to 22 May for northbound birds and 30 June to 27 September for southbound birds. The CBWMA files include 32 reports

and provide an earliest spring date of 11 April and a latest fall date of 24 October.

In this study Whimbrels were seen only in spring. Seven were seen in a flock on 23 April, one was observed on 2 May, two on 10 May, and one on 16 May.

Habitat Use. Whimbrels use a variety of habitats, including wet and sandy pastures, beaches, salt and freshwater marshes, coastal lagoons, and mudflats. These habitats all have soft substrates that can be probed by the birds' long bills. At Cheyenne Bottoms all of the Whimbrels observed were on the exposed mud of pools 2 and 5.

Food Preferences. Whimbrels feed mainly on relatively large burrowing invertebrates that are retrieved from the substrate by the birds' long, curved bills.

Spotted Sandpiper (Actitis macularia)

Spotted Sandpipers breed along streams and lakeshores from about the treeline in central Alaska and northern Canada south through most of the United States, excluding the southeastern coastal plain. They winter in the milder areas of their breeding range and south to northern Chile and Argentina. In Kansas they are occasional breeders and uncommon migrants throughout the state. Parmalee et al. (1969) considered them regular but uncommon transients, with records from 26 April to 15 June and 15 July to 7 October. The CBWMA files reported two nests in a park in Great Bend (in 1968 and 1969) and included a 30 June sighting at Cheyenne Bottoms. The banding records show 141 banded between the months of May and September.

During this study single Spotted Sandpipers were seen 23 September and 20 October, and four were present 2 to 4 May.

Habitat Use. Spotted Sandpipers prefer gravel bars, rocky beaches, revetments, and similar habitats with hard substrates abutting on open water. At Cheyenne Bottoms all sightings in this study were on riprapped sections of the Pool 1/Pool 2 dike. Suitable habitats for Spotted Sandpipers are rare at Cheyenne Bottoms, and those that do occur are artificial. Apparently Cheyenne Bottoms has never been important to this species.

Food Preferences. Spotted Sandpipers feed mainly on aquatic and terrestrial insects, except when wintering on ocean beaches where they eat a variety of crustaceans and mollusks (Johnsgard, 1981).

Willet (*Catoptrophorus semipalmatus*)

Willets breed in western North America in the Great Basin and Snake River valley and from the Canadian prairie provinces south to western Nebraska and eastern South Dakota. (A separate subspecies breeds on the Atlantic coast from Nova Scotia to northern South America.) Willets winter from the southern United States south to Brazil and northern Chile (AOU, 1983). In Kansas they are uncommon transients, primarily in the central and western parts of the state. Parmalee et al. (1969) considered them uncommon transients at Cheyenne Bottoms, with extreme dates of 7 April to 11 June and 26 June to 5 October. The CBWMA files extend fall records to 24 October. The banding summaries record 40 banded from April through September, with a peak in August.

In this study Willets were seen 22 to 23 September (five birds) and in spring from 13 April to 4 July, with a peak of 45 birds 10 May. A group of four birds seen 23 June included two breeding-plumage adults and two apparent juveniles. They stayed together as a group and acted somewhat like a family group. Willets are not known to breed in Kansas, but they do breed in western Nebraska.

Habitat Use. Willets use a wide range of wetland habitats, including beaches, mudflats, saltmarshes, lakeshores, and flooded meadows. At Cheyenne Bottoms most Willet sightings were in or near standing water in pools 3, 4, and 5, generally in unvegetated areas.

Food Preferences. Willets eat a variety of invertebrates, generally selecting larger prey than most other sandpipers. Crustaceans form a large part of the diet in some areas, and at Cheyenne Bottoms Willets may make use of the large crayfish populations. They also eat numerous insects.

Greater Yellowlegs (Tringa melanoleuca)

Greater Yellowlegs breed across Canada and Alaska in the zone of intergradation from tundra to tiaga (boreal forest), and south into the tiaga belt. They winter from Oregon and South Carolina south primarily along seacoasts all the way to Tierra del Fuego (AOU, 1983). In Kansas, Greater Yellowlegs are common in migration both in spring and fall. Parmalee et al. (1969) called them abundant transients, seen northbound from 8 March to 12 June and southbound from 20 June to 6 December. The CBWMA files include spring sightings as early as 27 February.

In this study Greater Yellowlegs were seen from 31 August to 9 November and from 5 March through spring and summer. High counts in fall were generally 25 to 35 birds, and most of these were seen in grassy pools in the pastureland northwest of Pool 2. After flooding of pools 3 and 4 in mid-October, some yellowlegs were seen in the more open areas between the blind islands. In spring, numbers peaked at 120 birds on 21 March and declined to 23 birds by 13 April. A major influx overnight produced a count of 340 birds 14 April, and numbers declined slowly after that.

Habitat Use. Greater Yellowlegs feed mainly while wading in shallow water. Unlike many shorebirds they are not averse to using areas with extensive emergent vegetation. At Cheyenne Bottoms in fall, they were common in the pools and potholes in the pastures northwest of Pool 2. In spring they were most numerous in pools 2, 3, and 5, wading in water 2-5 inches deep.

Food Preferences. Greater Yellowlegs generally feed on insects and other invertebrates caught in the water column or on exposed mud, and on small fish. Two Greater Yellowlegs collected 14 April contained fish and fish parts, and one also contained three aquatic hemipterans. One fish was identified as a Fathead Minnow.

Lesser Yellowlegs (Tringa flavipes)

Lesser Yellowlegs breed on wet tundra and in muskeg wetlands in the tiaga (boreal forest) zone, from western Alaska east to James Bay and south into British Columbia and the Canadian prairie provinces. They winter from the southern United States south through Latin America to Tierra del Fuego (AOU, 1983). In Kansas they are common migrants throughout, both northbound and southbound. Parmalee et al. (1969) gave dates ranging from 1 March to 6 December, with no clear break in summer. The CBWMA files include two sightings in February, the earliest on 19 February. The banding records include 1,053 birds. Most were banded during southbound migration (July-October), but 70 were banded during spring migration.

In this study Lesser Yellowlegs were present at Cheyenne Bottoms from the initial census on 12 August until freezeup, 21 November. The maximum fall count was 63 birds on 1 September. In spring the first recorded was 13 March, although a bird seen at a distance 23 February appeared to be a Lesser Yellowlegs or a Solitary Sandpiper. Numbers built gradually to a peak of 850

on 10 May, and dropped abruptly to 36 on 12 May. The 100 birds reappearing 23 June were all in complete breeding plumage and apparently were failed breeders returning south early.

Habitat Use. Lesser Yellowlegs prefer shallow freshwater ponds and lakeshores where they wade and pick at swimming food items. They seem to be less tolerant of salinity than are Greater Yellowlegs. At Cheyenne Bottoms in fall they were most frequent in the grassy pools in the pastures northwest of Pool 2, until mid-October, when they moved into the newly flooded areas of pools 3 and 4. In spring they frequented all pools and often foraged in areas with low emergent vegetation.

Food Preferences. Lesser Yellowlegs eat a variety of arthropods and worms taken from the water, from exposed mud, and occasionally picked from emergent vegetation. Like Greater Yellowlegs they occasionally capture small fish (Johnsgard, 1981).

Solitary Sandpiper (Tringa solitaria)

Solitary Sandpipers breed around ponds, streams, and bogs in spruce forests from central Alaska to Labrador. They winter from the southeastern United States and Baja California south to Argentina and Peru (AOU, 1983). In Kansas they are regular but uncommon to rare migrants, both in spring and fall. Parmalee et al. (1969) recorded only one in spring (30 April) and reported sightings in southward migration from 2 July to 18 September. The CBWMA files include five more records, including spring records from 27 April and 11 May, and a record for 30 June (presumed to be southbound).

In this study all sightings of Solitary Sandpipers were in the Mallard Club area northwest of the CBWMA. Five birds were seen here 31 August 1985, four were seen 2 May 1986, and one was present 18 July 1986. The single

shorebird seen 23 February 1986 could have been either a Lesser Yellowlegs or a Solitary Sandpiper.

Habitat Use. Solitary Sandpipers seem to prefer small pools of freshwater surrounded by vegetation. Cheyenne Bottoms provides little suitable habitat for this species.

Food Preferences. Solitary Sandpipers feed mainly on aquatic insects caught in the water column and also utilize terrestrial insects.

Red Knot (Calidris canutus)

Red Knots have a circumpolar breeding range in the high arctic. In North America they breed only in northern Alaska and on a number of the Canadian arctic islands. They winter on ocean beaches from the United States to South America and throughout the temperate and tropical old world (AOU, 1983). In Kansas they are irregular migrants, usually rare, but occasionally appearing in flocks. Parmalee et al. (1969) and the CBWMA files report only fall records, with extreme dates of 2 August to 26 September. Parmalee et al. (1969) did mention a sighting 1 June in Stafford County.

In this study Red Knots were not seen in fall but were recorded three times in spring. Four were present on 11 and 12 May, 20 on 16 May, and one on 3 June. All were in partial or complete breeding plumage, and all were seen on open mudflats in pools 2 and 5. These are not the first spring records for Cheyenne Bottoms. In recent years birders have been seeing them occasionally in May and June.

Habitat Use. Red Knots breed on high arctic tundra, and most migrate and winter along ocean beaches and on estuaries. At Cheyenne Bottoms all sightings were on open, exposed mud.

Food Preferences. Red Knots feed mainly on small crustaceans and insects which they pick from the surface of mudflats or sandy beaches, or obtain by shallow probing.

Pectoral Sandpiper (Calidris melanotos)

Pectoral Sandpipers breed on arctic wet tundra from Hudson Bay to western Alaska and across the arctic coast of Siberia from the Bering Sea to the Taimyr Peninsula. They winter in south-temperate South America (AOU, 1983). In Kansas Pectoral Sandpipers are abundant migrants throughout the state. Parmalee et al. (1969) gave dates of 18 March to 9 June and 8 July to 26 October. Almost 1,500 were banded in the months April through October; half of these were in August.

In this study Pectoral Sandpipers were seen from 20 August to 23 September 1985, in spring from 21 March to 4 May, and from July to September 1986. Maximum numbers were 600 birds 4 September.

Habitat Use. Pectoral Sandpipers have heavily streaked cryptic plumage, not unlike snipe and Upland Sandpipers. They prefer grassy meadows, pastureland, and grassy ponds rather than open areas. At Cheyenne Bottoms Pectoral Sandpipers were most often seen in pastureland south of Pool 5 and northwest of Pool 2, although occasionally they joined flocks of shorebirds feeding in the mud of pools 2, 3, and 4.

Food Preferences. Pectoral Sandpipers seem to feed mainly on terrestrial and marsh-dwelling insects (Johnsgard, 1981).

Comment. Because Pectoral Sandpipers prefer heavily vegetated habitats and have cryptic plumage,the censuses are very incomplete. Time simply was not available to walk the many grassy fields necessary for reasonable

censusing of this species. In spring 1986, Cheyenne Bottoms could easily have hosted an order of magnitude more Pectoral Sandpipers than were recorded.

Baird's Sandpiper (Calidris bairdii)

Baird's Sandpipers breed on arctic tundra from extreme eastern Siberia (eastern Chukchi Peninsula and Wrangel Island) east across northern Alaska and Canada to Baffin Island and extreme northwestern Greenland (AOU, 1983; Portenko, 1981). They winter in South America, primarily at high altitudes, from Ecuador to Tierra del Fuego (AOU, 1983). In Kansas they are common to abundant migrants, both in spring and fall. Parmalee et al. (1969) gave dates of 7 March to 17 June northbound, and 8 July to 6 December southbound. The CBWMA files provide early dates to 27 February. Only 450 were recorded in the banding summaries, an extremely low total compared to the other abundant small sandpipers. Perhaps Baird's Sandpipers are more difficult to trap. The captures were about evenly divided between northbound and southbound migration. In spring, April bandings outnumbered May ones, in contrast to the other small sandpipers.

In this study, Baird's Sandpipers were observed in 1985 from 12 August to 23 September in numbers up to 106 birds. In spring they were first observed 13 March and were present on all censuses until 16 May. Numbers reached 3,400 birds 21 March, climbed to 4,400 on 3 April, dropped overnight to 1,500 on 4 April and to 430 on 14 April. A major influx then occurred, with 36,000 present 23 April, dropping to 8,000 by 4 May, and 28 on 12 May. A single bird seen 4 July probably was an early southbound adult.

Habitat Use. Baird's Sandpipers breed on dry tundra. In migration they frequent lakeshores, mudflats, and grassy marshes. They migrate and winter primarily inland and seem relatively intolerant of salinity. At Cheyenne

Bottoms most were seen on the bare mudflats of pools 2 and 5, with small numbers on pools 3 and 4. They usually stayed on the wet or the dry mud and rarely waded.

Food Preferences. Baird's Sandpipers feed primarily on insect larvae and adults (Johnsgard, 1981).

White-rumped Sandpiper (Calidris fuscicollis)

White-rumped Sandpipers breed in the high arctic of North America, from the north slope of Alaska to Baffin Island. They winter in temperate South America, south to Cape Horn (AOU, 1983). In Kansas, White-rumped Sandpipers are abundant spring migrants and rare fall migrants. They follow a migration path similar to that of Hudsonian Godwits: fly to the Maritime provinces and New England in fall, thence south over the Atlantic to the Lesser Antilles and eastern South America. In spring they come across the Gulf of Mexico and up through the interior of North America, between the Mississippi River and the Rocky Mountains. They are the latest of the shorebirds to pass through Kansas in spring migration. Parmalee et al. (1969) give spring dates of 29 April to 19 June, with the peak movement occurring in late May. The banding records include almost 3,800 White-rumped Sandpipers. About 90% were banded in May, and virtually all of the others were banded in June.

In this study, no White-rumped Sandpipers were observed in fall 1985. In spring 1986 they were present from 2 May to 3 June. On 2 May, 10 were found among about 20,000 small sandpipers (peeps). Undoubtedly more were present, but still they could not have amounted to more than 2 or 3% of the birds present. On 10 May, 55,000 peeps were present, and 50 to 60% in the samples examined carefully were White-rumped, suggesting a total of 27,000-33,000 of this species. By 12 May about half the peeps left, but the 27,000 remaining

appeared to be mostly White-rumped. Approximately the same number of peeps were present 16 May, and again White-rumped Sandpipers seemed to predominate. One thousand White-rumped Sandpipers were present 3 June and on 23 July, 10 were seen.

Habitat Use. White-rumped Sandpipers breed on mossy or grassy tundra. In migration they frequent lakeshores, lawns, pastures, and mudflats. They (and Bairds's Sandpipers) seem less tolerant of salinity than the other small Calidris sandpipers. At Cheyenne Bottoms they mostly were seen on the mud of Pool 2 as it evaporated dry. Smaller numbers used similar mudflats in Pool 5.

Food Preferences. White-rumped Sandpipers' food habits are "very poorly documented" (Johnsgard, 1981), but they appear to feed on arthropods and worms burrowing shallowly in the mud.

Comment. The International Shorebird Survey considers Cheyenne Bottoms extremely critical habitat for White-rumped Sandpipers, with over 90% of the birds counted in spring migration using the Bottoms. In 1986 water levels were such that abundant high-quality habitat was available until 10 May, but relatively little good habitat was available for the next several weeks. Thus most of the shorebird species had abundant habitat through their migratory peaks but the late-arriving White-rumped Sandpipers probably experienced habitat shortages.

Least Sandpiper (Calidris minutilla)

Least Sandpipers breed on wet tundra in the low arctic from southern Alaska across Canada to Hudson Bay, northern Quebec, Labrador, and Newfoundland. They winter, primarily coastally, from Oregon and North Carolina south to tropical South America (AOU, 1983). Least Sandpipers are

abundant migrants through Kansas, both northboound and southbound. Parmalee et al. (1969) reported them from 29 March to 17 May and from 2 July to 11 December. The CBWMA files provide dates as early as 5 March and also provide June sightings, obscuring the break between northbound and southbound birds. The banding records include almost 6,800 birds, banded between April and October, with peak numbers in August-September and May.

In this study, Least Sandpipers were seen on all fall 1985 censuses through 21 October, with a peak of 120 birds 31 August. In spring 1986 they were seen from 3 April to 3 June. Numbers were low for most of that period, but 4,000 were counted 2 May, and at least several thousand were present among the 55,000 peeps 10 May. By 12 May, only 1,600 could be found. Southbound birds appeared by 18 July, and 64 were counted 14 August.

Habitat Use. Least Sandpipers breed on wet tundra and the rest of the year prefer mudflats, lakeshores, grassy marshes, and flooded fields. They also occur on ocean beaches but seem to prefer muddier and less saline habitats. At Cheyenne Bottoms they were most frequently seen around the standing water of pools 2, 3, 4, and 5. They spent most of their time on wet mud or wading at the waters' edge, and in fact waded more than the other peeps.

Food Preferences. Least Sandpipers feed on small arthropods taken from the surface of the substrate (Johnsgard, 1981).

Semipalmated Sandpiper (Calidris pusilla) and Western Sandpiper (C. mauri)

Western and Semipalmated sandpipers are considered together here because they are often indistinguishable in the field, except at very close range.

Semipalmated Sandpipers breed from coastal northwestern Alaska east to Baffin Island and south to Keewatin, northern Quebec and Ontario, and coastal

Labrador. They migrate along the Atlantic coast and through the interior of North America east of the Rocky Mountains, to wintering areas in the Caribbean and South America. Western Sandpipers breed on Alaskan coastal tundra from Point Barrow to Bristol Bay, on Nunivak and St. Lawrence islands, and in northeastern Siberia. They winter from California and North Carolina south to northern South America (AOU, 1983). In Kansas, Semipalmated Sandpipers are abundant migrants and Western Sandpipers are common migrants.

Parmalee et al. (1969) called Semipalmated Sandpipers "regular abundant migrants" and reported extreme dates of 16 March to 8 June and 7 July to 25 September. For Western Sandpipers, they reported only scattered spring records but called them abundant in fall. Extreme dates were 12 March to 30 September, with no obvious break between northbound and southbound birds. The banding summaries included an incredible 30,900 Semipalmated Sandpipers and an impressive 7,500 Western Sandpipers. The Semipalmated Sandpipers were caught from April through October, but half came from May. Numbers were much lower in June than in the other months (except October). For Western Sandpipers, fewer than 2% were banded in spring. July and August accounted for three-fourths of the birds banded.

In this study these sandpipers were present from 12 August to 30 September, with a maximum count of 2,200 birds on 2 September. In spring five Semipalmated Sandpipers were seen 13 March, and three each of the two species were found 13 April. By 2 May these species totaled about 7,000 birds (apparently most were Semipalmated) and may have numbered over 20,000 on 10 May. Numbers dropped to about 650 on 12 May. One Western and 35 Semipalmated Sandpipers were found on 3 June, and 58 Semipalmated Samdpipers were present 4 July. One Semipalmated Sandpiper observed in late April had a yellow plastic

tag on its leg, indicating that it was trapped on the Peruvian coast in 1982 or 1983 (J. P. Myers, personal communications, 1986).

Habitat Use. These sandpipers prefer open beaches, mudflats, lakeshores, and similar wet-mud habitats. At Cheyenne Bottoms they swarmed over the open mud and waded a few inches into the open shallows. Like most of the other small sandpipers, they tended to avoid vegetated areas.

Food Preferences. These sandpipers seem to feed mainly on larval and pupal insects when in freshwater habitats (Johnsgard, 1981) and crustaceans and worms in marine situations.

Dunlin (Calidris alpina)

Dunlins breed circumpolarly on arctic tundra and also on moorlands in western Europe. They winter coastally, throughout the temperate and subtropical northern hemisphere (AOU, 1983). They are uncommon to rare transients through Kansas, both in spring and fall. Parmalee et al. (1969) gave records from 23 April to 3 June and only one fall record, from 28 November. The CBWMA files provide a late-spring record of 6 June and fall records from 20 August to 23 November. Forty-seven Dunlins were reported in the banding records, and 40 of those were banded in the month of May.

In this study, eight Dunlins were seen 20 October, for the only fall record. They were feeding in a wet field in the Mallard Club area northwest of Pool 2. In spring 40 dunlins were seen in a flock 5 March. All were in winter plumage. Molting or breeding-plumage Dunlins were seen 13 April (one bird), 2 to 4 May (two Birds), 10 and 11 May (six birds), and 3 June (one bird).

Habitat Use. Dunlins nest in wet tundra and peatlands. Otherwise they use wet fields, mudflats, estuaries, marshes, beaches, and lakeshores. The eight Dunlins seen in October were in a flooded, plowed field. All others were on the mudflats of pools 2 and 5, wading or walking about on the wet mud.

Food Preferences. Dunlins feed on surface-dwelling and burrowing invertebrates, especially worms and arthropods.

Sanderling (Calidris [Crocethia] alba)

Sanderlings have a circumpolar high-arctic breeding range. They winter on sandy ocean beaches worldwide (AOU, 1983). In Kansas they are common-to-rare migrants in spring and rare in fall. Parmalee et al. (1969) gave extreme dates of 5 April to 8 June and 26 July to 9 November.

In this study only three Sanderlings were seen in fall 1985; one on 31 August and two on 11 September. In spring four were seen 24 May and four again 3 June. Evidently in 1986, Cheyenne Bottoms did not experience the great flocks of Sanderlings seen occasionally in the past (e.g., 14 to 16 May 1964 and 22 to 24 May 1963, Parmalee et al., 1969).

Habitat Use. Sanderlings nest on barren rocky tundra and the rest of the year prefer sandy ocean beaches. At Cheyenne Bottoms the sightings were all on open mudflats above or at the waterline.

Food Preferences. Sanderlings feed mainly on arthropods and worms on or slightly under the surface of the substrate. On ocean beaches they appear to specialize on mole-crabs (Emerita sp.).

Stilt Sandpiper (Calidris [Micropalama] himantopus)

Stilt Sandpipers breed in the North American arctic from the north slope of Alaska east and south to James Bay. They winter primarily in south-

temperate South America, although a few remain in the Caribbean Basin, Central America, and the southern United States (AOU, 1983). They are abundant throughout Kansas both in spring and fall. Parmalee et al. (1969) considered them abundant at Cheyenne Bottoms, with extreme dates of 24 April to 7 June and 8 July to 10 October. The CBWMA files include dates from 14 March through 18 November, without an obvious break between northbound and southbound migrations. The banding records include over 3,200 Stilt Sandpipers. Peak capture numbers were in August, and a secondary peak occurred in May.

In this study Stilt Sandpipers were seen from 12 August to 14 October 1985, with a maximum count of 66 birds 11 September. In spring they appeared 14 April and were present in all subsequent censuses except 16 May. Numbers peaked at 4,300 on 10 May.

Habitat Use. Stilt Sandpipers prefer muddy marshes, lagoons, lakeshores, and other wetlands where they wade in water 2 to 4 inches deep. During this study they were mainly found wading in the shallow water of pools 2 and 5, generally well away from emergent vegetation.

Food Preferences. Stilt Sandpipers feed on a variety of aquatic insects and larvae, which they obtain from the water or substrate. At Cheyenne Bottoms they fed primarily by probing into submerged mud in the manner of (and usually accompanied by) dowitchers.

Ruff (Philomachus pugnax)

Ruffs are essentially palearctic, cool-temperate to arctic breeders. The only North American breeding record is from northwestern Alaska, but breeding is suspected in the eastern Canadian arctic. A scattering of Ruffs migrate through North America, so that the species is considered rare to casual on the coasts and accidental in most interior states.

In this study a single female Ruff (Reeve) was seen from 11 May to 17 May. This appears to be the second record of the species for Cheyenne Bottoms.

Long-billed Dowitcher (Limnodromus scolopaceus) and Short-billed Dowitcher (Limnodromus griseus)

The two species of dowitchers are considered together here because they are often very difficult to distinguish in the field. This is particularly true of birds not in breeding plumage, and I regard birds in winter plumage to be reliably distinguished only by voice. In much of the data collected in this study they are not separated.

Long-billed Dowitchers breed in coastal northwestern Alaska and northeastern Siberia and winter from the southern United States to Panama. Short-billed Dowitchers breed in three disjunct areas of the North American arctic; southwestern Alaska, interior western Canada from the upper Mackenzie River valley to Hudson Bay, and in the interior of the Ungava Peninsula. They winter from the southern United States to central South America (AOU, 1983). In Kansas, Long-billed Dowitchers are abundant migrants, and Short-billed Dowitchers are uncommon to rare, both northbound and southbound. Parmalee et al. (1969) gave dates of 27 February to 19 June and 9 July to 20 November for Long-billed Dowitchers. They also suggested that Short-billed Dowitchers tended to appear in late May after the peak of the Long-billed Dowitcher migration and to return south earlier than the Long-billed Dowitchers. Fewer than 1,000 dowitchers were banded (943 Long-billed and 44 Short-billed), suggesting that these abundant birds are relatively difficult to catch. Both species were captured in all months from April to October with the exception of June.

In this study dowitchers were seen in fall 1985 from 12 August to 8 November. All that were identified to species were Long-billed. Numbers peaked at 1,100 on 30 September. In spring 1986, Dowitchers were first seen 13 March and were present continuously through 12 May. On 13 and 21-23 March, all the dowitchers seen (245 and 1,140, respectively) were in winter plumage, but the few that were identified (by calls) were Short-billed. From 3 April to 12 May all that were identified were Long-billed Dowitchers. About 3,500 were present 23 April and 4,000 on 14 April. Over 20,000 were present 23 April 27,000 on 2-4 May, and 28,000 on 10 May. Dowitchers joined the major exodus the night of 11 May, and on 12 May, only 4,000 remained. Those were gone by 16 May. Four Short-billed Dowitchers, all in breeding plumage, were present 23 June and 4 July. On 18 July 200 dowitchers were present and all were long-billed. I suspect that an early (March) movement of Short-billed Dowitchers occurred, followed by the major Long-billed Dowitcher migration in April and May. The previous records of Short-billed Dowitchers indicating a late spring migration and an early southbound movement correspond to the period when the birds are in breeding plumage and most easily identified. Short-billed Dowitchers migrating during the Long-billed Dowitcher migration would be very difficult to locate among the hordes of the latter species, as noted by Parmalee et al. (1969).

Habitat Use. Dowitchers are foraging specialists. Their foraging habits confine them to feeding habitats with an abundance of soft mud or loose sand, normally flooded to a depth of 1 to 4 inches. Thus they prefer muddy flats, lakeshores, and grassy marshes. In winter Long-billed Dowitchers prefer freshwater sites, while Short-billed Dowitchers tend to use estuarine locations.

Food Preferences. Dowitchers feed by probing with their long bills deep into soft mud or loose sand. They are tactile feeders utilizing a variety of invertebrate prey. These include nematode and annelid worms and a variety of arthropods. At Cheyenne Bottoms dowitchers ate mostly the larvae of chironomid midges, although fall-captured birds had eaten a few fairy shrimp.

Hudsonian Godwit (Limosa haemastica)

Hudsonian Godwits breed in several small areas in the North American arctic from Hudson Bay to Alaska. They winter in south-temperate South America. In Kansas Hudsonian Godwits are common spring migrants and rare fall migrants. This is one of the species of shorebirds that migrate to maritime Canada and New England in fall, and thence south over the Atlantic to South America, but return in spring across the Gulf of Mexico and through the interior of the United States. Parmalee et al. (1969) reported extreme dates of 19 April to 18 June and 30 June to 26 September. In the CBWMA files, the earliest spring date is 8 April.

In this study Hudsonian Godwits were seen only in spring. The first sightings were of 45 birds on 14 April (none were seen on a census 13 April), and numbers built to 550 on 23 April. Most of these left, as the 2-4 May maximum count was 45 birds, but 207 were present in a second influx 10 May. These in turn all left before 12 May. An additional 26 were seen 16 May and one remained 3 June. Assuming that individuals that left did not return, a minimum of about 750 Hudsonian Godwits passed through Cheyenne Bottoms in spring 1986.

Habitat Use. Hudsonian Godwits nest on tundra of various types, but in migration and winter frequent marshes, lakeshores, mudflats, and beaches. All

sightings during this study were in or around the open, shallow water of pools 2, 3, 4, and 5, and in the inlet canal.

Food Preferences. Hudsonian Godwits feed by probing in the mud for burrowing organisms. "Their foods are essentially unstudied" (Johnsgard, 1981). At Cheyenne Bottoms the Hudsonian Godwits fed like dowitchers and usually in the company of dowitchers, although often in slightly deeper water. They probably were feeding on the same chironomid larvae that made up the bulk of the dowitchers' diet.

Comment. The world population of this species is between 10,000 to 20,000 birds (personal communications, B. Harrington, 1985). The vast majority of these apparently fly nonstop across the United States, as sightings of more than a few hundred are rare. The 750 or so that used Cheyenne Bottoms this spring are several percent of the world population and are the largest concentration I know of in the United States in recent years.

Marbled Godwit (Limosa fedoa)

Marbled Godwits breed in the interior of North America in the Canadian prairie provinces and south to Montana, South Dakota, and Minnesota. A separate population may breed in southwestern Alaska. Marbled Godwits winter from central California and South Carolina south mainly on the coasts to northern South America. In Kansas Marbled Godwits are common migrants in spring and uncommon migrants in fall. Parmalee et al. (1969) gave dates ranging from 7 April to 5 June for spring and 20 June to 13 September southbound. The CBWMA files include a late record of 23 November.

In this study only one Marbled Godwit was observed in fall (11 September). In spring Marbled Godwits were seen from 13 April to 4 May, and

again 16 May and 3 June. Numbers peaked at 180 birds 23 April, dropped to 0, and peaked again at 55 birds on 16 May.

Habitat Use. Marbled Godwits breed around prairie wetlands. In migration and winter they prefer shallow lakes and marshes, mudflats, and similar very open habitats. They are quite tolerant of salinity. At Cheyenne Bottoms, Marbled Godwits were seen in or near the shallow water of pools 2 and 5, and occasionally 3 and 4.

Food Preferences. Marbled Godwits feed on a variety of invertebrates. They are capable of probing deeply for burrowing forms. Feeding individuals in this study were observed probing into the mud of pools 2 and 5, often in the company of dowitchers and Hudsonian Godwits.

Red-necked (Northern) Phalarope (Phalaropus lobatus)

Red-necked Phalaropes have a circumpolar breeding distribution on wet arctic and subarctic tundra. They winter at sea, primarily in the Pacific and Atlantic. Most Red-necked Phalaropes migrate at sea, but small numbers migrate north and south across the interior of the United States. In Kansas they are uncommon to rare migrants, both in spring and fall. Parmalee et al. (1969) reported these birds from 19 April to 28 May and 12 September to 10 October. The CBWMA files establish a late date of 15 October.

In this study, two Red-necked Phalaropes were seen 22 September, and in spring they were seen from 10 May to 23 June, with a maximum count of four on 12 May.

Habitat Use. Red-necked Phalaropes breed on wet tundra and migrate and winter at sea. The few that migrate inland prefer marshes with open water and lakes.

Food Preferences. Red-necked Phalaropes feed mainly on planktonic crustacea and aquatic insects (Johnsgard, 1981).

Wilson's Phalarope (Phalaropus tricolor)

Wilson's phalaropes breed in the interior of North America from southern Yukon south to south-central California and northern Texas. They winter in South America, primarily in the central Andean highlands and on temperate grasslands. In Kansas, Wilson's Phalaropes are abundant migrants and uncommon breeders. Parmalee et al. (1969) gave extreme dates of 5 April to 5 December. The CBWMA files contain an incredibly early record of 3 February and several March records. The banding records include 440 birds banded between April and October, with peaks in August and May.

In this study Wilson's Phalaropes were found to be unaccountably rare in fall migration in 1985. None were seen until 31 August, and then only 41 individuals. Seventeen were counted 11 September, five on 22 September, and one on 22 October. Because this dearth of phalaropes was so unexpected, some alternative habitats in central Kansas were examined to see if the birds had moved elsewhere. These alternatives included Quivira National Wildlife Refuge, and Cedar Bluff, Webster, Wilson, and Kanopolis reservoirs. Significant numbers of phalaropes were not found at any of these sites. Evidently in 1985 Wilson's Phalaropes used staging areas farther north or west.

In 1986, single Wilson's Phalaropes were seen 22 March, 3 April, and 13 April. A large influx occurred around 1 May, with 2,300 counted 4 May. Numbers increased to 5,500 on 10 May, dropped abruptly to 1,300 on 12 May, 550 on 16 May, and 15 by 3 June. Although Wilson's Phalaropes have nested fairly regularly at Cheyenne Bottoms in previous years, no evidence of nesting was observed in 1986.

Habitat Use. Wilson's Phalaropes prefer marshes with open water, and lakes, although they often forage on wet mudflats and lakeshores. In freshwater systems they usually feed in very shallow water, where invertebrate densities are greatest. In saline and alkaline lakes, they often swim over deeper water where planktonic crustacea such as Artemia are often abundant.

Food Preferences. Phalaropes unlike most sandpipers, feed by swimming and twirling to bring planktonic organisms to the surface. While Wilson's Phalaropes do feed in this manner, they use other feeding methods more frequently than other phalaropes.

WATERFOWL

INTRODUCTION

Since its acquisition by the Kansas Fish and Game Commission, Cheyenne Bottoms has been managed primarily to provide habitat for waterfowl during fall migration and to provide high quality waterfowl hunting opportunities. In general, these goals have been realized, although the number of birds and the quality of hunting has varied from year to year. The total numbers of waterfowl using Cheyenne Bottoms have tended to decline through its history as a management area, but these declines clearly have resulted from general declines in waterfowl populations throughout the central flyway.

Nonbreeding duck census data from September 1972 to March 1986 are presented in table 16.6. Duck numbers usually peak in October and early November and again in late February and early March. Duck numbers in the early and mid-1970's were consistently much larger than in the early and mid-1980's. Numbers in 1985-86 tended to be larger than in the previous three years, despite continuing declines in flyway populations. Since 1982, ducks have not wintered in significant numbers at Cheyenne Bottoms.

Table 16.7 provides goose census data at Cheyenne Bottoms since 1972. Geese (other than the few dozen resident Giant Canada Geese) do not appear until late September and early October. Numbers peak in late October or early November, and again in late February and early March. Most years a few thousand geese winter at the wetland. Numbers of geese using the Bottoms have tended to decline through the years, but not so severely as ducks. Goose populations in general have not been declining, and indeed many have been increasing. The decline in goose numbers may well reflect decreasing ability to provide appropriate habitat, with decreasing water availability.

Table 16.6--Censuses of nonbreeding ducks at Cheyenne Bottoms. Censuses are conducted twice per month from September through March each winter; numbers are thousands of ducks.

Month	Census #	YEAR 72-74 Ave.	75-78 Ave.	79-82 Ave.	82-83	83-84	84-85	85-86
September	1	49	28	29	12	12	0	18
	2	72	70	25	7	28	17	25
October	1	181	185	30	39	36	9	31
	2	178	94	16	25	26	14	156
November	1	231	48	28	112	12	16	57
	2	119	12	18	68	22	12	57
December	1	60	1	16	24	0	0	0
	2	38	2	10	32	0	0	0
January	1	24	1	3	5	0	0	0
	2	7	6	13	31	0	0	0
February	1	29	11	0	0	7	0	13
	2	69	20	3	0	20	2	12
March	1	298	76	34	19	14	16	29
	2	136	59	86	49	5	3	10

Table 16.7--Cheyenne Bottoms goose censuses. Censuses were conducted twice per month from September through March each year; numbers are thousands of geese.

Month	Census #	YEAR 72-74 Ave.	75-78 Ave.	79-82 Ave.	82-83	83-84	84-85	85-86
September	1	0	0	0	0	0	0	0
	2	0	1	0	0	0	1	0
October	1	2	9	1	0	1	1	0
	2	3	5	2	8	1	6	11
November	1	26	10	10	13	6	11	2
	2	28	13	8	16	7	3	4
December	1	12	7	9	10	3	3	0
	2	15	6	7	11	0	1	1
January	1	13	3	9	3	2	0	0
	2	11	5	12	2	0	0	3
February	1	32	15	1	0	8	0	3
	2	29	18	3	0	5	9	5
March	1	27	28	11	0	1	2	5
	2	10	1	0	1	1	1	0

The Kansas Fish and Game Commission has monitored waterfowl production from time to time. Waterfowl production was studied in some detail from 1963

through 1970. In those years summer waterfowl production ranged from an estimated 142 day-old young in 1970 to over 12,500 in 1969. In these years 12 species of ducks were found breeding in the bottoms. Four species (Mallard, Pintail, Blue-winged Teal, and Redhead) were found breeding all years. Blue-winged Teal accounted for 40-90% of the production. Mallards always were second most common, and pintails usually were third. The others (Mottled Ducks, Gadwalls, Green-winged Teal, Cinnamon Teal, Shovelers, Wood Ducks, Canvasbacks, and Ruddy Ducks) were sporadic, and together, never accounted for more than 15% of the young produced. With less reliable water availability and with the increasing dominance of dense cattail stands, waterfowl production has generally been lower in recent years. In 1986 only two broods of ducklings, totaling about 10 individuals, were observed. One brood was of Blue-winged (or Cinnamon) Teal, the other was not identified.

HABITAT SELECTION

Habitat preferences of the more common waterfowl are described in table 16.8. The habitat categories are mostly the same as those used for shorebirds (table 16.3), however, for waterfowl the boundary bewtween the open shallows and open water categories was defined at a depth of 10 inches. The upland open habitat (plowed fields) seemed not to attract significant waterfowl use and is not included in table 16.8.

Geese used open water (and expanses of ice) to roost and fed in vegetated areas. Canada and Snow geese fed primarily in agricultural land, while White-fronted Geese preferred the flooded millet plantings. The dabbling ducks were very opportunistic, utilizing almost five habitat types each. Overall, vegetated shallows were most important to this group of ducks. Within this category the dabbling ducks preferred the seasonally flooded areas, particularly in pools 3 and 4. Open shallows and open water also were

important. The diving ducks all preferred open water, and indeed three species (Common Goldeneye, Bufflehead, Common Merganser) appeared to restrict their activity to this habitat. All the diving ducks appeared to be restricted to the aquatic habitat; open water, open shallows, and vegetated shallows. For much of the year, the drainage ditches around Pool 1 contained the main open-water habitat in Cheyenne Bottoms and hosted most of the diving ducks present.

Table 16.8--Habitat preferences of the more common waterfowl at Cheyenne Bottoms. Habitat definitions: OW = open water--water free of emergent vegetation and at least 10 inches deep; OS = open shallows--water free of emergent vegetation and less than 10 inches deep; VS = vegetated shallows--water with emergent vegetation; OM = open mud--recently exposed unvegetated pool-bottom; VM = vegetated mud--vegetated exposed pool-bottom; UV = upland vegetated--pasture, prairie, harvested croplands, and winter wheatfields. The numbers are habitat rankings for the species; the species most important habitat receives a ranking of 1, the secondmost used habitat ranks 2, and so on.

Species	Habitats					
	OW	OS	VS	OM	VM	UV
White-fronted Goose	4		1		2	3
Snow Goose	3				2	1
Canada Goose	3		4		2	1
Wood Duck	1	2	3			
Green-winged Teal	4	2	3	1	5	
Mallard	2		3	4		1
Northern Pintail	3	2	1		4	5
Blue-winged Teal	4	2	1	3	5	
Northern Shoveler	2	1		3		
Gadwall	2	1	3	4	5	
American Wigeon	3	4	1	6	5	2
Canvasback	1	2				
Redhead	1	3	2			
Ring-necked Duck	1	2				
Lesser Scaup	1	2				
Common Goldeneye	1					
Bufflehead	1					
Common Merganser	1					
Ruddy Duck	1	2				

ROLE OF WATERFOWL IN THE ECOLOGY OF CHEYENNE BOTTOMS

Waterfowl probably have as large an impact on the ecology of Cheyenne Bottoms as shorebirds do, but their impact is more difficult to measure. Because they frequent more habitats (and more heavily vegetated habitats) than shorebirds, they are harder to census accurately. Many waterfowl have highly flexible migration behavior and so are less predictable in their movements. Waterfowl also have more diverse diets than shorebirds, and it was not possible to determine the relative proportions of animal and vegetable foods. An unknown but, seasonally varying proportion of the waterfowl fed outside the Bottoms on agricultural land. Despite these problems, certain aspects of their ecological impact can be described.

It has been recognized only very recently (e.g., Nudds and Bowlby, 1984; Armstrong and Nudds, 1985; Murkin and Kadlec, 1986) that dabbling ducks eat substantial quantities of invertebrates, especially in spring. Early studies were biased by differential digestion rates (seeds last much longer in the digestive tract) and were concentrated in fall, when plant foods may be most prominent in the diet. Invertebrates seem to be particularly important in the spring diet of females, as protein sources for egg production. The high invertebrate production at Cheyenne Bottoms may be extremely important to these birds in spring migration.

The 20,000 to 30,000 large dabbling ducks present in late February and early March consumed great quantities of chironomids, especially pupae and emerging adults. These prey were from overwintering populations, and the ducks were often seen taking them at the edges of the melting ice. The larger dabbling ducks (Mallards, Pintails, Gadwalls) seem to follow the melting ice north and are present in large numbers at Cheyenne Bottoms only briefly after the spring thaw. Later, through March and April, the shorebirds thronging to

the Bottoms were accompanied by substantial numbers of shovelers and Green-winged Teal. These ducks fed with the shorebirds, probably on the same chironomid prey. The shovelers mostly fed in the open shallows, and the teal often fed on open mudflats.

On the seasonally flooded habitats of pools 3 and 4, waterfowl ate great quantities of annual plant seeds and may have consumed enough to materially influence the composition of the seed bank. Dock (Rumex sp.) has persistent seeds that remain on the plant through the winter. By February, the shorter plants have been stripped completely of seeds, and the tallest plants retained seeds only at their tops, above the reach of swimming pintails.

The waterfowl that feed in upland areas (primarily Canada Geese, Mallards, and American Wigeons) undoubtedly contribute nutrients to the marsh in the same manner that blackbirds do (described later in this chapter), but the contribution cannot be estimated because of uncertainty in the percentage of food they obtain outside of the marsh and uncertainity in population sizes.

SPECIES ACCOUNTS

Species accounts are provided for the species of waterfowl most important at Cheyenne Bottoms in 1985 and 1986. These accounts begin with descriptions of species' ranges and status in Kansas. The distribution during the study follows. The accounts conclude with sections describing habitat use and food preferences. The food preference data come from the literature (primarily Palmer, 1976; and Johnsgard, 1975, 1978). They are based mainly on fall collections and for dabbling ducks do not reflect the importance of invertebrates in the spring diet (see above).

Greater White-fronted Goose (Anser albifrons)

Greater White-fronted Geese breed in arctic North America from Alaska to

Keewatin (i.e. west of Hudson Bay). Other subspecies breed in Greenland and arctic areas of Eurasia. The North American birds migrate, primarily west of the Mississippi River, to wintering areas on the Gulf Coasts of Louisiana and Texas, in central California, and south through much of Mexico (AOU, 1983). In Kansas, White-fronted Geese are common migrants both in spring and fall, and a few may winter.

The first White-fronted Geese to appear at Cheyenne Bottoms in 1985 arrived about 20 September. On 30 September, 13 White-fronted Geese (5 adults and 8 young) were found in the unvegetated areas of Pool 3, and later that day they were seen flying into the millet plantings. On 14 October about 5,000 were present, and by 26 October (opening day of hunting season), White-fronted Geese numbered 10,000-15,000 birds. Several thousand apparently left in response to hunting pressure the morning of 27 October. Numbers gradually declined over the next few weeks, and by late November essentially all were gone. In spring, about 5,000 White-fronted Geese visited in mid-March, but the birds apparently stayed less than a week before continuing north.

Habitat Use. White-fronted Geese fed extensively in the millet plantings in Pool 3, and to a lesser extent in Pool 4. They were often seen in the more open areas of pools 3 and 4, especially after water was diverted into these areas in mid- October. The west end of Pool 5, near the "goose pen," was often used, and on 14 October a few thousand geese were gathered on the south side of Pool 5 about midway along its length. White- fronted Geese were seldom seen on the open waters of pools 1 and 5, although a few thousand sat on Pool 1 the evenings of 25 and 26 October. Most White-fronted Geese left Cheyenne Bottoms before freeze-up, but a few birds roosted on the ice in Pool 1 on 22 November.

Food Preferences. On their arctic breeding grounds, White-fronted Geese feed primarily on green vegetation, but in migration and winter their diet consists of a mixture of green vegetation, grains and other seeds, and tubers. At Cheyenne Bottoms, they fed extensively in the Japanese millet plantings in Pool 3. They also fed extensively on private land in the area, but the mix of green vegetation and grain in their diets could not be determined.

Snow Goose (including Blue Goose) (Chen caerulescens)

Snow Geese are essentially North American in distribution, although substantial numbers breed in eastern Siberia. They breed across North America on arctic tundra, from western Alaska to Baffin Island and extreme western Greenland. Major wintering areas are in the central valley of California, on the Gulf coast of Louisiana and Texas, and on Chesapeake Bay and south to coastal North Carolina. In migration they are abundant in the Mississippi Valley and on relatively narrow corridors in the Pacific and Atlantic states (AOU, 1983). In Kansas, Snow Geese are abundant migrants in the eastern third of the state and are uncommon farther west.

In this study few Snow Geese were seen at Cheyenne Bottoms. The first were noted 24 October, just before the opening of duck and dark-goose seasons. On 26 October, opening day, at least 35 were present. About two-thirds of these were white-phase, and the remainder were blue. Opening morning one immature "Blue" goose was shot from a flock of White-fronted Geese. Numbers remained below 100 birds through the fall, and the last birds were seen 22 November. In spring a group of 18 Snow Geese (including three Blues) were seen repeatedly in mid- to late March in pools 3 and 4, often with a flock of about 300 small Canada Geese. These birds fed in the daytime on farmland about 1/2 mile north of Pool 3 and each evening flew into Pool 3 to

roost. Two Snow Geese seen 23 April on Pool 2 were assumed to be escapees from captivity.

Habitat Use. Snow Geese breed colonially on arctic wet tundra. They feed in winter and during migration in marshes, wet fields, and wet prairies, although in recent years they have been feeding more in agricultural land, including cornfields and ricelands (Johnsgard, 1975; Palmer, 1976; AOU, 1983). In general they feed in wetland habitats more than other North American geese. Lakes, ponds, and rivers are preferred for roosting. At Cheyenne Bottoms particular feeding habitats were not discovered, but the birds generally roosted in Pool 1 or in the western end of Pool 5.

Food Preferences. Snow Geese feed on tubers, corms, and roots more than other North American geese do, and apparently their heavy serrated bills are adapted to this habit. They also will eat cereal grains and seedling-grain plants and other grassy foliage (Palmer, 1976).

Canada Goose (Branta canadensis)

Canada Geese breed on arctic tundra from northwestern Alaska to northwestern Greenland and south to California, Utah, Kansas, Arkansas, Tennessee, Ohio, and New England. They winter coastally from southern Alaska and Newfoundland south to northern Mexico and inland from southern Canada and the Great Lakes to the Gulf states and again northern Mexico (AOU, 1983). This broad-brush picture is a bit misleading, for Canada Geese can be subdivided into a large number of subspecies, stocks, and local populations, each with its own breeding area and migration route, but with great overlap in migration and winter. In general Canada Geese breeding at the highest

latitudes are smallest and migrate farthest, and those with the most temperate breeding ranges are largest and least migratory. In Kansas, Giant Canada Geese (B. c. maxima or B. c. moffitti) are resident. Undoubtedly similar birds bred here historically, but the present populations are the result of reintroductions. A variety of smaller Canada Geese migrate through Kansas, including Lesser Canada Geese (B. c. parvipes) and Richardson's Canada Geese (B. c. hutchinsii).

In this study small numbers of Giant Canada Geese were seen at all times of the year. About 35 were present, generally in a single flock, from the beginning of the study in August 1985 until early November. About five of these local geese were killed early in the hunting season. In November more large geese moved in, and at least a few hundred remained through the winter. These apparently were Giant Canada Geese from farther north in the subspecies' range. In spring the local Giant Canada Geese were very evident in pairs in and around Cheyenne Bottoms. About eight pairs appeared territorial on Cheyenne Bottoms, but several of these behaved as if they did not nest. Other pairs were seen in the Mallard Club area and elsewhere in the basin. Two broods of young were hatched on Cheyenne Bottoms, one from a nest on a muskrat house on the east side of Pool 1, the other from a nest somewhere on the west side of Pool 1. The fates of these broods could not be followed. On 3 September 1986 a flock of 120 Giant Canada Geese was observed in Pool 5, so apparently the geese in the local region had a fairly successful nesting season (or else geese came to Cheyenne Bottoms from a larger area than in 1985).

Small Canada Geese (apparently B. c. hutchinsii) appeared at Cheyenne Bottoms in mid-October and remained into December, well after freezeup.

Lesser Canada Geese apparently arrived in early November. Through the hunting season, numbers increased from a few hundred birds in late October to several thousand in mid-November. Numbers dropped after freezeup, and apparently most of the smaller birds departed for more southerly wintering areas. About 500 small geese were present in late February, and another 350 visited in late March.

Habitat Use. Canada Geese are very catholic in their habitat use, although most of the time they remain within an hour's flying time of suitable roost sites (large bodies of open water or frozen lake surfaces). They mainly feed terrestrially and prefer areas free of extensive cover for feeding. At Cheyenne Bottoms, Canada Geese used virtually all open habitats. They roosted on exposed mud in pools 3, 4, and 5, on the water in pools 1 and 5, and after freezeup, on the ice of Pool 1. They fed extensively on the winter-wheat plantings in pools 3 and 4 in fall 1985, but most left the Bottoms to feed in agricultural fields and returned only to roost.

Food Preferences. Canada Geese feed mainly on vegetable matter, including green foliage of grasses and grains, seeds of cultivated grains, and a wide variety of wild plants (Palmer, 1976).

Wood Duck (Aix sponsa)

Wood Ducks breed in eastern North America from east-central Saskatchewan east to the maritime provinces, south (mainly east of the High Plains) to Texas and the southeastern states. A separate population breeds in western North America from southern British Columbia and southwestern Alberta south to southern California. The populations winter in the southern halves of their

breeding ranges (AOU, 1983). In Kansas, Wood Ducks are common breeders in the eastern part of the state, becoming progressively less common to the west. Some winter in the state.

In this study, Wood Ducks were present from the first census in August until early November. Numbers in the fall ranged from 20 to 200 birds. About 30 wintered on the ice-free ponds at the Great Bend Zoo. Wood Ducks were essentially absent all spring but returned in July.

Habitat Use. Wood Ducks nest in tree cavities, so for breeding they require wooded habitats with ponds, streams, or other open water. They are most common in riparian woodlands and around forest ponds. Apparently birds breeding in central Kansas make post-breeding movements to larger bodies of water, including Cheyenne Bottoms.

Food Preferences. Wood Ducks eat mainly vegetable food, including duckweed, a variety of plant seeds, acorns, and some grains. They also eat a variety of aquatic insects and small amounts of other insects and fish (Palmer, 1976). At Cheyenne Bottoms their preferred foods must differ from those in the typical habitats further east, for many of the listed foods do not occur at Cheyenne Bottoms.

Mallard (Anas platyrynchos)

Mallards have a holarctic breeding distribution. In North America they breed from northern Alaska across boreal Canada to Maine, and south through most of the United States. They winter from southern Alaska and southern Canada south to central Mexico (AOU, 1983). In Kansas they are abundant migrants both northbound and southbound and less common as breeding birds and in winter.

In this study Mallards were present on all censuses except 18 December, when no open water remained. They were uncommon in August and September but increased in abundance in October, until over 10,000 were present on 26 October, when hunting season opened. They remained common until freezeup in late November. On 18 December none could be found on Cheyenne Bottoms, although a number of apparently wild Mallards joined the captive flock at the Great Bend Zoo. On 11 and 12 January numerous leads had melted in the ice of Cheyenne Bottoms, and a few hundred Mallards were again present. By late February a few thousand were present, but numbers dropped abruptly, and the March counts averaged only a few Mallards each. Some remained to summer on Cheyenne Bottoms, although apparently none raised young.

Habitat Use. Mallards use a great variety of aquatic habitats. Most breed and winter on freshwater, but estuarine wintering areas are not uncommon. Mallards generally nest on the ground in heavy herbaceous cover, often but not always close to water. At Cheyenne Bottoms, Mallards were found in all aquatic habitats. Mallards used the borrow ditches around Pool 1 more than the other dabbling ducks did, both in spring and fall. They also used the flooded areas of pools 3 and 4, especially in fall. Paired Mallards did not seem to select markedly different habitats than flocking birds.

Food Preferences. Mallards eat a variety of vegetable matter, including seeds and foliage of a wide variety of marsh sedges, grasses, and broad-leaved annuals, cultivated grains, acorns, and other tree seeds. They also eat a variety of animal food (e.g., aquatic insects, crustacea, snails, fish spawn) but normally in much smaller volume (Palmer, 1976).

Mottled Duck (Anas fulvigula)

Mottled Ducks breed in peninsular Florida and along the Gulf coast from southern Louisiana through Texas to northeastern Mexico. Since 1963 a small population has been found breeding inland from western Kansas and southeastern Colorado southeast to northeastern Texas (AOU, 1983). In Kansas Mottled Ducks were considered accidental, known only from a single specimen from before 1900, until a nest was found at Cheyenne Bottoms in 1963 (McHenry, 1968). Since then they have been seen regularly at Cheyenne Bottoms and occasionally elsewhere in the region.

The population has remained small and may be in precarious shape. Apparently none were sighted in 1985. One sighting of this species was made in this study of a bird flying over the cattails on the west side of Pool 1 the evening of 18 July 1986. It was seen well enough to distinguish it with certainty from a Black Duck or a female Mallard but the sex of the bird could not be determined (the main external differences are in bill pattern).

Northern Pintail (Anas acuta)

Northern Pintails have a holarctic breeding distribution and a north-temperate to tropical winter distribution. In North America they breed from northern Alaska and northern Quebec south to southern California, Arizona, New Mexico, Kansas, Iowa, the Great Lakes states, and New England. North American pintails winter in Hawaii, and in North America from coastal southern Alaska, southern Idaho, Colorado, Kansas, the Ohio valley, and Massachusetts south to the Greater Antilles, Mexico, Central America, and northern South America (AOU, 1983). In Kansas pintails are abundant migrants, both northbound and southbound, and are uncommon to rare winter and summer residents. Pintail migration is complex (Palmer, 1976). Flocks of migrating pintails appear in Kansas by the first week of September. In 1986, for example, over 1,000

pintails were present at Cheyenne Bottoms on 4 and 5 September. These early pintails tend to move south rather quickly, but additional waves of birds keep arriving through the fall and into early winter.

In fall 1985, pintails were present in small numbers in August and September and built to about 1,000 birds by 21 October. At least several thousand pintails were among the 100,000 or so ducks present 25 October, the eve of hunting season. Pintails were common until freezeup, 20 to 22 November. In spring pintails migrated north very early. On 21 and 22 February over 10,000 were feeding in pools 3 and 4. Numbers dropped to about 1,000 on 15 March, 240 on 20 March, and 29 on 15 April. Several pintails summered at Cheyenne Bottoms in 1986, but no evidence was seen of nesting.

Habitat Use. Northern Pintails typically breed in open country with scattered small bodies of water. They use shallow water bodies and marshes during migration, apparently without particular preferences for freshwater. Winter habitats are similar (Palmer, 1976). At Cheyenne Bottoms pintails used all flooded habitats, but seemed to prefer the recently flooded areas of pools 3 and 4.

Food Preferences. Northern Pintails eat mainly vegetable food and at least in fall and winter eat seeds more often than foliage. They often feed in grainfields (Palmer, 1976). At Cheyenne Bottoms most observations of feeding pintails were in pools 3 and 4. They seemed to feed more in the areas of terrestrial annuals than in the millet plantings. On 20 to 22 February the flooded areas of pools 3 and 4 had large numbers of floating seeds of Kochia and thousands of pintails and teal werre feeding there. Standing dock plants (Rumex sp.) had seeds stripped from the lower portions about to the height a pintail could reach.

Green-winged Teal (Anas crecca)

Green-winged Teal breed from western Alaska across Canada to southern Labrador and south to Oregon, Nevada, Utah, Colorado, South Dakota, Minnesota, southern Ontario and Quebec, and Maine. They winter from southern Alaska, the northern Great Plains, the Great Lakes, and southern New England, south to central America and the southeastern United States (AOU, 1983). In Kansas they are common migrants, both northbound and southbound, and less common in winter. They breed occasionally at Cheyenne Bottoms, well south of their regular breeding range in the Great Plains.

In this study, Green-winged Teal were present from late August to late November. They could not be found on 8 December or 18 December, but were present 1 February, and were common by 20 February. In early and mid-March they were the most abundant duck, and in late March and early April they were second in abundance to shovelers. The last Green-winged Teal disappeared in mid-May, and the first fall migrants appeared in late August 1986.

Habitat Use. The habitat preferences of Green-winged Teal are rather generalized and do not differ much from those of other Anas ducks. They nest near water in grassy and brushy terrain, and in migration and winter they prefer shallow marshes and lakes with emergent vegetation. They were seen at Cheyenne Bottoms in all flooded areas but occurred in the largest flocks in pools 3 and 4.

Food Preferences. Green-winged Teal eat predominantly vegetable matter and seeds (Palmer, 1976). At Cheyenne Bottoms they fed extensively in pools 3 and 4 especially in fall and early spring. Later in spring they fed with shorebirds on the exposed mud of pools 2 and 5, where they may have been taking chironomid larvae.

Gadwall (Anas strepera)

Gadwalls have a north-temperate breeding distribution, both in North America and in Eurasia. In North America they breed from southern Alaska, southern Yukon and MacKenzie, northern Saskatchewan, central Manitoba, southern Ontario, southwestern Quebec, and the maritime provinces south to southern California, Nevada, and New Mexico, northern Texas, the Great Lakes states, and the Carolinas. Breeding is quite localized east of the prairie states and provinces. Gadwalls winter from southern Alaska and British Columbia,the northern Great Plains, the Great Lakes, and Chesapeake Bay, south to southern Mexico and the Greater Antilles (AOU, 1983). In Kansas Gadwalls are common migrants both northbound and southbound and less common summer and winter residents. In this study Gadwalls were present from August 1985 to late November, and from January through the end of the study. They were uncommon until October, but by 21 October were second only to Ruddy Ducks in numbers, with almost 2,000 birds present. Numbers increased markedly between 21 and 25 October, and at the latter date, Gadwalls, Mallards, and Pintails were the dominant dabbling ducks. Numbers could not be determined accurately during opening weekend of hunting season, but Gadwalls probably numbered well over 10,000 birds. Some Gadwalls remained until freezeup in late November but none were observed in December. In 1986 a few Gadwalls were present 11 January and 1 February. Numbers peaked at about 1,000 birds 20 to 22 February. This species was uncommon the rest of the spring, with counts never exceeding 300 birds. A few individuals summered, but no evidence of nesting was detected.

Habitat Use. Gadwalls were seen in all flooded areas of Cheyenne Bottoms. They seemed to use the drainage ditches in Pool 1 more than

pintails, wigeons, and teal. In addition they often sat with wigeons in the east end of Pool 5.

Food Preferences. Like wigeons, Gadwalls graze more than most other dabbling ducks, but apparently Gadwalls graze less on dry land than wigeons.

American Wigeon (Anas americana)

American Wigeons breed from central Alaska across Canada to the maritime provinces, and south to northeastern California, northern Nevada, Utah, New Mexico, South Dakota, Minnesota, Michigan, and New York. They winter on the coasts from southern Alaska and Nova Scotia and in the interior from the southern United States south through Mexico and Central America to northern South America. In Kansas, wigeons are common migrants and uncommon wintering birds throughout the state and are rare as breeding birds.

In this study American Wigeons were present from late August to late November, and from February to May. Only 300 were found 21 October, but at least several thousand were present a week later when hunting season opened. Virtually all wigeons left Cheyenne Bottoms by freezeup in late November. In spring, wigeons appeared as soon as the ice left in late February. A flock of about 300 remained in the south end of Pool 3 until late April, although wigeons were seldom seen elsewhere in Cheyenne Bottoms. In late April a drake wigeon wearing patagial tags was seen on Pool 2. This bird apparently had been tagged in the Texas panhandle (Personal Communication, Alan Fednyich, 1986).

Habitat Use. American Wigeons generally breed in relatively large, permanent marshes. They winter on both freshwater lakes and rivers, and

estuaries. At Cheyenne Bottoms they roosted in the marsh, but apparently fed outside of it.

Food Preferences. Wigeons eat largely vegetable matter, at least in fall and winter (Palmer, 1976). Their food includes a variety of small seeds and foliage. Wigeons graze on shoots and leaves of grass and grains, far more than other Anas ducks. The 300 wigeons that spent March and April in Pool 3 spent the spring grazing on the winter wheat planted in the area.

Blue-winged Teal (Anas discors)

Blue-winged Teal breed in North America from central Alaska and the boreal forest belt of Canada south to central Nevada and Utah, the southern Great Plains, Tennessee, and North Carolina. They winter from North Carolina across the southern tier of states to California, and south to northern South America (AOU, 1983). They are abundant migrants and breed in suitable habitats throughout Kansas.

In this study Blue-winged Teal were common from August 1985 into October, uncommon in early November, and absent by freezeup. They are one of the principal targets of the early teal season conducted in mid-September. Teal were difficult to census, as they spent much time in and around the emergent vegetation. In spring, Blue-winged Teal re-appeared in February and were common through March and April. Numbers declined in May, but a few birds remained through the summer, and a single brood of young was seen 18 July (these young are assumed to be Blue-winged Teal, but the possibility exists they were Cinnamon Teal). Spring census numbers peaked at 1,140 birds on 15 April, but that number undoubtedly is an underestimate.

Habitat Use. Blue-winged Teal could be found swimming in all flooded areas. When pools 3 and 4 were flooded, these teal seemed to prefer them to

pools 1, 2, and 5. The preferred pools had remained dry through the summer of 1985 and most of the cover in them was terrestrial annual plants. In 1986 pools 3 and 4 dried up in early May, and most of the Blue-winged Teal left. Those that remained mainly used pools 1 and 5, when water permitted. The one brood seen was in the southeastern corner of pool 1, swimming in a lead in the cattails.

Food Preferences. Blue-winged Teal feed largely on vegetable matter, and especially on seeds (Palmer, 1976; Johnsgard, 1975). Johnsgard commented that animal food was more frequent in spring than in other seasons. At Cheyenne Bottoms these teal often fed (in spring) on shallowly flooded mudflats, where they probably took invertebrates such as chironomids and small crustaceans.

Cinnamon Teal (Anas cyanoptera)

Cinnamon Teal breed in western North America, from southern British Columbia, Alberta, and Saskatchewan, the Dakotas, and western Nebraska south to northern Mexico. They winter from the southern quarter of the breeding range south to northern South America (AOU, 1983). Other subspecies occur in South America (Palmer, 1976). Cinnamon Teal are uncommon migrants and breeders in central and western Kansas and rare further east.

In this study no Cinnamon Teal were seen in 1985. In 1986 one was found swimming in a lead in the ice of Pool 2 on 11 January. This is far north of the species' normal wintering range. Two drakes appeared on 13 March, and by mid-April about 10 drakes were present. The last sighting of the season was 16 May.

Habitat Use. Within its range this species seems to use the same habitats as Blue-winged Teal.

Food Preferences. This species appears to feed in the same way as the Blue-winged Teal, although its bill is somewhat more expanded, and it may filter smaller prey.

Comments: The breeding range of the Cinnamon Teal is largely contained within the breeding range of its close relative the Blue-winged Teal. Throughout most of their range, they are the common or predominate species. A number of hybrids of the two species have been reported (e.g., Bolen, 1979). Almost all of these come from the eastern edge of the Cinnamon Teal's range, where they are much rarer than Blue-winged Teal. Virtually all are drakes (female Cinnamon and Blue-winged teal are often inseparable in the hand). Two hybrid drakes were observed in this study in spring 1986. The first was seen swimming in the water of Pool 4 on 2 April. The other was seen repeatedly in Pool 3 near the Pool 2/Pool 3 water-control structure between 14 and 22 April. It appeared territorial and often chased Blue-winged Teal drakes. The two differed substantially in head pattern and clearly were different birds.

Northern Shoveler (Anas clypeata)

Northern Shovelers breed in western North America from northern Alaska east to Hudson Bay, and south to Oregon, northern Utah and Colorado, and Kansas, and casually to the south and east; they also breed in Eurasia from Britain to eastern Siberia. They winter in the Americas on the west coast, and from the southern United States south to Central America. In Kansas shovelers were present from the beginning of the study in August 1985 until early November. A group of migrants came through in mid-September, making shovelers one of the more common ducks during the early teal season. Numbers dropped to about 100 birds on 20 October, but increased to at least 1,000 birds by opening day. The last shovelers of the season were seen 9

November. In spring shovelers appeared in February. Overall, they were relatively late migrants in spring. On 13 March, after pintails and Mallard numbers had peaked, there were still only 400 shovelers. Shovelers increased to 1,600 birds on 20 March, 2,350 birds on 22 March, and 1,900 on 15 April. Several hundred shovelers remained until early May, when pools 2, 3, and 4 dried up. No evidence of nesting was found in 1986.

Habitat Use. Shovelers tend to be more aquatic than other Anas ducks, feeding less often terrestrially. They prefer shallow marshes, shallow lakes, reed beds, and muddy lagoons. At Cheyenne Bottoms shovelers used pools 1, 2, and 5 extensively. In particular, they fed in the shallows of pools 2 and 5 throughout March and April. They also were common all spring in the drainage ditches and leads in the cattails in Pool 1.

Food Preferences. Shovelers eat more animal matter than most other Anas ducks but still eat much vegetation. Seeds and foliage of aquatic plants are particularly important. The animal matter in their diet tends to be dominated by small insects, insect larvae, crustaceans, and other invertebrates that are sieved from the mud and water. Feeding behavior at Cheyenne Bottoms was not well-studied in fall, but in spring shovelers fed extensively in the muddy shallows of pools 2 and 5. These areas lacked macrophytes, but were rich in chironomid larvae.

Redhead (Aythya americana)

Redheads breed from southern Alaska and from central British Columbia, southwestern Mackenzie, Saskatchewan, Manitoba, and Minnesota south to southern California, Arizona, New Mexico, and the Texas panhandle, and sporadically east of the Mississippi River. They winter coastally from

British Columbia and New England, and from Nevada, Utah, Colorado, Kansas, and the Great Lakes south to Central America and the Caribbean (AOU, 1983). In this study Redheads were present from August 1985 to freezeup in November and sporadically in spring. Fewer than 50 birds were present in August 1985, and numbers remained low until just before hunting season. On 25 October several thousand were present, and Redheads remained common until mid-November, just before the last open water froze. In spring Redheads were present on most censuses through late April, but never numbered more than 50 birds and occasionally were not found at all.

Habitat Use. Redheads breed in large marshes and lakes where open water can be found adjacent to dense emergent vegetation. They winter mostly on brackish or marine lagoons and estuaries. In migration they use a variety of lakes, rivers, and marshes, requiring expanses of open water. At Cheyenne Bottoms they concentrated in the drainage ditches on the east side of Pool 1, except in October, when they were common in the flooded millet plantings.

Food Preferences. Redheads feed extensively on submerged aquatic vegetation, and aquatic invertebrates. They also will eat cereal grains from flooded fields. In late October they fed extensively in the millet plantings at the Bottoms; otherwise they mainly fed in the drainage ditches in Pool 1.

Ruddy Duck (Oxyura jamaicensis)

Ruddy Ducks breed in the western hemisphere from Alaska to southern Chile. In North America, they breed in east-central Alaska, and from British Columbia east to western Ontario, and south to the southern tier of states. East of the Mississippi River breeding is scattered and sporadic. Ruddy Ducks winter from the breeding range south to Central America. These ducks require

open water, thus the northern limit is determined by ice conditions. In Kansas Ruddy Ducks are uncommon breeding birds and common migrants.

In this study Ruddy Ducks were seen from August 1985 to freeze-up in November, and from late February to early May. About 50 to 100 Ruddy Ducks were present in August 1985. Numbers remained low until October. On 21 October, and again on 26 October, over 10,000 Ruddy Ducks were present on the open water of Cheyenne Bottoms. Numbers dropped sharply with cold weather on 9 November, and the last Ruddy Ducks left before freezeup. In spring Ruddy Ducks were uncommon from February through May. Numbers never rose above 100 birds during this period.

Habitat Use. Preferred Ruddy Duck breeding habitats are marshes with dense stands of cattails, bulrushes, or other tall emergents, interspersed with rather deep channels free of vegetation. Outside the breeding season they use lakes, rivers, and estuaries. Ruddy Ducks observed during this study were usually seen in the drainage ditches in Pool 1. However, in October they were abundant and were distributed in flocks over the open water of pools 1, 2, and 5.

Food Preferences. Ruddy Ducks eat a variety of submerged aquatic plants and much animal food. The latter seems to be dominated by insects but also includes mollusks, small crustaceans, and a variety of other invertebrates (Palmer, 1976).

SEED-FOOD RESOURCE ESTIMATES

The estimation of seed-food resources is based on the populations of ducks and geese and the amount of time that these populations are present at the Bottoms. In 1985 population peaks were around 80,000 ducks and 15,000

geese (table 16.9). Projected population goals, the largest populations under optimum conditions, are as many as 400,000 ducks and 40,000 geese.

The calculation of the total use days estimates based on peak populations present for 30 days, half the peak population present for 30 days, and 10% of population present for 30 days. The total use for fall 1985 are as follows:

Mallard	=	300,000	+ 150,000	+ 30,000	=	480,000
Pintail	=	450,000	+ 225,000	+ 45,000	=	720,000
GW Teal	=				=	720,000
Gadwall	=				=	480,000
Wigeon	=	30,000	+ 15,000	+ 3,000	=	48,000
BW Teal	=	150,000	+ 75,000	+ 15,000	=	240,000
Shoveler	=				=	240,000
Redhead	=				=	480,000
Ruddy	=			Total	=	3,888,000

The above figures represent 80,000 birds - adjusting to other peaks:

100,000 = 4,875,000 use days

200,000 = 9,750,000 use days

300,000 = 19,500,000 use days

400,000 = 39,000,000 use days

Likewise for geese:

White-fronted geese	=			=	720,000
Lesser snow	=	3,000	+ 1,500 + 300	=	4,800
Canada	=	15,000	+ 7,500 + 1,500	=	24,000
			Total	=	748,800

These figures represent 15,600 geese. When the figures are adjusted to a peak of 40,000 geese, the resultant use days value is 1,923,000.

To estimate the food consumption, the bird weights published by Bellrose (table 16.9) was utilized and food consumption of 0.2 pounds of food per day for a mallard sized bird. For Blue-winged teal, Shoveler, Redhead and Ruddy were adjusted according to weights and food habits (assumed only 1.2 of foods were seeds). The food consumption values for ducks are as follows:

Mallard	= 480,000	use days x	0.200 lbs. =	96,000 lbs.
Pintail	= 720,000	use days x	0.160 lbs. =	115,000 lbs.
GW Teal	= 720,000	use days x	0.050 lbs. =	46,000 lbs.
Gadwall	= 480,000	use days x	0.150 lbs. =	72,000 lbs.
Wigeon	= 48,000	use days x	0.130 lbs. =	6,240 lbs.
BW Teal	= 240,000	use days x	0.035 lbs. =	8,400 lbs.
Shoveler	= 240,000	use days x	0.055 lbs. =	13,200 lbs.
Redhead	= 480 000	use days x	0.090 lbs. =	43,200 lbs.
Ruddy	= 480,000	use days x	0.045 lbs. =	21,600 lbs.
			Total	= 3,470,000 lbs.

Adjusted to:	100,000 peak =	4,400,000 lbs.
	200,000 peak =	8,800,000 lbs.
	300,000 peak =	17,600,000 lbs.
	400,000 peak =	35,200,000 lbs.

Geese require additional food, but are grazers, so it was assumed that no more than 50% of the diet would be seeds. The food consumption values for geese are as follows:

White-front Goose	= 720,000	x 0.23 =	165,600 lbs.
Lesser Show Goose	= 4,800	x 0.22 =	1,056 lbs.
Canada Goose	= 24,000	x 0.22 =	171,836 lbs.

Adjusting the above figures for 40,000 geese fives a value of 440,000 pounds.

The day use calculations used in this section are considered to be liberal values. For example, peak numbers probably are not present for 30 days. Plus, all species consume more invertebrates in the spring and are present for shorter time periods than projected in the fall.

Table 16.9 - Arrival datea, departure dates, peak numbers, and average weights of males of waterfowl at Cheyenne Bottoms in 1985.

Species	Arrival	Departure	Date & Peak Numbers		Male Weight (lb.)
Geese					
White-front	10/1	12/1	11/1	15,000	6.3
Lesser Snot Goose	10/15	12/1	11/1	100	6.1
Canada Goose	10/15	12/15	11/1	500	6.1
Ducks					
Wood Duck	9/1	11/15	10/15	200	1.5
Mallard	10/1	11/15	11/1	10,000	2.8
Mottled Duck					2.5
No. Pintail	9/1	12/15	11/1	15,000	2.3
Green-winged Teal	9/1	12/1	10/25	15,000	0.7
Gadwall	9/1	12/15	11/1	10,000	2.1
Am. Wigeon	9/1	12/1	11/1	1,000	1.8
Cinnamon Teal					0.75
Blue-winged Teal	9/1	11/15	10/15	5,000	1.0
Northern Shoveler	9/1	11/15	10/15	5,000	1.5
Redhead	9/1	12/15	11/1	10,000	2.5
Ruddy Duck	9/1	12/1	11/1	10,000	1.2

OTHER BIRDS

This section contains information on other birds of special interest at Cheyenne Bottoms. These include raptors (including eagles and Peregrine Falcons), large waders, Whooping and Sandhill cranes, White Pelicans, and blackbirds.

RAPTORS

Raptors are a prominent feature of the avifauna of Cheyenne Bottoms. Red-tailed Hawks, Northern Harriers, American Kestrels, and Barn, Eastern Screech, and Great Horned owls are present throughout the year. The owls undoubtedly are resident; for the others it is uncertain whether the individuals present in winter include those that summered in the area. Swainson's Hawks and Mississippi Kites, and Burrowing owls summer in the area. Sharp-shinned, Cooper's, Rough-legged, and Ferruginous Hawks, Bald Eagles, Prairie Falcons, and Short-eared Owls winter at Cheyenne Bottoms. At least 12 other species have visited the bottoms, most notably Peregrine Falcons and Golden Eagles.

The raptors at Cheyenne Bottoms feed primarily on mammals, insects, and birds. Rodents and rabbits are particularly important, and the Great Horned Owls may eat significant numbers of skunks and oppossums. During waterfowl-hunting season, Bald Eagles and several of the large hawks regularly cruised over the flocks of ducks, apparently hunting for crippled birds.

SPECIES ACCOUNTS

Brief species accounts are presented for the endangered eagles and Peregrine Falcons. The accounts describe the species' ranges, status in Kansas, and occurence at Cheyenne Bottoms.

Bald Eagle (Haliaeetus leucocephalus) and

Golden Eagle (Aquila chrysaetos)

Bald Eagles are listed as endangered by the U.S. Fish and Wildlife Service in most of the 48 contiguous states, including Kansas and all other Great Plains states.

Bald Eagles breed from central Alaska and the western Aleutians east across the boreal-forest zone of Canada to Labrador, and south to Baja California, Arizona, and the Gulf Coast. Currently they do not breed in most of the plains and prairie states (AOU, 1983). In Kansas they are uncommon winter residents, mainly along rivers, and on reservoirs and wetland areas.

Two sets of data are available for assessing the winter abundance of eagles in and around Cheyenne Bottoms (table 16.10). The Kansas Ornithological Society Bulletin annually publishes summaries of winter bird censuses conducted in late December. These are generally the same censuses published as Christmas Bird Counts by American Birds (previously Audubon Field Notes) but include some censuses not published by that journal. Counts are available for the Cheyenne Bottoms area for the years 1964 and 1967 through 1977. The second set of data come from statewide eagle censuses conducted from 1979 to the present, in mid-winter. Data for Cheyenne Bottoms are available for 1980 through 1984, and for 1986.

Bald Eagles were present in the area in all the winters censused, and numbers ranged from two (1975) to 25 (1981). Numbers were generally lower on the winter bird censuses (1964-1977). This difference probably reflects seasonal differences rather than population changes, as some eagles may not arrive until early January. Otherwise, trends are not obvious: Cheyenne Bottoms tends to host up to 25 eagles each winter, and these typically are about 80% adults and 20% immatures.

In this study the first Bald Eagle of the winter was seen 22 November 1985, and the last was seen 5 March 1986. The highest count was 26 birds, on 11 January, which is very similar to the count of 24 obtained during the statewide survey.

Golden Eagles were recorded on all winter bird censuses from 1964 through 1976, with a maximum of three birds in 1967 and 1975. They were not, however, recorded at Cheyenne Bottoms on the 1977 count, nor on any of the subsequent eagle censuses. Statewide, the eagle censuses record 140 Golden Eagles in 1981, and 32 to 40 in the other 6 years available. The 1981 census clearly was anomalous: 100 or so eagles usually wintering elsewhere must have visited Kansas that year. Otherwise, the data suggest a slight decline in Golden Eagle numbers in Kansas between 1979 and 1985.

No Golden Eagles were observed in or around Cheyenne Bottoms in this study, and no sightings were discovered in conversations with Kansas Fish and Game Commission personnel and birders frequenting the area. Central Barton County seems to no longer host Golden Eagles in winter. A geographic analysis of the sightings in the statewide eagle surveys might show whether the winter range in Kansas is shrinking in general.

Habitat Use. Bald Eagles at Cheyenne Bottoms, at least for the last several years, have roosted in a shelter-belt on private land just east of the CBWMA. During the day the eagles roost on the duck-blinds in the marsh, and more frequently, on the ice of the pools. Occasionally eagles were seen perched in the trees along the dikes, but these were not often used, apparently because of disturbance by vehicles. On 1 February 1986, eight eagles were found in mid-afternoon perching in the grove of trees at the north end of Pool 2 (1 mile west of the Redwing entrance road).

Food Preferences. Wintering Bald Eagles feed primarily on fish and waterfowl. The latter generally are crippled or unhealthy birds. At Cheyenne Bottoms Bald Eagles were often seen eating carp in Pool 2. These carp seemed to be winter-killed and taken as carrion by the eagles. On two occassions, eagles were seen eating jackrabbits (Lepus californicus) in pastureland a few miles southeast of Cheyenne Bottoms.

Table 16.10--Eagle counts (total counts only for 1964-1977) in the Cheyenne Bottoms area and the statewide eagle census (total counts only).

	Winter Bird Census		Statewide Eagle Census					
			Cheyenne Bottoms				State Totals	
Year	Bald	Golden	Bald (Ad.)	(Imm.)	(Total)	Golden	Bald	Golden
1964	8	2						
1967	9	3						
1968	6	2						
1969	3	1						
1970	11	1						
1971	12	1						
1972	14	1						
1973	23	1						
1974	5	1						
1975	2	3						
1976	5	1						
1977	12	0						
1979			-	-	-	-	188	38
1980			17	7	24	0	341	33
1981			20	5	25	0	308	140
1982			9	0	9	0	464	40
1983			14	1	15	0	436	37
1984			3	0	3	0	355	32
1985			-	-	-	-	330	33
1986			19	5	24	0	-	-

Peregrine Falcon (Falco peregrinus)

Peregrine Falcons are almost worldwide in distribution, but populations are in trouble throughout most of their range (AOU, 1983). In North America they are listed as endangered by the U.S. Fish and Wildlife Service. The small subspecies F. p. tundrius breeds in the North American arctic and migrates through the eastern and central United States on its way to and from South

American wintering areas. The subspecies F. p. anatum formerly was widespread in temperate and boreal North America but has been exterpated from most of its historic range. Peregrines (anatum) formerly bred at several sites in Kansas, but no longer do so.

Three Peregrine Falcons were seen at Cheyenne Bottoms during this study. The first was a very large juvenile female, seen the morning of 1 October. It was too large and too heavily marked to be tundrius. It may have been anatum, or more likely, it could have been one of the birds of mixed ancestry being released in programs to reintroduce Peregrines into the historic range of anatum.

Two Peregrine Falcons made extended visits at Cheyenne Bottoms in spring. The first, an adult male tundrius, was first seen 23 April and stayed at least to 10 May. It was often observed chasing shorebirds over Pool 2. The other was a subadult, probably a female tundrius. It was seen from 6 to 16 May and it too was often seen chasing shorebirds. It was seen twice with prey, both times with Long-billed Dowitchers.

Food Preferences. Peregrine Falcons feed mostly on birds. Most Peregrines live near seacoasts, marshes, lakes, or large rivers and feed mainly on aquatic birds--shorebirds, seabirds, herons, and waterfowl.

LARGE WADERS

Cheyenne Bottoms regularly hosts 12 species of large waders (herons, storks, and ibises) and another three species are accidental (Table 16.11). Eleven of the 12 regular species have been found breeding in or around Cheyenne Bottoms, and six generally breed together in a large colony, often in Pool 1. Ernsting (1984) studied nesting distributions of White-faced Ibises and several herons, and much of the nesting information described here comes

from him. The CBWMA files also provided important information. Waders were censused four times in August and September 1985 and three times in the summer of 1986 by evening flightline counts. Table 16.11 lists the large waders known from Cheyenne Bottoms. Only two of these, the accidental White Ibis and Wood Stork, were not seen during the present study. The Green Heron and the two bitterns are not normally colonial and generally do not use communal roosts. The night herons are colonial nesters, but because they are active at night do not take part in the evening flights to the roost.

The wader colonies have been located at several places in the marsh (Ernsting, 1984). The movements of the colonies have generally been in response to changing water levels and vegetation conditions. At Cheyenne Bottoms these birds breed primarily in dense stands of cattails surrounded by water. For the last several years the colony has been located in the eastern part of Pool 1. The dates of discovery of first nestings (Martinez and Schwilling, 1974; CBWMA files) indicate that with the exception of White-faced Ibises, waterbird colonies were not found in the Cheyenne Bottoms marsh before the early 1970's. The colonial herons apparently did not breed in the Cheyenne Bottoms marsh until cattails began to dominate the emergent vegetation. White-faced Ibises were first found breeding at Cheyenne Bottoms in 1951, and were found nesting several times in the 1960's. They are more willing than the herons to breed in stands of bulrushes.

In 1982, according to Ernsting (1984) Cheyenne Bottoms hosted 450 Black-crowned Night-herons, 300 Cattle Egrets, 75 Snowy Egrets, 10 Little Blue Herons,and 32 White-faced Ibis in two colonies. In 1983 the single colony hosted 20 Snowy Egrets, 70 Cattle Egrets, 110 Little Blue Herons, 70 ibis, and 600 Black-crowned Night-herons. The disparity in number for some species between the two years is not surprising, for these birds often move from

colony to colony as water conditions change, and some individuals skip years of breeding. Great Blue Herons prefer to nest in trees, so the birds nesting in Barton County generally are not on Cheyenne Bottoms.

The Cattle Egrets, Little Blue Herons, and White-faced Ibises in the Cheyenne Bottoms colony mainly fed on private pastureland northwest of Cheyenne Bottoms. The Snowy and Great egrets often fed in that area but also fed throughout the marsh. Generally, Black-crowned Night-herons mostly were seen feeding along the edges of cattail stands in the main marsh. Yellow-crowned Night-herons also were seen feeding in those habitats but more often were seen in the Mallard Club area northwest of Cheyenne Bottoms.

Table 16.11--Large waders of Cheyenne Bottoms. Status codes: RB = regularly breeds; OB = occasionally breeds; RV = regularly visits; AV = accidental visitor; NC = species not counted in the flightline censuses.

Species	Status	Colonial	Max. count this study
American Bittern	RB	-	NC
Least Bittern	RB	-	NC
Great Blue Heron	(RB)	+	55
Great Egret	RV		16
Little Blue Heron	RB	+	425
Tricolored Heron	OB	+	1
Snowy Egret	RB	+	98
Green Heron	RB	-	NC
Cattle Egret	RB	+	900
Black-crowned Night-heron	RB	+	NC
Yellow-crowned Night-heron	RV		NC
Wood Stork	A		0
White-faced Ibis	RB	+	190
White Ibis	A		0
Roseate Spoonbill	A		1

CRANES

The two North American cranes, Whooping Cranes and Sandhill Cranes, are among the largest and most interesting birds to visit Kansas. Whooping Cranes are endangered, and Cheyenne Bottoms is considered critical habitat for them.

Whooping Crane (Grus americana)

The Whooping Crane is listed as an endangered species by the U.S. Fish and Wildlife Service and is subject to intensive management efforts.

Whooping Cranes historically bred from southern Mackenzie, northern Alberta, Saskatchewan, and Manitoba south to North Dakota, Minnesota, and Iowa. These birds migrated to the Gulf coast of Texas and Louisiana to winter. A separate, resident population bred on the coastal plain of Louisiana and eastern Texas (AOU, 1983). The sedentary population was exterpated by 1950 (Johnsgard, 1983). The migratory population was reduced to a minimum of about 15 birds in the early 1940's, and has disappeared from all but the northwesternmost corner of its breeding range. Currently, the wild migratory population numbers nearly 100 birds. Since 1975 Whooping Crane eggs have been placed in Sandhill Crane nests at Gray's Lake, Idaho, in an attempt to establish a second migratory population. These birds now number 30 or so, and the oldest survivors are near 10 years of age, but none of them have attempted to breed, so the outcome of this experiment is very much in doubt. In addition, 70 to 100 Whooping Cranes are presently in captivity, mostly at Patuxent Wildlife Research Center in Maryland, and at the International Crane Foundation, in Baraboo, Wisconsin.

The native migratory population travels annually to and from Wood Buffalo National Park, MacKenzie (Canada), to Aransas National Wildlife Refuge, Texas, and virtually the entire population passes through (or over) Kansas twice each year. Some cranes stop in Kansas each year, but most fly right over, to and from staging areas in south-central Nebraska.

The files at the Cheyenne Bottoms Waterfowl Management Area headquarters include an apparently complete listing of Whooping Crane sightings by Kansas

Fish and Game Commission personnel at Cheyenne Bottoms since 1960 (table 16.12). The table includes 17 sightings since 1960, or two sightings in every 3 years. These sightings have included an average of 2.5 birds each.

Several trends are evident in the table. As the size of the crane population has increased, the number of cranes per sighting has also increased. The first eight sightings (1961-1973) averaged 1.25 birds each, and the later nine sightings (1974-present) have averaged 3.6 birds. Apparently as the population has grown, the birds have tended to travel in somewhat larger groups. The frequency of sightings peaked in the mid-1970's, and in recent years apparently has declined. In the period 1960-1968, three sightings were recorded, or 0.33 per year. From 1969 to 1976, eight sightings were made (0.89 per year), and since 1976 cranes have been reported six times, for a frequency of 0.67 per year. The last sighting on Cheyenne Bottoms was made in 1982.

Several possible explanations are available for this decline in sighting frequency. First, if the birds are migrating in larger groups now, the number of groups might actually have decreased as the population has increased. Second, with complete protection, the birds may have become more willing to roost in small marshes and agricultural land and thus could be less dependent on the remnant large marshes. Third, artificial reservoirs may also be providing new stopover habitat. Fourth, the habitat at Cheyenne Bottoms may be less attractive to Whooping Cranes than it was prior to 1980. Unfortunately, the data are inadequate to distinguish among these possibilities.

Table 16.12--Whooping Crane sightings at Cheyenne Bottoms.

Year	Dates	# birds	Notes	Population size
1961	Oct.	1	1 week	39[1]
1963	28 Apr.	1		33
1968	2 May	2	1 stayed 3 days?	50
1970	30 Oct.	1		57
1971	30 Oct.	1	2 seen over Great Bend	59
1972	17 Oct.	1	seen flying over	51
1972	19 Oct.	2	overnight	
1973	27 Oct.	1		49
1974	17 Oct.	2	seen flying over	49
1974	19 Oct.	4	seen flying over	
1974	12 Nov.	1		
1978	22 Oct.	5	2 stayed 3 days	75
1978	7 Nov.	5	stayed overnight	
1980	7 Nov.	5	seen flying over	78
1981	24 Oct.	6	seen flying over	73
1982	31 Oct.	7	3 stayed overnight	72
1985	6 April	1	near Susank (12 mi N of CBWMA)	-

[1] from Johnsgard, 1983; based on winter censuses in Texas.

Note: Since this report was written, in fall 1986 Cheyenne Bottoms received the largest visit by Whooping Cranes on record. In the first weeks of November, about 29 Whooping Cranes were seen on the Bottoms, including two groups of about 10 individuals. These cranes were not all present at once, but enough of the birds were carrying colored tags that it was clear that separate groups were involved. This is almost one-third of the cranes in the natural population that migrates from Canada to Texas.

Sandhill Crane (Grus canadansis)

Migratory populations of Sandhill Cranes breed on arctic tundra from eastern Siberia and western Alaska east across arctic Canada to Baffin Island, and south spottily into eastern Oregon, Idaho, western Montana and Wyoming, northern Utah and Colorado, South Dakota, Minnesota, and Michigan. They winter in several discrete areas, including central California, New Mexico and

adjacent areas of northern Mexico and northern Texas, the Gulf coast of Texas, and peninsular Florida. Separate sedentary populations reside in southern Mississippi, Florida, and Cuba (AOU, 1983; Johnsgard, 1983).

In this report all Sandhill Cranes seen at Cheyenne Bottoms are assumed to be G. c. canadensis, the Lesser Sandhill Crane. Cranes follow rather traditional migration paths, and Cheyenne Bottoms is located on one of the primary routes for Lesser Sandhills (Walkinshaw, 1974) and distant from the routes taken by the various populations of Greater Sandhills (G. c. tabida). The subspecies of Sandhill Cranes are difficult to distinguish in the field, but bill and forehead profiles differ slightly. Some of the cranes observed at Cheyenne Bottoms in late October had the forehead profile of Lesser Sandhills, but most could not be seen well enough to make this distinction.

In fall 1985 Sandhill Cranes were first detected at Cheyenne Bottoms on 23 September. A small number of them were heard, but they could not be located visually. Counts of up to a few hundred cranes were made on the censuses of 30 September, 14 and 20-21 October, and 2-3 November. On 25 and 26 October several hundred cranes were present in the area, but beginning about 1730 hours, flocks of 50-500 cranes began arriving from the north. Most of the cranes came in over the western part of Pool 2, turned east across Pool 1, and landed in the flooded millet plantings in the north end of Pool 3. Several flocks, totaling a few thousand birds came in over the town of Redwing and proceeded directly to the roost area in Pool 3. At the peak of the movement, 10-15 flocks at a time were visible strung out across the sunset. The cranes called continuously, as migrating Sandhills generally do. By dark approximately 14,000 cranes had arrived. Their roost area was opened to waterfowl hunting 30 minutes before sunrise on 27 October, and 20 to 30 minutes before legal shooting time, goose hunters began setting out decoys in

the cranes' roost area. The cranes flushed and split into several flocks and milled about over the marsh calling constantly. Shortly after sunrise many moved onto adjacent pastureland and settled in the fields. Shortly before noon,the cranes began circling and climbing over Cheyenne Bottoms in flocks of 50-500 birds. After ascending to 3,000-5,000 feet, the flocks headed off toward the southeast. By late afternoon only a few hundred Sandhills remained. Sandhill Cranes were last seen 8 November. In 1986, Sandhill Cranes were found on all the March censuses and on 4 April, but numbers were never greater than a few hundred birds.

Habitat Use. Most Sandhill Cranes observed were in flight. Sandhills seen on the ground usually were in the milo plantings or adjacent areas in Pool 3. The overnight roost of 14,000 birds 26-27 October was in this area. Sandhill Cranes prefer to roost in very shallow water with little emergent vegetation, on exposed sandbars surrounded by water, or in extensive plowed or heavily grazed fields. The millet areas held a few hundred cranes and several thousand White-fronted Geese, when the 14,000 birds arrived, so they may have been "decoyed" to that area.

Food Preferences. Sandhill Cranes eat primarily vegetable matter, including roots, corms, and tubers, grains, and foliage of grasses. They also eat smaller amounts of insect and other invertebrate life (Johnsgard, 1983). Feeding was seldom observed at Cheyenne Bottoms in this study, but cranes often frequented the millet plantings, and millet may have been their main food.

American White Pelican (Pelecanus erythrorhynchos)

American White Pelicans breed from south-central British Columbia, northern Alberta and Saskatchewan, central Manitoba, and southwestern Ontario

south to Minnesota, South Dakota, northern Colorado and Utah, western Nevada, and northeastern California. Within this range they breed in fewer than 30 permanent colonies, and a scattering of other sites are used sporadically. White Pelicans winter coastally and on warm-water lakes from Florida, the Gulf coast, and central California south to southern Mexico, and sporadically into Central America. About two decades ago, a colony was established on the Texas coast, within the normal winter range, and these pelicans have periodically nested in central and southern California (AOU, 1983).

American White Pelicans were present at Cheyenne Bottoms from the beginning of the study in August 1985 until early November. In August and September large numbers were present but accurate counts were difficult because the birds moved among the three flooded pools, and flocks often were hidden behind cattail stands. During this period the birds may have moved rather frequently between Cheyenne Bottoms and Quivira National Wildlife Refuge and perhaps Cedar Bluff and Kanopolis reservoirs. Several time in evenings most if not all of the pelicans on Cheyenne Bottoms were observed to gather into a large flock and then fly, generally single file, from Pool 2 over the dike into Pool 1. Extremely accurate counts of the pelicans doing this were possible, but because some birds may not have participated in these movements the counts should be considered minimums. On 14 August 4,500 pelicans were counted in this manner, and a count the evening of 21 August yielded 7,200 pelicans. The 2,200 pelicans counted 22 September probably were only part of the birds present, but numbers did seem appreciably lower than in previous weeks. On 30 September only 500 pelicans were found, and by 20 October fewer than 100 remained. Half a dozen stragglers remained into early November, but these seemed to be unhealthy birds.

In spring 1986 White Pelicans first appeared in late March and were present sporadically throughout the spring and summer. Maximum counts were in the 500 to 800 bird range, and flocks of that size seldom stayed more than a few days. Apparently the low water levels in 1986 depressed fish populations to the extent that Cheyenne Bottoms was much less attractive to the pelicans.

Habitat Use. In 1985 American White Pelicans usually were seen in the open water of pools 1, 2 and 5, or resting on exposed mud-banks in Pool 2. They often entered fairly restricted leads in the cattails. The inlet canal often was used by up to 50 birds. In 1986, with less water present, use patterns were different. In early spring, when shallow water remained in Pool 3, pelicans often roosted on some of the outermost blind islands in the pool. Later in spring and through the summer, the exposed mud on the south side of Pool 5 was the preferred roosting area. Throughout 1986 most feeding activity observed was in Pool 1.

THE ROLE OF BLACKBIRDS (ICTERIDAE) IN THE ECOLOGY OF CHEYENNE BOTTOMS

Cheyenne Bottoms hosts large breeding populations of Red-winged Blackbirds (Agelaius phoeniceus) and Yellow-headed Blackbirds (Xanthocephalus xanthocephalus) and much smaller populations of Great-tailed and Common grackles (Quiscalus mexicanus and Q. quiscula). During the breeding season these birds feed primarily on emerging and emergent aquatic insects. At this time they probably are not abundant enough to greatly affect the ecology of the marsh, although they do play a role in nutrient cycling in the marsh. Their presence in the marsh probably affects the emergence behavior of Odonatas (dragonflies and damselflies) and perhaps other insects (Orians, 1980).

After the breeding season, however, and through the winter these blackbirds join into a huge communal roost. In these seasons, the blackbirds forage outside the marsh, entering it only at dusk and generally departing shortly after sunrise. Numbers in the roost are far greater than the numbers of locally breeding birds, so the roost must contain birds migrating in for the winter. The roost plays an important role in the nutrient budget of Cheyenne Bottoms, for the birds feed all day in the surrounding countryside to a distance of 50 or more miles (primarily on waste grain in harvested fields, on standing milo, and on feed grains in feed lots) and deposit guano in the roost through the night.

The birds return to the roost each evening in long and very cohesive flightlines. The birds in these flightlines do not always take the shortest possible courses back to the roost, but often detour to follow brushy fence-rows, or to avoid flying over water. They may also alter course to avoid hawks or other possible predators, and the flightlines often become quite sinuous, winding across the sky. Clearly the birds following those that

altered course would rather follow the new, longer course than break from the lines and establish their own more direct course. The positions of the flightlines, and the numbers of birds in them, vary from night to night, evidently in response to daily differences in the preferred feeding locations.

This winter roost apparently first formed in 1969. The winter bird censuses reported in the Kansas Ornithological Society Bulletin prior to 1969 (1964, 1967, 1968) included, respectively, zero, three, and 58 Red-winged Blackbirds. In contrast, the December 1969 count reported over 2 million. The roost apparently did not form in 1970, as only 263 Red-winged Blackbirds were reported, but apparently it has been active every winter since. Maximum counts were over 9 million birds in 1974, 12.5 million in 1975, and 12.3 million in 1977. These censuses were not conducted from 1978 through 1984, but observers in the area consider the roost an annual phenomenon.

In the winter of 1985-86, the roost formed in late August and early September, but remained fairly small (probably fewer than 50,000 birds) until early November. The initial roost probably contained mainly local birds, and the influx in early November apparently consisted of migrants from further north. An incomplete census on 18 December 1985 recorded over 320,000 birds, but at least two flightlines were not censused that day. A census was attempted 1 and 2 February, counting some flightlines one evening and the others the next. The combined count for the two evenings was approximately 600,000 birds. This 2-day procedure was suspect, for birds may switch foraging areas and hence flightlines from day to day. At a census the evening of 22 February apparently all flightlines were covered, and a count of 548,000 birds was obtained, providing substantial agreement with the previous census.

The different species could not be counted separately during these censuses, but subsamples were counted for species composition on several

occasions. In all cases over 90% of the birds counted were Red-winged Blackbirds. Brown-headed Cowbirds (Molothrus ater) seemed to be the second most numerous, followed by Starlings (Sturnus vulgaris) and Common Grackles. Most of the Great-tailed Grackles in the roost arrived early and spent half an hour or so sitting in flocks in the trees on the dikes: they numbered at most 800 birds. Brewer's Blackbirds and Rusty Blackbirds (Euphagus cyanocephalus and E. carolinus) were seen in the area in small numbers in the daytime. They probably joined the roost at night as well, but they were not detected in the flightlines. In September and October at least 10,000 Yellow-headed Blackbirds used the roost, but they all migrated out of the area by mid-November. The roost had reformed by 4 September 1986, when 80,000 birds were counted leaving just before sunrise.

The roost changed locations frequently during the course of the winter of 1985-86. In late November it was located somewhere in the north end of the marsh, but the precise location was not established. On 11 January it was located in the northeast corner of Pool 2. On 1 February it was still in the northeast corner of Pool 2 but had shifted about half a mile west. On 2 February part of the roost shifted across the dike into the northern end of Pool 1. On 21 February the roost was located in the southwest corner of Pool 1. The next day, 22 February, the main roost shifted about 200 yards to the north, still in Pool 1, and a smaller satellite roost of about 60,000 birds roosted in the southeastern corner of Pool 1. On 18 March the roost was located on the eastern side of Pool 1, but its precise location could not be determined.

Blackbird-roost shifts, as observed in Cheyenne Bottoms, are not well understood. Most of the roosts that have been studied are in trees, and typically the same group of trees is used throughout the winter. Guano may

accumulate several feet deep under these tree-roosts and commonly kills the trees. The roost shifts at Cheyenne Bottoms likely result from the roosts' location in cattails. The activities of the birds seem to break down the dead stalks of the cattails, so that after several nights a given stand may have a lower density of suitable perch sites. In addition, cattail-roosting blackbirds may be more subject to disturbance by nocturnal predators. Skunks and raccoons were common in the marsh through the winter, and numerous partially eaten blackbird carcasses were seen in the roosts. Roost movements probably would not have been very effective in avoiding these predators, but the birds may have attempted such escape anyway.

The formation of the small satellite roost on 22 February suggests a mechanism for roost movements. That evening three flightlines came in from the northeast, east, and southeast, and coalesced in the southeastern corner of Cheyenne Bottoms. Some of the birds flew directly from there along the Pool 1/Pool 5 dike to the main roost site. Many, however, lit for a while on the tops of the cattails in the southeastern corner of Pool 1. Most of these birds later picked up in flocks and proceeded west to the main roost site. Rather suddenly, about 20 minutes after sunset, all of the birds remaining in the southeastern corner of Pool 1 dropped deep into the cattails and became silent. This satellite roost may have become the nucleus for the main roost on subsequent nights. Probably such roost shifts tend to move the roost toward the side of the marsh closest to the primary foraging areas at the time of the shift.

The energetic contribution of the roost to Cheyenne Bottoms is substantial. Because the birds are feeding outside the marsh, the droppings they deposit represent net inputs of energy and nutrients to the marsh. In contrast, birds living and feeding in the marsh merely process and recycle

nutrients already present. Attempts to measure rates of guano deposition directly failed, but estimates can be calculated from known rates of guano production for other birds. Assuming that Red-winged Blackbirds deposit between 1.5 and 3.0 grams of droppings in the roost per night, 548,000 birds would deposit between 822,000 grams (822 kilograms) and 1,644,000 grams (1,644 kilograms of guano per night). Bird droppings typically contain no more than 50% water, so this works out to 411 to 822 kilograms dry weight of droppings per night. The roost persisted at roughly comparable numbers about from mid-November to mid-March (120 days), so the birds apparently deposited 49,000 to 98,000 kilograms (108,000 to 216,000 pounds) of guano through the winter. This guano was deposited mainly in the cattail beds of pools 1 and 2. In winter 1985-86, Pool 1 has essentially complete coverage of water (3,300 acres) and Pool 2 contained about 2,000 acres of water. The pools remained frozen through much of the winter, so the guano probably remained localized in the various roost sites until spring. During spring the nutrients from the guano probably reached all areas of the two pools that were covered by water, although concentrations may have varied with distance from the roost sites. The spring of 1986 was very windy, and the frequent wind-driven movements of the water probably flushed much of the nutrients out of the cattail beds and distributed them about the marsh. If the amounts of guano suggested above were distributed uniformly over the 5,300 acres of water in pools 1 and 2, 9.25 to 18.5 kilograms (20.4 to 40.8 pounds) dry weight per acre would result.

Large blackbird roosts are notoriously difficult to census, so the counts of 6 to 12 million birds reported in the mid-1970's may be subject to substantial error. If they were accurate, however, the nutrient contribution to the marsh would be 10 to 20 times that recorded in 1985-86. Of course, if

more water were present, or if water were transferred between pools in spring, the nutrients may have been dispersed over a larger area.

As previously noted, the roost seems to date from 1969. Prior to 1969, the marsh was recognized as being very productive even without this major nutrient inflow. Currently the marsh appears extremely eutrophic and seems to be depositing large quantities of nutrients in organic sediments. Prior to the formation of the blackbird roost, the marsh may have been substantially less eutrophic, but good comparative data are not available.

The blackbird roost may have one substantial negative effect on the ecology of the marsh. The blackbirds feed extensively at feedlots in the region and are considered pests. The feedlot operators often poison them, and some poisoned birds manage to return to the marsh before dying. The toxins used have not been identified, but if they include persistent chemicals, the blackbirds may be transporting significant quantities of these back to the marsh where they may affect a variety of predators and scavengers.

REACTIONS OF BIRDS TO HUNTING AT CHEYENNE BOTTOMS

Currently, Cheyenne Bottoms is managed primarily to provide habitat for migratory waterfowl and to provide Kansans with opportunities to hunt ducks and geese. Because Cheyenne Bottoms also provides important habitat for nongame birds, an understanding of the reactions of the important birds to hunting is important to a more integrated management scheme. Accordingly, observations of birds' reactions to hunting activity were made on several occasions during waterfowl and pheasant hunting seasons (table 16.13).

Table 16.13-Schedule of Observations.

Dates	Hunting activity	Hunting pressure
1-2 Sept.	Dove season	light
22 Sept.	Last day, teal season	light
26-27 Oct.	Opening weekend, duck, dark-goose season	moderate to heavy
2-3 Nov.	Waterfowl season	moderate
7-8 Nov.	Goose season	light
9 Nov.	Waterfowl, opening day pheasant season	heavy
19-21 Nov.	Waterfowl, pheasant	light
8 Dec.	Waterfowl, pheasant	light
17-18 Dec.	Goose, pheasant	light
11-12 Jan.	Pheasant only	light

RESULTS

Dove season opened 1 September, and dove hunters were observed along several of the county roads near Cheyenne Bottoms, but no hunting activity was seen on CBWMA itself. However, a Long-billed Dowitcher was found shot on the shore of a small pool of water along the roadway in Pool 3, and the implication is that it was shot by a dove hunter.

No obvious reactions of birds to hunters were noted on 22 September, but hunting pressure was very light. Some hunters were successful that day, but the successful hunts were not observed. Shorebird and rail activity seemed about normal, and the peak areas for shorebird feeding did not experience hunting activity.

Observations on opening weekend (26-27 October) of duck and dark-goose season included pools 1-4 but concentrated on Pool 3. Water had been diverted into pools 3 and 4 over the previous two weeks, and on 26 October water averaged 3-6 inches deep in the blind areas of Pool 3 and in the areas planted to millet. Several thousand White-fronted Geese had been feeding in the millet for several days, and 50,000-120,000 dabbling ducks and Redheads were using the flooded areas. The evening of 25 October, just prior to opening

day, 40,000 waterfowl gathered on Pool 1 (refuge pool). Many of these were too distant for positive identification, but Gadwalls, Mallards, Pintails, Redheads, and White-fronted Geese were prominent.

Opening morning observations were made from the dikes and from the parking lot on the north end of Pool 3. Most of the blinds in Pool 3 were occupied, and the areas behind the blinds also received heavy use. The hunting pressure in the area was sufficient to keep waterfowl from landing and feeding, and the area was attractive enough that waterfowl flew overhead all morning. Hunters took only a few hundred birds from the area, apparently because many hunters fired at excessive range and scared off most birds before they came into range. Avocets and Lesser Yellowlegs foraged among the blinds in the northwest part of Pool 3 but moved around often in response to hunter activities. No hunters were seen to shoot at the shorebirds. Pool 3 was closed to hunting at noon, and geese and ducks began moving in as hunters left. Pools 2 and 4 remained open through the afternoon, but hunting pressure declined significantly.

That evening about 50,000 waterfowl gathered on Pool 1, not a significantly higher number than the previous night. That evening 14,000 Sandhill Cranes arrived from the north and settled into the millet plantings in the north end of Pool 3. They began arriving about 5:30 p.m. in flocks of 50-500 and continued to arrive until dark. Before dawn Sunday, goose hunters began moving into the millet areas to set up decoys and portable blinds. The cranes flushed and relit several times and milled around in the air until about sunrise, when many moved northeast and settled on privately owned farmland. About 11:00 a.m. cranes began circling and soaring high over Cheyenne Bottoms in groups of 50-500 birds. The flocks circled to altitudes

of 3,000 to 5,000 feet and headed off southeast. As near as could be determined, no hunters attempted to shoot cranes.

At least a few thousand White-fronted Geese also left to the southeast Sunday morning, and numbers of ducks declined as well. Hunting pressure Sunday morning was substantially lighter than Saturday, evidently because some hunters were put off by the opening-day crowds. Birds' reactions seemed similar, although fewer waterfowl attempted to enter the hunted areas.

The next weekend, 2-3 November, hunting pressure was moderate. Bird numbers were substantialy lower, and hunting success seemed to be concentrated in pools 3 and 4. Geese and ducks moved into the millet in Pool 3 after the noon closing, but only in small numbers. Interactions between hunters and other birds were not noticed. Shorebird numbers were very low, and only a few hundred Sandhill Cranes were present.

Hunting pressure was very light 7 and 8 November, as duck season was closed. Goose numbers were low (at most 1,500 to 2,000 birds), and few goose hunters were active.

Duck season reopened and pheasant season opened Saturday, 9 November. Hunting pressure was very heavy, especially in the upland areas. In parts of pools 2, 3, and 4, parties of pheasant hunters formed lines to sweep through the fields and drive birds from the vegetation. Several Short-eared Owls and Northern Harriers (Marsh Hawks) were observed to be flushed by the hunters from their ground roost-sites. These birds seemed to have little trouble finding alternate roost-sites, however. Shorebird numbers were so low by this date that hunting had little effect on shorebird behavior.

Hunting pressure on the subsequent trips (19-21 November, 8 December, 17-18 December, 11-12 January) was so light that significant effects on bird distribution and behavior were not obvious.

DISCUSSION

The effects of hunters on the behavior of birds at Cheyenne Bottoms was clearly graded by hunter density. The density of hunters on opening weekend apparently was sufficient to cause 14,000 Sandhill Cranes and an unknown but substantial number of ducks and geese to leave the area. Otherwise, disturbance of birds by hunters did not seem to be a serious problem. The waterfowl season opened after most of the shorebird migration was past, so interactions between hunters and shorebirds were minimal.

As noted above, the hunting pressure on opening weekend apparently was sufficient to drive many of the ducks and geese further south, making them unavailable to Kansas hunters. Management options might be possible that would provide enough protection to the birds to induce them to remain longer at Cheyenne Bottoms. For example, closed (refuge) areas could be provided with high-quality food, or the planted hunting areas could be subjected to rotating closures, such that some of the millet plantings were closed on any given day. These options might induce birds to stay longer and thus remain available to hunters longer, but probably would reduce the opening-weekend bag. They would thus favor the local hunters who could hunt weekday mornings and evenings and reduce opportunities for hunters traveling to Cheyenne Bottoms for the weekends.

Disturbance by hunters apparently also caused the 14,000 Sandhill Cranes that arrived 26 October to move on south the next day. Several options might be possible to prevent such disturbance.

First, the cranes' roost area could have been closed temporarily to hunting. This roost was in the best goose hunting area on Cheyenne Bottoms at that time, and such a closure would have caused great inconvenience for the hunters, many of whom had traveled substantial distances for the weekend

hunt. Current management apparently calls for such closures when the endangered Whooping Cranes roost at Cheyenne Bottoms.

Second, if the roost site were deliberately disturbed during evening, as the birds were arriving, they might have moved to roost in one of the refuge areas.

Third, research on the Platte River has defined the preferred roost-sites of Sandhill Cranes sufficiently that similar high-quality roost sites could be developed in refuge areas. Indeed, the reasons the birds chose the millet plantings are clear: this area provided shallow water with only very short emergent vegetation and a reasonably secure bottom. The refuge pools either were deeper (at least their muddy water would have appeared deeper) or were choked with cattails.

Lesser Sandhill Cranes are abundant birds, and special management for their sake is probably unwarranted unless it can be shown that an extended stopover in Kansas is nutritionally important. On the other hand, a hunting season for cranes in Kansas has been proposed, and if cranes are to be hunted, management to retain migrants within the state may be important.

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CHAPTER 17: THE MAMMALS OF CHEYENNE BOTTOMS

Wayne Hoffman and Paul Arbetan

INTRODUCTION

The Cheyenne Bottoms Wildlife Management Area (CBWMA) supports about 20 species of mammals or about 25% of the Kansas mammalian fauna. No endangered or threatened species are known to occur at the CBWMA. The fauna does include two species of big game, mule deer and white-tailed deer, and three species of small game, eastern cottontail rabbits, black-tailed jackrabbits, and fox squirrels. The unprotected coyote and black-tailed prairie dog occur there, as do at least five of the huntable furbearers (opossum, raccoon, badger, bobcat, striped skunk) and three other furbearers, mink, muskrat, and beaver. Cheyenne Bottoms generally supports large populations of raptorial birds, particularly in winter, and small mammals are important as food resources for these birds. At Cheyenne Bottoms prairie voles, hispid cotton rats, and cottontails are the most important of these prey species.

Some years Cheyenne Bottoms supports substantial populations of nesting waterfowl, and mammalian nest predators are an important consideration in managing this resource. One objective of this study, then, was to identify the mammals most likely to be significant predators of nesting waterfowl and other marsh birds.

Proper vegetation management at Cheyenne Bottoms includes control of the proliferation of dense stands of cattails. Two furbearer species, muskrats and beavers, might possibly be effective in cattail control, so an objective of the study was to assess the effectiveness and potential of these animals for cattail management.

METHODS

One of us Wayne Hoffman (WH) made casual notes of mammal activity from August 1985 through September 1986 while studying the birds of Cheyenne Bottoms and conducted a series of 12 nocturnal-mammal surveys in spring 1986. The other of us Paul Arbetan (PA) examined the mammal collection at the Museum of Natural History (KU) for specimens from Cheyenne Bottoms, searched the literature for Barton County records, compiled trapping records from the files of the CBWMA, and conducted more intensive mammal surveys at Cheyenne Bottoms in June 1986. The nocturnal surveys were conducted by driving a vehicle along the dike roads through the marsh and recording all mammals observed in the headlights or with a hand-held spotlight. Muskrat censuses were conducted in June 1986 by canoe.

RESULTS

The mammals of Cheyenne Bottoms are listed in table 17.1. Records of 20 species were found for the Bottoms. In this study all of these 20 species were observed. Records of an additional 14 species were found for Barton County (Bee et al., 1981), and these species may occur within the Management area. The mammal fauna includes the only marsupial native to North America (opossum), two species of bats, one edentate (nine-banded armadillo), 17 species of rodents, two lagomorphs (rabbits), seven carnivores, and two ungulates. Two of the species known from the county deserve further mention. Nine-banded armadillos are largely tropical in distribution but reach the northern limit of their range in central Kansas. We know of no records from Cheyenne Bottoms, but they have occurred in Ellinwood for a number of years (pers. comm., G. Ernsting, 1986). Spotted Skunks formerly were

Table 17.1--The mammals of Cheyenne Bottomsand Barton County, Kansas.

Species	Seen this study	Relative abundance on CBWMA	Previously known from CBWMA	Known from Barton Co.
Opossum	x	common	x	
Short-tailed Shrew	x	?	x	
Eastern Mole				x
Red Bat				x
Hoary Bat				x
Nine-banded Armadillo				x
Plains Pocket Gopher				x
Plains Pocket Mouse				x
Hispid Pocket Mouse				x
Ord's Kangaroo Rat				x
Black-tailed Prairie Dog	x	rare	x	
Thirteen-lined Ground Squirrel	x	?	x	
Fox Squirrel	x	uncommon	x	
Deer Mouse	x	common	x	
White-footed Mouse				x
Plains Harvest Mouse				x
Western Harvest Mouse				x
Northern Grasshopper Mouse				x
Hispid Cotton Rat	x	?	x	
Prairie Vole	x	abundant	x	
Muskrat	x	common	x	
House Mouse				x
Beaver	x	uncommon	x	
Eastern Cottontail	x	abundant	x	
Black-tailed Jackrabbit	x	uncommon	x	
Coyote	x	common	x	
Raccoon	x	abundant	x	
Bobcat	x	uncommon	x	
Striped Skunk	x	common	x	
Spotted Skunk				x
Mink	x	common	x	
White-tailed Deer	x	common	x	
Mule Deer	x	uncommon	x	

quite common in Kansas, but have become very rare and may no longer occur in Barton County. The list (table 17.1) undoubtedly is incomplete: porcupines, other species of bats, and long-tailed weasels probably occur in the county as well.

Trapping records from Cheyenne Bottoms in the last 10 years are summarized in table 17.2. Muskrats, mink, and raccoons were the only animals reported trapped in all 10 years. Coyotes, skunks, opossoms, beavers, and bobcats have also been taken, but much less frequently. Overall, muskrats have accounted for over 90% of the animals taken, but since the 1983-84 season have dropped to 30% or less of the total. The trapping records are discussed in more detail in the species accounts.

Table 17.2--Trapping records from Cheyenne Bottoms.

Season	Muskrat	Mink	Raccoon	Coyote	Skunk	Opossum	Beaver	Bobcat
76-77	1384	11	9	1	0	0	0	0
77-78	1064	5	11	0	0	0	0	0
78-79	578	12	14	0	0	2	0	0
79-80	850	45	22	0	7	1	0	0
80-81	1049	29	15	0	4	0	2	0
81-82	295	20	9	0	2	0	0	0
82-83	344	20	26	0	5	10	0	0
83-84	15	1	14	0	4	10	4	1
84-85	9	3	15	0	3	13	4	0
85-86	22	4	18	0	17	17	6	1
Average	561.0	15.0	15.3	0.1	4.2	5.3	1.6	0.2

SPECIES ACCOUNTS

This section contains species accounts for the 14 species of mammals we considered most important in Cheyenne Bottoms. The species accounts begin with statements of legal status (furbearer, game species, protected species, unprotected species) and relative economic importance at Cheyenne Bottoms. A description of species' abundance at Cheyenne Bottoms follows, along with descriptions of habitat and food preferences.

Finally, most accounts contain a statement of the role of the species in the ecology of Cheyenne Bottoms.

Virginia Opossum (Didelphis virginianus)

Opossums are classified as furbearers in Kansas and may be hunted or trapped during a winter open season, but low prices for the fur have kept the trapping effort at Cheyenne Bottoms very low.

Opossums are abundant inhabitants of Cheyenne Bottoms. They use the dikes extensively but also forage out in the marsh and in adjacent upland areas. Because trees are rare at Cheyenne Bottoms, they probably den in rubble piles along the dikes.

Habitat Use. Opossums require moist habitats, generally with standing or running freshwater, and prefer wooded habitats. They usually den in trees but may use fallen logs, rockpiles, or the crawl spaces of buildings. Cheyenne Bottoms is atypical as opossum habitat because it lacks many trees.

Food Preferences. Opossums are most commonly preyed upon by Great Horned Owls and also may be taken by coyotes and bobcats. They are potentially significant as nest predators of waterfowl and other marsh birds. Opossums are susceptible to tularemia.

Black-tailed Prairie Dog (Cynomys ludovicianus)

Prairie dogs are unprotected in Kansas and may be hunted, trapped, and poisoned throughout the year.

Three small prairie dog towns are located in privately owned pastureland adjacent to Cheyenne Bottoms. One is approximately 1/2 mile south of the CBWMA headquarters and contains 15 or so active dens. The second is 2 miles east and 1 mile south of the headquarters and contains at least 35 dens. The third is north of Pool 2, about 1 mile south of the community of Redwing. A

single dispersing prairie dog was seen several times in May and June 1986 on the dike between pools 1 and 2.

Habitat Use. Black-tailed prairie dogs prefer short-grass prairie or heavily grazed pastureland, with sufficiently drained soils that they can excavate dry burrows. They are unable to invade rank prairie vegetation, and where they do live they keep the grass trimmed very short.

Food Preferences. Prairie dogs are herbivores and eat a variety of grasses and herbaceous vegetation.

Ecological Role. Prairie dogs provide nest holes for Burrowing Owls. Their towns are used by several species of migratory shorebirds, including Mountain Plovers, Lesser Golden Plovers, Upland Sandpipers, and Buff-breasted Sandpipers. The Ferruginous Hawks and Prairie Falcons wintering around Cheyenne Bottoms were most often seen around the dog towns. Prairie dog towns may be reservoirs of the disease sylvatic plague.

Muskrat (Ondatra zibethicus)

Muskrats are classified as furbearers in Kansas and may be trapped during a winter trapping season. From 1976 to 1983, they were by far the most commonly trapped furbearers at Cheyenne Bottoms (table 17.2). The greatly reduced take since then may reflect a drop in value of muskrat fur rather than a population decline.

Muskrats were quite common in Cheyenne Bottoms in fall 1985 and spring 1986. During waterbird surveys up to several were seen per day, particularly in the borrow ditches in Pool 1 and Pool 5. Muskrat houses in the marsh were located primarily on the edges of deep-water areas, particularly borrow ditches. Bank dens also were used, at least in Pool 5. The muskrat population declined precipitously during May 1986. Sightings became rare, and few fresh cattail cuttings were seen in the marsh. During the June canoe

surveys, muskrats were seen only in the southeastern corner of Pool 1 and in the outlet hub. A variety of evidence suggests that this population decline was the result of a contagious-disease outbreak. First, no unusual predator activity was noted, and in fact the raptor density on May was much lower than in the winter months. Second, PA found several rotted carcasses of muskrats in the marsh in June. Third, the population decline in muskrats coincided with a decline in striped skunk numbers (see the striped skunk account), and behavioral indications of disease were noted in that species.

Habitat Use. Muskrats prefer to inhabit marshes with relatively deep water adjacent to extensive stands of emergent vegetation. At Cheyenne Bottoms, water depth seems to limit muskrat distribution. Shallow water will freeze to the bottom, so that the muskrats cannot swim from their houses to forage under the ice.

Food Preferences. Muskrats eat the roots, stems and tender foliage of a variety of aquatic and terrestrial plants. At Cheyenne Bottoms they seem to feed almost exclusively on the roots and succulent lower stems of cattails (Typha).

Ecological Role. Muskrats are preyed upon by large raptors and by a variety of carnivores, but especially by mink. Muskrats are extremely important in cattail marshes for their role in increasing habitat dispersion by clearing areas of open water as they feed and build their domed houses. Muskrats are susceptible to a variety of pathogens, including the fungi Trichophyton and Haplosporangium, coccidia (Eimeria), and several bacteria, most notably Salmonella and Pasturella (causing tularemia; Errington, 1961).

Beaver (Castor canadensis)

Beavers are classified as furbearers in Kansas and may be trapped during a winter trapping season. Up to six beaver per season have been taken at Cheyenne Bottoms in recent years.

Two active beaver lodges are located in Pool 1. One is in the borrow ditch on the east side of the pool, and the other is in the ditch on the west side. Many of the cottonwood trees in the outlet hub show old beaver toothmarks, but no evidence of recent activity was found. Evidence of beaver activity is present along the inlet canal just above the drop structure and along the outlet canal about 1 1/2 miles dounstream from highway 156.

Habitat Use. Beavers require fairly permanent freshwater and prefer locations with an abundance of riparian trees, including willows, cottonwoods, and ash. The beavers inhabiting Pool 1 are in rather atypical habitat, as trees essentially are absent. Density in Pool 1 probably is limited by water depth, as most of the marsh may be too shallow to allow them to swim under the winter ice.

Food Preferences. Over most of their range beavers feed mainly on the cambium layer of the bark of trees and eat lesser amounts of aquatic vegetation. The beavers inhabiting Pool 1 seem to feed mainly on the tubers and stems of cattails.

Ecological Role. Beavers have the potential for opening cattail stands, much as muskrats do, but are unlikely to achieve the densities necessary to achieve major changes in the marsh structure.

Eastern Cottontail (Sylvilagus floridanus)

Cottontails are classified as small game in Kansas and may be hunted throughout the year. At Cheyenne Bottoms they mostly are hunted incidently to bird hunting.

Cottontails are among the most abundant animals at Cheyenne Bottoms. They were seen on virtually all nocturnal censuses and were common on the dikes throughout the year. Numbers were very high in August and September 1985, with sightings of 10-15 animals per mile of dike. Through the winter of 1985-86, density dropped greatly, probably because of predation by the abundant eagles, hawks, and owls. In spring and summer 1986, numbers built back rapidly but appeared not to reach the densities of 1985.

Habitat Use. Eastern cottontails use diverse and variable habitats but remain near adequate cover. They prefer thickets, brush piles, fallen trees, tall grass, and other cover permitting the use of forms. Forms typically are small depressions excavated in the ground and protected by overhanging cover. Cottontails also excavate underground burrows in some habitats.

Food Preferences. In summer cottontails choose a diet of green vegetation of both herbaceous and woody plants. The winter diet includes twigs of shrubs and trees, and at times tree bark.

Ecological Role. Eastern cottontails are important prey for many raptors and carnivorous mammals. Cottontail populations tend to be cyclic, but with more variable periodicity than hares and jackrabbits (Lepus). During population highs they will support large populations of predators, thus increasing predation pressure on waterfowl and other marsh-nesting birds. Cottontails are extremely susceptible to tularemia and may transmit it to muskrats and other wildlife.

Black-tailed Jackrabbit (Lepus californicus)

Jackrabbits are considered small game in Kansas and are legally hunted throughout the year.

During this study jackrabbits were not common on the CBWMA but were more frequent on adjacent higher ground. Most sightings were northwest of Pool 2,

in the pasture areas of the lower Deception Creek drainage, and southeast of Pool 5. On the CBWMA, sightings were made along the south boundary of Pool 5, west of Pool 2, and in the eastern end of Pool 3.

Habitat Use. Jackrabbits prefer more open country than do cottontails and often are found in pastureland, fallow fields, and short-stature croplands. Around Cheyenne Bottoms they were observed most often in pastureland and conservation-tilled fields.

Food Preferences. Jackrabbits are herbivorous and have a diet similar to that of cottontails. In winter they may eat more dry vegetation and fewer woody twigs.

Ecological Role. Jackrabbits are preferred prey of coyotes, bobcats, and a variety of large raptors. On 18 December an adult Bald Eagle was observed eating a jackrabbit 3 miles south of Pool 5. Most jackrabbit populations are highly cyclic, often with a periodicity of 9 years. The stage of the cycle at Cheyenne Bottoms is unknown, so it is not clear whether the current low populations reflect a low stage of the cycle or more general population suppression. Jackrabbits are susceptible to tularemia and may act as reservoirs, transmitting it to other mammals.

Coyote (Canis latrans)

Coyotes are not classified as furbearers in Kansas although they have moderately valuable fur. They may be hunted or trapped throughout the year.

Coyotes are common in the Cheyenne Bottoms area but were seen in pastureland and upland areas more often than in the CBWMA. Sightings were most frequent to the northwest and to the southeast of Cheyenne Bottoms, in the areas supporting the largest Jackrabbit populations. Coyote tracks were distributed throughout Cheyenne Bottoms, suggesting that they used the Bottoms more nocturnally than the adjacent upland areas.

Habitat Use. Coyotes feed primarily on mammalian prey. Rabbits, mice, and ground squirrels are particularly important. Carrion, larger mammals, birds, fish, and a variety of fruits and seeds also are eaten.

Ecological Role. Coyotes currently have no significant natural predators in Kansas. They are potentially important as predators of marsh-nesting birds. They also are susceptible to tularemia and rabies.

Raccoon (Procyon lotor)

These animals are classified as furbearers in Kansas and may be hunted or trapped during fall and winter open seasons.

Raccoons may be the most common carnivores at Cheyenne Bottoms. They were seen commonly on the dikes throughout the area and in the pools as well. They were most often seen at night but daytime sightings also were common. A group of four raccoons was seen regularly in April around the southwest end of Pool 1 and along the eastern end of the inlet canal. An adult female with small kits was seen in mid-May on the east side of Pool 1, and older juveniles were seen on a number of occasions.

Habitat Use. Raccoons usually live near water, but with that restriction, they occupy a great variety of habitats. They are common in swamp forests and marshes, along rivers, creeks, and seashores, and even in urban areas.

Food Preferences. Raccoons are omnivores and eat a great variety of fruits, vegetation, and animal food. Crayfish, snails, and insects are important; along with clams, fish, frogs, snakes, birds and their eggs and young, and carrion. In April 1986 raccoons were seen three times out on the mud of the drying Pool 2 feeding on the carcasses of stranded carp. These animals were so coated with mud that their facial masks were obscured and their tails appeared hairless and ratlike.

Ecological Role. Raccoons are potentially very important as nest predators of marsh-living birds. They have few natural predators but may be taken by bobcats and coyotes. Raccoons are susceptible to rabies and may often serve as reservoirs for the disease.

Bobcat (Lynx rufus)

Bobcats are classified as furbearers in Kansas and may be hunted or trapped during a winter open season. Only two have been reported trapped on Cheyenne Bottoms in the last 10 years.

Two bobcats were sighted during this study. The first crossed the Pool 1/Pool 5 dike at dusk on 11 January, and the other was seen after dark on 25 April working along the water's edge in Pool 3.

Habitat Use. Bobcats use a great variety of habitats, from swamps, marshes, and forests to prairie, agricultural land, and desert. They seem to be increasing in abundance throughout Kansas.

Food Preferences. Bobcats eat a variety of mammals, birds, reptiles, and other animals. Rabbits are often dominant in their diets. Currently bobcats appear to be too rare at Cheyenne Bottoms to have significant impacts on bird or mammal populations.

Badger (Taxidea taxus)

Badgers are classified as furbearers in Kansas and may be hunted or trapped during a winter furbearer season. None were recorded as trapped at Cheyenne Bottoms between 1976 and 1986.

Badgers are uncommon residents of Cheyenne Bottoms. One was observed crossing the Pool 2/Pool 3 dike the night of 25 April. An active badger den was discovered in June 1986 on the east side of Pool 4. Badger populations

seldom are very dense, and the dearth of burrowing rodents for prey easily explain their rarity at Cheyenne Bottoms.

Habitat Use. Badgers prefer open-prairie, pastureland, and desert habitats, preferably with deep, well-drained soils. They do occur in woodlots but much less often than in more open habitats.

Food Preferences. Badgers mainly eat burrowing rodents, especially pocket gophers and ground squirrels. They catch these prey by burrowing after them and trapping them underground.

Striped Skunk (Mephitis mephitis)

Striped skunks are classified as furbearers in Kansas and may be trapped throughout the year.

Striped skunks were common at Cheyenne Bottoms from August 1985 through April 1986. Six were seen on a single dawn survey on the Pool 1 dikes in August 1985, and smaller numbers were seen most evenings that fall and spring. In early May 1986 skunks were sighted several times walking about slowly in mid-day. One such sighting was in the prairie dog town north of Pool 2, and the others were around the south end of Pool 2. Such behavior clearly is aberrant and often indicative of illness. During the June surveys, only two skunks were seen, and skunks remained rare through the summer of 1986. The period of decline for skunks (May) coincided with that for muskrats, suggesting that a single disease may have been involved.

Habitat Use. Striped skunks can tolerate a wide variety of habitats but are common in brushland and sparse woods, grassy and weedy fields, and around rock outcrops. They are much less common in dense forest and in desert.

Food Preferences. Striped skunks are omnivorous, but animal foods predominate. Insects form a major portion of the diet in warm weather, and small mammals, fruits, grains, and carrion are important throughout the year.

Ecological Role. Skunks' use of scent as a defense mechanism deters most predators. Great Horned Owls are their primary predators, and they are occasionally taken by coyotes, foxes, badgers, and bobcats. Skunks are potentially important as nest predators of waterfowl and other marsh-nesting birds. Skunks are susceptible to rabies and to tularemia.

Mink (Mustela vison)

Mink are classified as furbearers in Kansas and may be trapped during an open season in late fall and winter.

Mink are common predators at Cheyenne Bottoms. They were seen throughout the area but almost always in or near open water. They commonly were seen crossing the dikes along the inlet canal and around Pool 1.

Habitat Use. Mink are rarely found far from water. They prefer brushy areas along stream and river banks, lakeshores, forest edges near water, and marshes. They swim and dive very well.

Food Preferences. Mink are strictly carnivorous, but have a highly variable diet. They eat a variety of small mammals, including muskrats, cottontail rabbits, mice, voles, and squirrels. They also eat a variety of birds, reptiles, amphibians, fish, and crayfish.

Ecological Role. Mink are potentially important as predators of muskrats and of marsh-nesting birds.

White-tailed Deer (Odocoileus virginianus) and Mule Deer (Odocoileus hemionus)

Deer are classified as big game animals in Kansas and are hunted during a lengthy fall archery season and a short firearms season. Populations of both species are increasing rapidly in Kansas.

Deer were seen commonly at Cheyenne Bottoms throughout the study. All deer identified to species in 1985 and spring 1986 were white-tailed deer.

Two mule deer bucks were seen commonly in the marsh in June and July 1986. In the fall of 1985 deer were most often seen on the upland edges of pools 2, 3, and 5. They often bedded down in patches of annual sunflowers in these areas. During winter most of the white-tailed deer at Cheyenne Bottoms gathered into two herds. One, of about 15 animals, was commonly seen in the refuge area at the southwest end of Pool 2, about 1/2-1 1/2 miles east of the CBWMA headquarters. The other, of about 20 animals, was seen most often in an area of relatively high ground in the eastern part of Pool 3. In summer 1986 white-tailed deer were most often seen along the Pool 3/Pool 4 dike.

Habitat Use. White-tailed deer use a variety of habitat types but prefer an interspersion of woodlots or shelterbelts and agricultural land. Mule deer show an interesting dichotomy of habitat preferences. They are most often associated with xeric habitats--dry open woodlands, short-grass prairies, and shrubby deserts. They also, however, frequent the great marshes scattered throughout the western United States. At Cheyenne Bottoms the two mule deer bucks mentioned above were seen more often in the cattail stands than were the more numerous white-tailed deer.

Food Preferences. Both deer are primarily browsers. They often use agricultural crops, especially corn, milo, soybeans, and alfalfa. Marsh-living mule deer must feed on herbaceous vegetation, as browse is not available.

Ecological Role. Deer may be common enough at Cheyenne Bottoms to inhibit growth of trees along the dike, by browsing any seedlings that become established.

Other Mammals

Bats, shrews, and small rodents were not systematically covered in this study, but a variety of observations of these animals were made. Unidentified

bats were seen on several occasions, but seemed to be rare at Cheyenne Bottoms. Two shrews (Blarina sp.) and several mice (Microtus ochrogaster and Peromyscus maniculatus) were obtained in drift-traps set for reptiles and amphibians (see Chapter 15). Fox squirrels (Sciurus niger) were seen along the outlet canal south of highway 156, and thirteen-lined ground squirrels (Spermophilus tridecemlineatus) were seen occasionally along the eastern and southern boundaries of the CBWMA. Hispid cotton rats (Sigmodon hispidus) are abundant at times on the dikes, but did not appear to be common during this study. Several other mammals that have been exterminated from Kansas within the last century (bison, elk, grizzly and black bears, gray wolf, cougar, black-footed ferret, otter) may also have occurred in or around Cheyenne Bottoms.

DISCUSSION

Since Cheyenne Bottoms was obtained by the Kansas Fish and Game Commission, it has been managed primarily for migratory waterfowl. The current mammal populations thus have developed without deliberate management. In a well managed marsh system, mammal populations generally can be expected to take care of themselves, and we propose no major management strategies specifically for mammals.

If increased production of waterfowl is desired, more active predator control may be necessary. This could be accomplished directly by Kansas Fish and Game Commission personnel or through encouragement of trapping. Raccoons, striped skunks, opossums, and coyotes are the most important mammalian predators in the system.

Muskrats, and to a lesser extent beavers, are potentially very useful in the marsh for their role in maintaining habitat dispersion, and because their houses are used as nesting platforms and roost sites by waterfowl. Muskrat

and beaver populations in Cheyenne Bottoms seem to be limited by inadequate water depth. Physical deepening of sections of the marsh, for example by dredging channels or blasting potholes, should allow these animals to invade more areas in the cattail stands and increase the area of open water.

The collapse, in May 1986, of the muskrat and striped skunk populations at Cheyenne Bottoms focuses attention on the role of contagious disease in mammalian population dynamics. Because the population crashes of striped skunks and muskrats occurred simultaneously, a single disease may have been responsible. Both species are susceptible to tularemia, but populations of several mammals susceptible to tularemia (e.g., cottontails, jackrabbits, beavers) seemed unaffected, so this disease is not indicated. Many small mammals have cyclic populations and disease may often become epidemic when population densities are high. Several of these diseases (rabies, tularemia, plague, salmonellosis) are potential human-health hazards.

Current mammal faunas in Kansas and elsewhere in the Great Plains differ from historic faunas mainly in the loss of the top carnivores and the largest grazers. The loss of the carnivores (wolves, cougars, bears) may have removed a degree of natural control from populations of other mammals, allowing disease to assume a more important role.

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CHAPTER 18: AN ECOLOGICAL OVERVIEW OF THE CHEYENNE BOTTOMS MARSH

Wayne Hoffman

INTRODUCTION

Chapters 12 through 17 of this report catalog and describe the major sections of the biota of Cheyenne Bottoms. This chapter attempts to integrate the data gathered in these biological investigations into a unified picture of the ecological processes driving the marsh system. The system is examined from the points of view of trophic dynamics, energy flow, and keystone organisms. The discussion describes the implications of these studies for marsh management. Trophic dynamics is the study of plant-herbivore and predator-prey relationships. This section concentrates on the trophic interactions governing community structure. The energy flow section examines sources of energy and nutrient inputs into the marsh, cycling within the system, and export from the system. Keystone organisms are organisms that operate at critical points in the interacting system and so have effects disproportionate to their abundance (after Paine, 1966). These are the species that govern community composition, in the sense that changes in their abundance can cause major fluctuations in other parts of the system.

The picture assembled here necessarily is incomplete, for the time and resources available did not allow investigations of all relevant processes. In particular, the importance of plant decomposition in the system was realized fairly late in the study. The microbiological aspects of this process could not be investigated at all. Many of the important cyclic processes in the marsh ecology may have periodicities longer than this study, so the investigations could cover only parts of the cycles. Many ecological processes are tuned to the availability of water, and these could be investigated only under the particular water regimes experienced in 1985 and

1986. Despite these shortcomings, the picture assembled here should contribute to an understanding of the system and should provide important insight into the ways to achieve systems-oriented management goals.

TROPHIC DYNAMICS

Trophic dynamics in ecological systems commonly are illustrated by trophic pyramids. These are triangle-shaped diagrams showing the primary producers (organisms that use inorganic energy sources to build organic biomass) at the bottom, the organisms that feed on the primary producers (primary consumers) immediately above, and their predators on the next level up. The pyramid shape illustrates the concept that biomass is generally greatest at the level of primary producers and decreases rapidly up through the levels of consumers. The trophic pyramid for Cheyenne Bottoms is illustrated in figure 18.1.

PRIMARY PRODUCERS

Cheyenne Bottoms resembles most other systems in that the primary producers are green plants. In non-marine aquatic systems, the dominant producers fall into three categories: microphytes, submerged macrophytes, and emergent macrophytes. Microphytes are planktonic and benthic algae living under water. Submerged macrophytes are vascular plants that produce their foliage under water. Emergent macrophytes grow in standing water but raise their flowers, leaves, and upper stems into the air. In addition, some aquatic systems receive significant amounts of biomass from terrestrial plants through leaf-fall and through periodic flooding.

At Cheyenne Bottoms primary production currently seems to be dominated by emergent macrophytes, particularly narrow-leaved cattails, with smaller contributions by terrestrial annual plants (bottom left of pyramid, figure

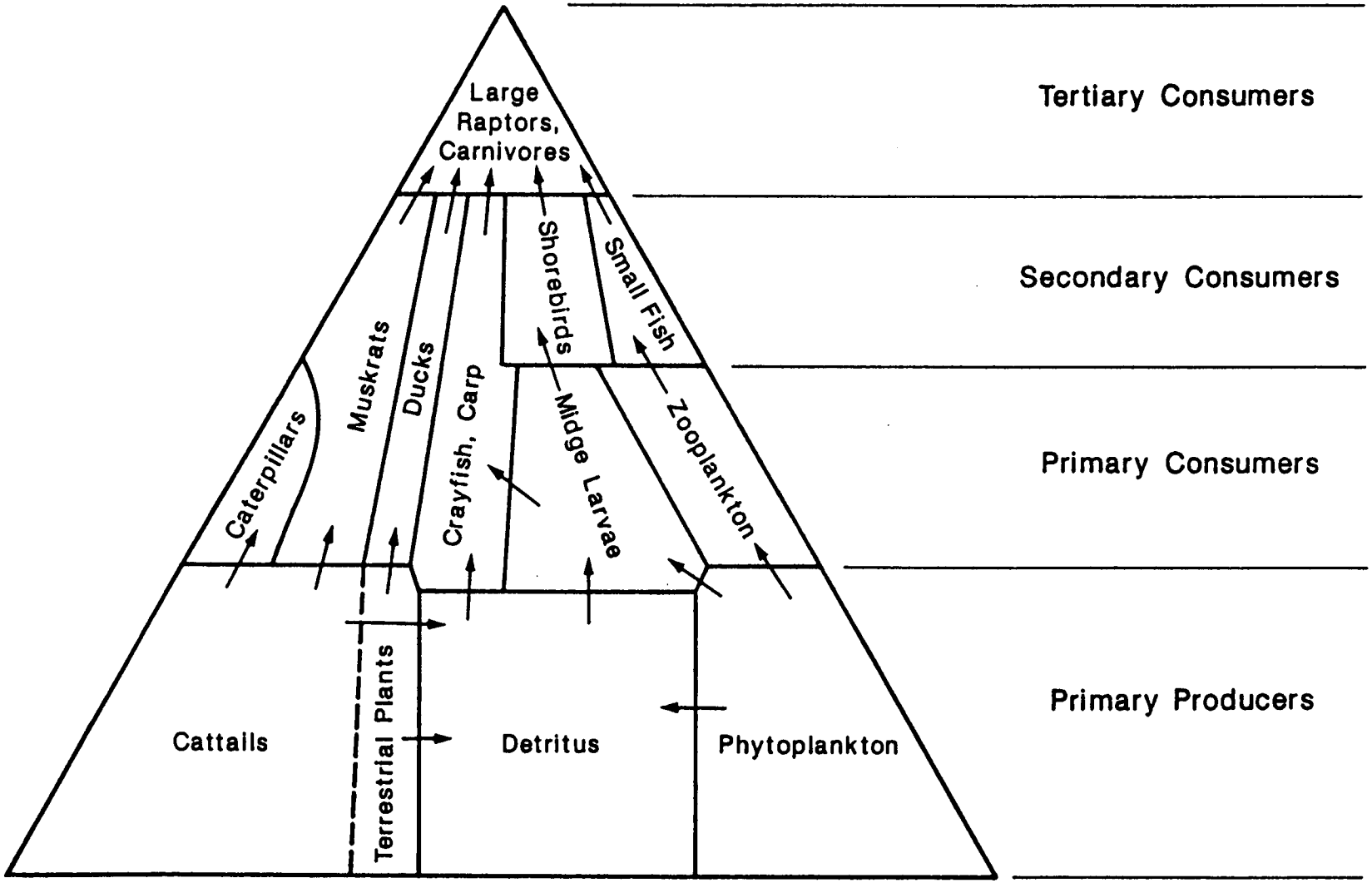

Figure 18.1 - Trophic pyramid of the Cheyenne Bottoms marsh. Arrows indicate generalized energy flow between compartments.

18.1) and algae (bottom right). In the past, bulrushes were a very abundant and important plant but currently exist in small and comparatively rare stands. Submerged macrophytes seem to have been more prevalent before development of the dike system and inlet canal, but the presence of carp and the large open expanses of shallow water in Kansas' windy environment keep water too turbid for their continued establishment and growth. Planktonic and benthic algae certainly are present, but they also may be limited by turbidity. Seasonally flooded areas of pools 2, 3, 4, and 5 grow extensive stands of terrestrial annuals (including planted Japanese millet) when drained, and these also contribute biomass to the system.

DETRITUS CYCLE

In many terrestrial and aquatic systems, energy (and biomass) flow from the plants to the consumers primarily through the consumption of living plant tissue by herbivores. In other systems herbivory is less important, and most plant tissue is allowed to die and enter a decomposition (detritus) cycle to reach the consumers. Cheyenne Bottoms is a strongly decomposition-driven system. Most of the biomass produced by the dominant plants (cattails) is killed by frost each fall, and gradually degrades into litter over the next 2 years (Davis and Van der Valk, 1978). This litter is distributed throughout the system by water movement and is the primary food of a large class of invertebrate detritivores. It also undoubtedly supports substantial bacterial and fungal populations, but these remain unstudied. As noted above, terrestrial annual plants also contribute biomass to the system. Large areas at Cheyenne Bottoms are drained in spring and summer and grow extensive stands of annuals through the summer. These areas are reflooded in fall, if possible, and these annuals' vegetative production enters the aquatic-detritus

cycle. In figure 18.1, the bottom-center section represents the plant detritus biomass in the system.

PRIMARY CONSUMERS

The next level in the pyramid contains the primary consumers: the planktivores, herbivores, and detritivores. The phytoplankton support planktivorous zooplankton, including copepods, cladocerans, and ostracods. The cattails have only two major herbivores, muskrats and the caterpillars of the marsh moth, Simya henrici. Muskrats root up the plants and eat the tubers and lower stems; they use cattail leaves and upper stems to build their domed houses. Muskrats probably turn more cattail biomass into litter than they eat. The other major herbivores, the caterpillars, often occur in great abundance and kill much of the cattail foliage, but still leave behind more dead cattail biomass than they consume. The terrestrial annuals produce substantial seed crops. When flooded these seeds provide important food for spring and fall migrant waterfowl. The detritivores seem to be more numerous and important in the system than the herbivores. The most important detritivores seem to be crayfish and chironomid midge larvae. The crayfish play an important role in shredding the litter into small bits and also feed extensively on other detritus in the system, including dead fish and other animals. The midge larvae play a variety of roles in the detritus cycle. Some burrow into dead cattail leaves and stalks and help to process and degrade them. Others live burrowed in the surface of submerged mudflats and feed on the finely divided organic ooze that ultimately results from the litter breakdown. These larvae undoubtedly ingest the bacteria and fungi participating in the breakdown process. Carp feed on detritus and small detritivores rather indiscriminantly and probably contribute to the physical degradation of the litter.

SECONDARY CONSUMERS

The primary consumers support a layer of secondary consumers which, at Cheyenne Bottoms, include a variety of birds, especially shorebirds and waterfowl, small fish, and aquatic insects. The secondary consumers are illustrated in the inset at the sides of the pyramid at the third level (figure 18.1). The zooplankton support large populations of two species of planktivorous shorebirds, Wilson's Phalaropes and American Avocets. They also support large populations of forage fishes, especially Fathead Minnows and Red Shiners, and a variety of aquatic beetles, hemipterans, and odonates. The midge larvae are the principal food of most of the great flocks of migrant shorebirds responsible for Cheyenne Bottoms' international reputation. The midge larvae also seem to provide critical high protein food for northbound migrant ducks. Some crayfish are consumed by these shorebirds. Crayfish also are the sole food of Graham's crayfish snake, one of the most abundant reptiles at Cheyenne Bottoms.

TERTIARY CONSUMERS

The apex of the pyramid contains the tertiary consumers, or top predators. Predatory mammals and raptorial birds play this role Cheyenne Bottoms. Among mammals, the most important species seem to be mink, raccoons, and opossums. Striped skunks also are common at Cheyenne Bottoms, but they seem to feed mainly in upland areas. Among birds, Bald Eagles, Peregrine and Prairie falcons, Northern Harriers, Red-tailed and Rough-legged hawks, and Great Horned, Barn, and Short-eared owls are the dominant tertiary consumers. These top predators tend to be more generalized in their food preferences than many animals at lower levels in the system. They feed on both the primary and the secondary consumers, and occasionally, on each

other. Most will move frequently from the marsh system to adjacent uplands and so are not completely tied to wetland habitats.

ENERGY CYCLING AND PRODUCTION

This section provides estimates of biomass and production for many of the more important organisms illustrated in the trophic pyramid. Ecological systems in general exhibit about 10% efficiency in energy and biomass transfer between trophic levels. In other words, only 10% of the primary producers' stored energy and biomass is transfered to primary consumers; only 10% of the primary consumers' stored energy and biomass is transfered to secondary consumers; and so on. This relationship is a general rule and numerous deviations are known. It breaks down whenever organisms operate at two or more trophic levels and is difficult to apply when organisms move across the boundaries of the system. The rule is useful as a test to see how reasonable production estimates might be.

Throughout this section, biomass will be expressed in terms of dry weight, for organisms differ greatly in their water content, and water contributes weight but not energy in the system.

PRIMARY PRODUCTION

As noted in the previous section, cattails dominate primary production at Cheyenne Bottoms. A sample of narrow-leaved cattail stalks and leaves was cut, dried, weighed, and measured. These cattails averaged 0.8 grams per inch of length, or 57.6 grams dry weight per plant (excluding roots and tubers). These plants occur in densities of approximately 200 plants per square meter, which works out to 9.75 kilograms (21.48 pounds) per square meter. This figure is much higher than the 2 kilograms per square meter reported for primary productivity of "swamps and marshes" by Whittaker (1975). The figure

for Cheyenne Bottoms is for the most productive areas in the marsh. Whittaker's figure is apparently averaged over whole marsh systems. However, Cheyenne Bottoms seems to be exceptionally productive, even in comparison to other marshes. Converting to mass per acre (the conversion factor is 4044.82 square meters per acre) yields figures of 86,865 pounds (43.4 tons) per acre. The incredible productivity of this marsh system becomes evident when this is compared to the productivity of Kansas alfalfa fields, which yield averages of 2 to 6 tons per acre (Kansas State Board of Agriculture, 1984). Cattails growing in areas drained of water early in the growing season may have similar plant densities, but the plants remain much smaller. For this analysis such plants are assumed to have only about 30% of the biomass, or 13 tons per acre. In 1986 Cheyenne Bottoms contained an estimated 1,338 acres of flooded cattails, and 2,580 acres of cattails drained early in the growing season, so production is estimated as 1,338 X 43.4 tons + 2,580 X 13 tons = 91,609 tons (83,180 metric tons) dry weight. In 1985, a wetter year, about 3,100 acres were flooded throughout the growing season (800 acres drained) so production is estimated at 145,030 tons (131,700 metric tons).

The terrestrial annuals, in contrast, produced no more than one ton of biomass per acre. The 3,600 acres of these plants flooded in the winter of 1985-86, then, produced a maximum of 3,600 tons (3,268 metric tons) total production. Similar figures could not be calculated for 1986 because the maximum extent of flooding in pools 2, 3, 4, and 5 this winter was not yet known.

Most of the plant biomass produced at the marsh is not consumed by herbivores but dies and enters the detritus cycle. Cattail litter gets reduced to about 40% dry weight in one year in water (Davis and Van der Valk, 1978), but the amounts surviving through the first year should be similar to

the amounts carried over from the previous year, so decomposition can be treated as if it occurs within one year. Assuming 80% of the 145,030 + 3,600 = 148,630 tons of biomass produced becomes detritus in the aquatic system, then the system received 118,900 tons of detritus for the 1986 season.

PRIMARY CONSUMERS

The invertebrate surveys (chapter 13) demonstrate the dominance of chironomid larvae in the primary consumer trophic level. Chironomids collected in the surveys were counted and measured, and densities calculated (in individuals per square meter) for each size class in the samples. Representatives of each size class were dried and weighed (table 13.5), and the densities were converted to grams per square meter. These were then multiplied by areas of the habitats to determine total biomass (table 13.3). The total biomass of chironomid larvae was highest in March, June, and November, at 112, 104, and 98 tons respectively, and was much lower in April, May, and July. The maximum biomass (112 tons) is only about one one-thousandth of that of the detritus, rather than the expected 10%. Chironomid midges, however, have a number of generations per year, so yearly productivity may be much greater than the biomass measures would indicate. If biomass turned over twice per month during ice-free months (typical of some other chironomid populations), then the productivity from November through July would have been 810 tons, and for a whole year should be at least 1,000 tons and close to 1% of the detrital biomass. Chironomid populations at Cheyenne Bottoms could turn over faster than twice per month but undoubtedly do not turn over the 20 times per month necessary to approach the 10% of detritus production expected. Several other factors can explain the discrepancy. First, chironomid larvae are subject to heavy predation by migratory shorebirds and waterfowl. This predation is highly seasonal and peaks in

April and May, when chironomid biomass appeared relatively low. Shorebird-food requirements, however, only amounted to about 30 tons over the 2-month migration period. This food was not gathered uniformly throughout the marsh but was taken mostly from shallow open water and exposed mud. The April and May chironomid populations in those habitats (which dominate the biomass) may have experienced higher than average predation.

Second, chironomid larvae do not feed entirely on detritus but may also eat bacteria and fungi that are themselves feeding on the detritus. If the chironomids are doing that at Cheyenne Bottoms, they are operating at a higher trophic level, and their biomass production would be expected to be lower than 10% of detritus.

Third, the highly organic nature of the Bottoms sediments demonstrates that not all detritus is being consumed, but rather that substantial amounts of biomass are being deposited in the substrate.

Other primary consumers in the study, including zooplankton, carp, crayfish, muskrats, and marsh moth caterpillars could not be censused accurately enough for biomass estimates but clearly were of minor importance compared to chironomids. Waterfowl fed extensively on the seeds of annual plants, including planted millet, and may have consumed as much as 400 tons in fall 1985. They also feed to varying degrees on invertebrates, so they are functioning on at least two trophic levels.

SECONDARY CONSUMERS

Shorebirds, waterfowl, small fishes, and some aquatic insects are the predominant secondary consumers in the system. Shorebird biomass in spring 1986 totaled 8,500-13,000 kilograms (18,700-28,600 pounds, or 9.3-14.3 tons), or about 1-2% of the biomass productivity of their chironomid prey. Most of the shorebirds were present only in April and May, so their biomass

constituted 7-11% of the estimated chironomid biomass production for those months. The relevance of this ratio is uncertain, however, because the shorebirds are only a temporary component of the system, and their numbers are likely controlled by factors operating in other parts of their ranges. Interestingly, in 1986 shorebirds carried from the system about 2,800 kilograms of fat (25 million kilocalories of energy), a sizeable export. The 1986 spring shorebird migration was substantially smaller than some reported in recent years, so presumably the impact in those years was much greater.

Blackbirds that nest in the marsh are secondary consumers of moderate importance, but their major contribution to energy and nutrient flow in the system comes in winter. In winter they feed almost exclusively outside the marsh but return to roost each night in the cattail beds. They contribute, through their droppings, 49-98 metric tons (108-216 English tons) of fertilizer rich in phosphorus and fixed nitrogen. In some recent years, the roost was reported to be at least an order of magnitude larger than in 1985-86, so the energy contribution would have been correspondingly larger. The impact of this fertilizer is problematical, for as noted above, the highly organic nature of the sediments suggests that nutrients are over-abundant at Cheyenne Bottoms.

TERTIARY CONSUMERS (TOP PREDATORS)

The most important top predators in the Cheyenne Bottoms marsh include several mammals (raccoon, mink, coyote, striped skunk, opossum), raptorial birds (Bald Eagle, Red-tailed and Rough-legged hawks, Northern Harrier, Great Horned Owl), and a reptile (snapping turtle). Most of these could not be censused accurately enough for calculations of biomass. Interestingly, these top predators are all generalists, occupying a wide range of habitats and eating a great variety of prey. Tertiary consumers necessarily occur at low

densities. In rare habitats, such as marshes in dry environments, these consumers cannot support viable populations unless they are generalists.

KEYSTONE ORGANISMS

As noted earlier, keystone organisms are consumers that feed at critical points in the food web and thus exert influence disproportionate to their abundance. These organisms are attractive targets for management because enhancing or reducing their numbers can have far-ranging effects on the ecology of a system. In this section, three groups of keystone organisms are discussed. Undoubtedly more exist in the system, but our present understanding of the system is inadequate for identification of these organisms. The three groups are muskrats, the caterpillar of the marsh moth, and the group of mammals that are efficient nest predators.

Muskrats at Cheyenne Bottoms feed almost exclusively on cattails. They clear open-water zones around their domed houses, thus greatly affecting habitat dispersion in the marsh and improving the habitat for fish, turtles, water snakes, aquatic birds, and other components of the system. Muskrat distribution at Cheyenne Bottoms seems to be limited by water depth, and modifications of the marsh such as cleaning borrow ditches or blasting potholes might greatly increase the effectiveness of the muskrats at opening the cattail stands.

The caterpillar of the marsh moth is capable of killing great quantities of cattail foliage and eats much less than it kills. This foliage kill reduces the total biomass produced per year and hence the litter production. It also reduces the stature and density of the cattail stands, altering the habitat for a great variety of vertebrates. Populations of the moth seem to be limited by a parasitic wasp, so management of the wasp populations

potentially could be effective in freeing the caterpillars to control cattails.

Three of the top predators in the system, raccoons, striped skunks, and coyotes, together are capable of being extremely effective as nest predators of waterfowl and other ground-nesting marsh birds. Their effect was not measured directly in this study, but American Avocets suffered virtually complete nesting failure that may have involved nest predation. Waterfowl also produced very few young in 1986, but that may reflect failure to nest as well as nest loss. If waterfowl production at Cheyenne Bottoms becomes a management priority, predator control may be a necessary management tool.

DISCUSSION

Cheyenne Bottoms is an enclosed basin, formerly without an outlet (the artificial outlet is small and currently rarely used). The Bottoms also is an island of wetland habitat in a sea of relatively xeric uplands. These features suggest that the Bottoms might be a relatively closed system, ideal for studies of energy and nutrient cycling. Such investigations were not a major goal of this study, but the information that can be gleaned from the study results indicates that the system is far less closed than might be expected. The migratory waterfowl and shorebirds carry substantial quantities of energy out of the system when they move to other sections of their range. The blackbirds import great quantities of nutrients into the marsh in the form of guano. Most of the top predators in the system are not limited to the marsh but also range into adjacent uplands (mink are a notable exception). Indeed, the populations of these predators may be controlled by cycles in abundance of terrestrial mammalian prey (rabbits and rodents) in the adjacent upland areas.

Ecological systems can be classified according to the degree that community composition and energy cycling are controlled by biotic versus abiotic factors. Marshes in general tend to be strongly influenced by abiotic factors, and Cheyenne Bottoms is no exception. Water availability and seasonality and winter weather play crucial roles in determining community composition and productivity. In general, systems with predominantly abiotic control mechanisms have more potential for productive management, because they have loose linkages between biotic components and thus greater reservoirs of energy and nutrients available for use. Therefore, managers have "room" to modify the systems without "ripple effects" extending as far through the system. Abiotically controlled systems also may be more susceptible to invasion by exotic organisms, because the energy and nutrient reservoirs are available to organisms that have novel ways of using them. In systems with tight biotic control, exotic organisms generally can invade only by displacing existing organisms from the resources they use. This is not to say that exotics invading an abiotically controlled system do not displace native organisms. Rather, in systems with abiotic control, invaders have more opportunity to gain a foothold.

The ecology of Cheyenne Bottoms has changed greatly since active management began in the 1950's. The emergent aquatic vegetation has changed from a diverse community featuring several species of bulrushes, grasses, and forbs, to a virtual monoculture of narrow-leaved cattails. Even in areas clear of cattails, habitat diversity is greatly reduced. Submerged aquatic plants have virtually disappeared from the Bottoms. Some of these changes are undoubtedly a result of the management practices, but some of the changes are the result of invasions by exotic organisms. Narrow-leaved cattails were virtually unknown in Kansas prior to 1950 (see Chapter 12) and were rare at

Cheyenne Bottoms as recently as 1959. This invasion of the marsh (and of the state) clearly is not a result of management practices at Cheyenne Bottoms. Cattail pollen did appear at various levels in a core sample, but this pollen is referable to the broad-leaved cattail, Typha latifolia. Submerged aquatic plants probably have never been dominant at Cheyenne Bottoms, but historically several species were common when and where water conditions were suitable. Carp, which appeared in the Bottoms coincident with management, and turbidity now probably keep these plants from ever becoming common.

Two exotic plants that have appeared in the system have the potential to become major pests. Salt cedar is a serious pest in riparian and wetland habitats throughout the Southeast and could easily become a problem at Cheyenne Bottoms. Velvet-leaf (Abutilon theophrasti), a serious agricultural pest in eastern Kansas, was first found at Cheyenne Bottoms during this study. It has the potential of dominating the terrestrial-annual communities that produce waterfowl food on the seasonally flooded areas.

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CHAPTER 19: THE ECONOMIC IMPACT OF CHEYENNE BOTTOMS ON KANSAS AND ON BARTON COUNTY

Shirley Sicilian and Carolyn Coleman

INTRODUCTION

This chapter contains the results of a study conducted by the Institute for Public Policy and Business Research (IPPBR) to determine the usage of the Cheyenne Bottoms Wildlife Management Area and the economic impact on Kansas and Barton County of this usage and of state expenditures for managing and maintaining the Bottoms. The chapter is divided into two parts. Part one contains an estimation of the type and extent of Cheyenne Bottoms uses during 1986 and their resulting primary economic impacts to the county and state along with the primary impact of fiscal 1986 state expenditures on the Bottoms. Part two reports the secondary economic impacts that accrue as the primary impact diffuses through the county and state economies. The secondary impacts are estimated using the static input-output model developed at IPPBR and adapted specifically for this project. Clearly the presence of Cheyenne Bottoms wetlands has a significant and quantifiable impact on state and regional economic vitality. Expenditures made by Cheyenne Bottoms users generate income for all sectors of the Kansas and Barton County economies.

DETERMINING THE PRIMARY IMPACT

PRIMARY IMPACT OF BOTTOMS USERS

Estimating usage.

The type and extent of activities engaged in by Cheyenne Bottoms users were determined by first separating the year into the specific wildlife seasons shown in table 19.1. Total daytime usage during spring shorebird season, an off-season fall shorebird season, and teal season was determined

using traffic counters, which were installed at each of the four entrances to the Bottoms. The traffic counters recorded the hourly total of vehicles entering and leaving the Bottoms during the four seasons. The summation of these totals for the season, divided by two, gives the total number of vehicles entering the premises for that season. We used this number to approximate the total number of Cheyenne Bottoms users, or person/days, for the season. We believe this is a good compromise number because of two offsetting factors: more than one person was likely per vehicle, which would raise the usage from the traffic counter totals, but the same vehicle was also likely to make more than one visit to the Bottoms per day, which would lower the usage from the traffic counter totals.

Table 19.1--Cheyenne Bottoms wildlife seasons.

Season	Duration
1) Spring shorebird migration	Apr. 17 - May 18
2) Off seasons	May 19 - Jul. 31,
	Sep. 21 - Oct. 1,
	Jan. 11 - Apr. 17
3) Fall shorebird migration	Aug. 1 - Sep. 12
4) Teal hunting	Sep. 13 - Sep. 21
5) Duck hunting	Oct. 25 - Nov. 2
	Nov. 8 - Dec. 7
	Dec. 24 - Jan. 1
6) Goose hunting	Nov. 1 - Jan. 11
7) Pheasant hunting	Nov. 8 - Jan. 31
8) Deer hunting (fire arm and archery)	Oct. 1 - Dec. 14

During fall shorebird season and teal season, traffic counters malfunctioned on two of the four roads leading to Cheyenne Bottoms. Usage data for the two roads during these seasons was extrapolated using contemporary data for the other two roads and past data for all four roads.

Given the total number of users, or person/days, for a season, knowing how people were using the Bottoms and the number of person/days spent on each

type of activity was desirable. For this purpose, IPPBR performed four two-day on-site surveys (appendix 19.1), one during each of the first four seasons. Two researchers attempted to hand out written surveys to everyone at the site over the survey period. The surveys asked respondents to identify the purpose of their trip by checking one (or more) of 10 possible activities listed or by writing in their activity if it was not on the list. Using these responses, we found what percent of those surveyed were engaged in each of the activities. This proportion determined how we allocated the total seasonal use, as estimated from the traffic-counter data, among the possible activities.

Since we did not survey at night, we were not able to estimate the types of activities taking place between 22:00 and 5:00. Therefore, we do not include the usage for these time periods in the total seasonal usage figures.

In the case of Cheyenne Bottoms fishing use, modifications were required in order to reduce bias in the on-site survey. Fishing use was reduced by half because fishers tend to enter the Bottoms and settle into one place where they are easily spotted and approached by the surveyors. By contrast, bird watchers and environmentalists are much more mobile within the area and are therefore harder to find and approach.

Due to the limited duration of this study, operating traffic counters during duck and goose, pheasant, and deer seasons or the remaining off-seasons was not possible. Therefore, Kansas Fish and Game Commission data were used to determine use of the Bottoms during the hunting seasons. We assumed that no birdwatching, fishing, or environmental study took place during hunting seasons. This assumption is supported by our on-site surveys during the 1986 teal season, which turned up only teal hunters. Usage for the September 21 to October 1 off season was extrapolated from the traffic counter data for the

May 15 to July 31 off-season. The composition of activities is assumed to follow the pattern established during the earlier off-season period. Usage for the January 11 to April 1 off-season was not estimated. We felt that the level and composition of use among these winter and early spring months could be sufficiently different from the summer off-season usage that projection would not be appropriate.

Total use of the Bottoms during duck and goose season was extrapolated from the 1985-86 records of permits issued at the hunter check station for use of hunting blinds. According to the area managers, total waterfowl hunting at Cheyenne Bottoms is roughly divided such that 40% of hunters use the blinds and 60% use the perimeter areas of pools 2, 3, and 4. Considerable overlap occurs between duck and goose seasons, and the 1985-86 blind use records do not distinguish between duck hunter days and goose hunter days during the overlapping periods (Kansas Fish and Game Commission, 1986). However, the 1980 Waterfowl Harvest Summary indicates that hunters generally obtain both duck and goose permits when the seasons overlap (Kansas Fish and Game Commission, 1980). Therefore, use of the Bottoms for duck and goose season was estimated as an aggregate waterfowl hunting season usage.

Pheasant hunting season usage was estimated to be the same as that determined by the Public Lands Use Survey (Kansas Fish and Game Commission, 1985). This survey contains the most recent estimates available for pheasant-hunter use of Cheyenne Bottoms.

Cheyenne Bottoms deer hunter (firearm and archery) usage statistics for 1985 from the Kansas Fish and Game Commission were employed as our estimate of deer season use (Kansas Fish and Game Commission, 1985).

With the combination of Kansas Fish and Game data from 1985 and 1986 and our own data collected during the study period, we have estimated current usage of Cheyenne Bottoms.

The data necessary to determine general past usage of the Bottoms do not exist. However, our survey results suggest that a substantial core of current users have been coming to the Bottoms for many years (figure 19.1).

Concerning expected future use, only one survey respondent answered that he did not intend to return to Cheyenne Bottoms in future years. Certainly future use depends on management of the Bottoms and environmental conditions; several respondents wrote that they intended to return to the Bottoms as long as there was water.

Table 19.2 sets out the current Cheyenne Bottoms usage data for each season. Table 19.3 shows the number of cars entering the Bottoms between 22:00 and 5:00; this usage is not included in the total seasonal usage estimates in table 19.2.

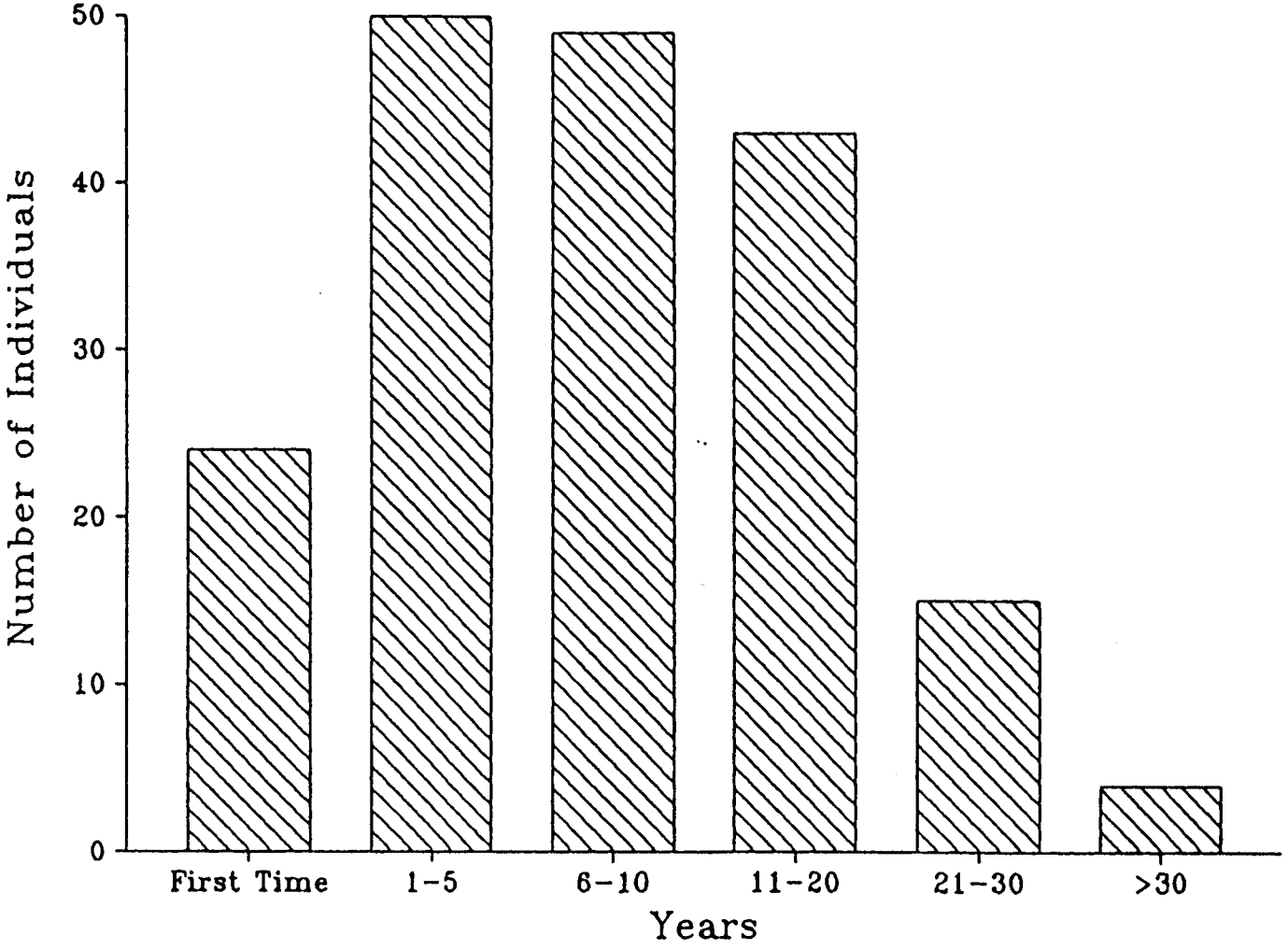

Figure 19.1 - Number of years respondent has visited Cheyenne Bottoms.

Table 19.2--Seasonal usage of Cheyenne Bottoms. Seasonal use after September 21 was estimated using existing data; other use was determined using IPPBR on-site surveys and traffic counter data.

	Number of on-site survey respondents participating	Percent of total participation	Estimated total season participation
Spring Shorebird Season: April 17-May 18			
birdwatching	20	76%	1,628
environmental study	5	20%	428
fishing	1	4%	86*
Totals	26	100%	2,142
Off-Season: May 19-July 31, Sept. 21-Oct. 1			
birdwatching	3.5	88%	5,144
fishing	0.5	12%	701*
Totals	4.0	100%	5,845
Fall Shorebird Season: Aug. 1-Sept. 12			
birdwatching	5	100%	8,796
Teal Hunting Season: Sept. 13-Sept. 21			
teal hunting	20	100%	1,911
Duck and Goose Hunting Season: Oct. 25-Jan.11			
duck and goose hunting	n.a.	n.a.	3,833
Pheasant Hunting Season: Nov. 8-Jan.31			
pheasant hunting	n.a.	n.a.	1,246
Deer Hunting Season: Oct. 1-Dec. 14			
deer hunting	n.a.	n.a.	89

* indicates adjusted total.

Table 19.3--Seasonal nighttime usage of Cheyenne Bottoms (22:00-5:00).

Season	Dates	Nighttime Usage
Spring shorebird	April 17-May 18	463
Off-season	May 19-July 31	
	Sept. 21-Oct. 1	992
Fall shorebird	Aug. 1-Sept. 12	44
Teal	Sept. 13-Sept. 21	70

Estimating expenditures.

A second objective of the four on-site surveys was to estimate average daily expenditures in Kansas and in Barton County for each type of Cheyenne Bottoms use. For this purpose, further surveys were administered at a shell-

shot ballistics seminar in Great Bend, sponsored by the Kansas Fish and Game Commission, and mailed in from the Kansas Ornithological Society newsletter. Visitors to the Cheyenne Bottoms hunter check station also completed surveys during the seasons. The surveys listed possible expenditure categories and requested respondents to write in the amount spent in each category. An "other" category was also available. The categories were formed so that expenditures would be reported in a manner compatible with the industry sectors of the IPPBR static input-output model. In tabulating the data, we divided the numerous expenditure categories into 1) travel expenditures for the trip, like food, lodging, and gasoline, and 2) equipment expenditures for long-term use, like camper-shells, guns, and cameras. For the sake of accuracy, respondents were asked to report their travel expenses for their entire trip since it was believed the total would be easier to recall than average daily expenditures.

In order to differentiate between impacts to Kansas and impacts to Barton County, we considered the origin of the Cheyenne Bottoms user when we calculated daily travel expenditure. The assumption was that users filled their gas tanks once before they left on their trips and once before they returned, so if they were not from Kansas, half of their gasoline would have been purchased outside of the state and would not be a primary impact on the Kansas economy. Likewise, when users were not from Barton County, we assumed they bought half their gas outside the county. Since over 95% of the trips to the Bottoms were for four days or less, we assumed that other travel expenditures were made in the Bottoms area. We divided the total of respondents' modified per trip travel expenditures by their reported number of days per trip to get the average daily travel expenditure in Kansas and the average daily travel expenditure in Barton County.

Long-term equipment expenditures were handled differently. We allocated only a portion of the long-term expense to Cheyenne Bottoms usage, since a person might not buy equipment solely for use at the Bottoms. We determined the proportion of the expenditures to be charged to Cheyenne Bottoms usage by asking respondents to estimate what percent of their sport activity takes place at Cheyenne Bottoms. By asking only for long-term expenses made during the past year, we avoided having to amortize a wide variety of purchases in order to determine annual expenditure. The assumption is that the sampling process would yield a valid average. Further, to put these long-term expenses on an average daily basis, we divided them by the number of days respondents reported that they spend at Cheyenne Bottoms per year.

Given an average equipment expenditure, determining how much of the spending will have a primary impact on the Kansas economy and how much will have a primary impact on the Barton County economy is still necessary.

Recognizing that most equipment is purchased near the user's home, we used survey results to determine the percent of each user group who were from Kansas and the percent who were from Barton County and allocated the primary impact of equipment purchases to Barton County and Kansas proportionately.

Table 19.4 sets out the average daily equipment and travel expenditures for all survey respondents in each user group as estimated based on IPPBR on- and off-site surveys. Table 19.4 also presents estimates of average daily expenditures for U.S. sportsmen in each user group (U.S. Department of the Interior, 1982).

Table 19.4--Average daily expenditures for each type by activity group. National survey figures are adjusted for inflation using GNP implicit price deflators. National categories are somewhat broader than IPPBR's, e.g., national figures are for all migratory bird hunters.

	Average Daily Expenditures			
	IPPBR Survey		1980 National Survey	
Activity	Travel	Equipment	Travel	Equipment
Birdwatching	$34.79	$24.92	$11.86	$ 2.05
Duck and geese hunting	20.10	20.11	10.43	7.03
Fishing	14.62	18.19	9.61	13.11
Teal hunting	23.64	18.98	10.43	7.03
Deer hunting	4.68	47.66	17.25	13.70
Pheasant hunting	27.13	16.17	11.20	9.28
Environmental study	35.09	34.90	11.86	2.05
Other	30.51	12.53	--	--

Table 19.4 shows a pattern of higher travel expenditures from the IPPBR survey than from the national survey. This is probably because across the nation many people can make afternoon outings to participate in nearby outdoor activities, but Cheyenne Bottoms is far from any major population center. Because of this fact, a higher percentage of the users must travel a considerable distance and perhaps stay overnight.

An exception to this pattern is the average daily expenditure for deer hunting. The deer hunters' average expenditures at the Bottoms were probably less than the national average because all deer hunters surveyed were from Barton County.

Our expenditure information, along with the traffic counter data collected during the three wildlife seasons and the off-season, allow us to estimate the total annual expenditures for each of these different Cheyenne Bottoms user groups. The primary economic impact of each type of activity in 1986 is the product of that activity group's total annual usage and the

activity group's average daily expenditures. The primary impact for each activity group is shown in table 19.5.

Table 19.5--Primary impacts by activity group in Kansas and Barton County.

	Primary Impact	
Activity Group	Travel	Equipment
KANSAS		
Birdwatching	$538,618	$377,812
Duck and goose hunting	75,050	73,220
Fishing	11,506	14,316
Teal hunting	40,953	34,449
Deer hunting	417	4,051
Pheasant hunting	31,187	19,145
Environmental study	14,856	8,934
Total Activity Group primary impact	$712,587	$531,927
BARTON COUNTY		
Birdwatching	$477,284	$128,911
Duck and goose hunting	62,746	21,578
Fishing	10,396	12,751
Teal hunting	33,710	10,154
Deer hunting	417	1,192
Pheasant hunting	28,072	5,643
Environmental study	13,195	5,829
Total Activity Group primary impact	$625,820	$186,058

PRIMARY IMPACT OF STATE EXPENDITURES

Determining the primary impact of the state expenditures is a relatively straightforward matter since the Kansas Fish and Game Commission provided the relevant data in sufficient detail to categorize each type of expenditure as a wage and salary expenditure or as an expenditure made in one of the 11 sectors of the model. The wages and salary expenses are in turn allocated among the 11 sectors on the basis of the average propensity of wage and salary earners to consume of each sector. The average propensity to consume for each sector is derived from actual data on income and consumption patterns by dividing

consumption for the sector by total personal income. The resulting average propensities to consume are listed in table 19.6.

Table 19.6--Average propensities to consume by sector.

Sector	Average Propensity to Consume
1) Agriculture	0.007655
2) Mining	0.0
3) Construction	0.0
4) Durable-goods manufacturing	0.078594
5) Nondurable-goods manufacturing	0.178675
6) Transportation and utilities	0.050132
7) Wholesale	0.000308
8) General merchandise stores and other retail	0.055689
9) Travel	0.088967
10) Finance, insurance and real estate	0.136506
11) Services	0.125455
Total Average Propensity to Consume	0.7220

DETERMINING THE SECONDARY IMPACT

THE INPUT-OUTPUT MODEL FOR KANSAS

The secondary effects of each user group's Cheyenne Bottoms-related expenditures were determined using an Input-Output (I-O) model. IPPBR is in the second year of a 3-year grant to develop a dynamic I-O model of Kansas. Although the model is not yet complete, enough data have been gathered to provide the basic static model necessary for this study. The I-O model is a structural description of the intricate flow of goods and services among sectors of the Kansas economy. Fundamentally, the demand for any good or service can be broken down into two parts: final demand (consumers, government, and exports) and intermediate demand, which is the use of a good or service in the production of another good or service. While the primary impact, discussed above, is the change in final demand, it is through the complex flows of intermediate demand that the secondary impacts are created.

An increase in final demand for a product increases the demand for all of the intermediate products used in its production. In the I-O model the intermediate flows are captured by using a coefficient matrix which reflects the proportion of all other goods used in the production of one good. By multiplying this coefficient matrix by total output in each sector, one gets total intermediate demand in the Kansas economy. Then by adding intermediate demand to final demand one gets total Kansas output. This basic relationship can be compactly written in matrix form. Let A be the coefficient matrix for intermediate demand, X be a column vector for total output, and D be a final-demand vector. Then

$$AX + D = X$$

using elementary matrix alegbra, one can show that

$$D = X - AX = (I-A)X$$

where I is the identity matrix. Then

$$(I-A)^{-1} D = X$$

where the minus one indicates the inverse operation. What the final equation shows is that some matrix, $(I-A)^{-1}$, multiplied by final demand gives total output. Thus a change in final demand multiplied by the same matrix will give the change in total output. The matrix $(I-A)^{-1}$ is then the matrix by which we can determine the changes in intermediate demand due to the change in final demand.

For our purposes, we need the coefficient matrix in order to develop the $(I-A)^{-1}$ matrix. A special coefficient matrix was created for this project to reflect the sectors relevant to Cheyenne Bottoms. The data used to construct IPPBR's I-O model classified the Kansas economy into 125 sectors. However, certain assumptions inherent in the model allow us to aggregate those 125 sectors into a more manageable 11 sectors. Most of the 125 sectors were

grouped together to create major fields of endeavor: agriculture; mining; construction; durable-goods manufacturing; nondurable-goods manufacturing; transportation and utilities; wholesale; finance, insurance, and real estate; and services. A travel sector was formed by grouping the individual sectors of hotels, restaurants, gas stations, and car dealerships. The general merchandise and other retail sector was kept separate to best reflect the economic effects of equipment and other retail purchases by Cheyenne Bottoms users.

Our estimate of secondary effects of Cheyenne Bottoms users' expenditures was found in a simple two step procedure. In the first step, the $(I-A)^{-1}$ matrix was multiplied by the change in final demand estimated in Part One of this chapter. The result of this operation is the total change in output in each sector of the Kansas economy due to the change in final demand. The second step is to subtract the primary effect from the total effect in each sector to give the secondary effect. The primary, secondary and total effects are listed in table 19.7.

Table 19.7--Primary, secondary, and total impacts on the Kansas economy of user and State expenditures by sector. Discrepancies are due to rounding.

USER EXPENDITURES
Birdwatching

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$132,642	$ 132,642
2. Mining	0	80,066	80,066
3. Construction	0	25,596	25,596
4. Durable-goods manufacturing	0	106,400	106,400
5. Nondurable-goods manufacturing	0	288,628	288,628
6. Transportation and utilities	0	78,215	78,215
7. Wholesale	0	8,089	8,089
8. General merchandise stores and other retail	377,812	2,895	380,707
9. Travel	538,618	24,696	563,314
10. Finance, insurance, and real estate	0	150,437	150,437
11. Services	0	87,791	87,791
Totals	$916,430	$985,455	$1,901,885

The birdwatching multiplier for the Kansas economy is 2.08.

Deer Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 412	$ 412
2. Mining	0	278	278
3. Construction	0	126	126
4. Durable-goods manufacturing	0	332	332
5. Nondurable-goods manufacturing	0	950	950
6. Transportation and utilities	0	394	394
7. Wholesale	0	41	41
8. General merchandise stores and other retail	4,051	14	4,065
9. Travel	417	103	520
10. Finance, insurance, and real estate	0	807	807
11. Services	0	477	477
Totals	$4,468	$3,934	$8,402

The deer hunting multiplier for the Kansas economy is 1.88.

Duck and Goose Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 20,175	$ 20,175
2. Mining	0	12,340	12,340
3. Construction	0	4,150	4,150
4. Durable-goods manufacturing	0	16,192	16,192
5. Nondurable-goods manufacturing	0	44,197	44,197
6. Transportation and utilities	0	12,723	12,723
7. Wholesale	0	1,318	1,318
8. General merchandise stores and other retail	73,220	468	73,688
9. Travel	75,050	3,905	78,955
10. Finance, insurance, and real estate	0	24,741	24,741
11. Services	0	14,472	14,472
Totals	$148,270	$154,681	$302,951

The duck- and goose-hunting multiplier for the Kansas economy is 2.04.

Environmental Study

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 3,536	$ 3,536
2. Mining	0	2,123	2,123
3. Construction	0	664	664
4. Durable-goods manufacturing	0	2,836	2,836
5. Nondurable-goods manufacturing	0	7,673	7,673
6. Transportation and utilities	0	2,026	2,026
7. Wholesale	0	209	209
8. General merchandise stores and other retail	8,934	76	9,010
9. Travel	14,856	648	15,504
10. Finance, insurance, and real estate	0	3,876	3,876
11. Services	0	2,260	2,260
Totals	$23,790	$25,927	$49,717

The environmental-study multiplier for the Kansas economy is 2.09.

Fishing

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 3,347	$ 3,347
2. Mining	0	2,070	2,070
3. Construction	0	724	724
4. Durable-goods manufacturing	0	2,688	2,688
5. Nondurable-goods manufacturing	0	7,374	7,374
6. Transportation and utilities	0	2,225	2,225
7. Wholesale	0	231	231
8. General merchandise stores and other retail	14,316	81	14,397
9. Travel	11,506	668	12,174
10. Finance, insurance, and real estate	0	4,361	4,361
11. Services	0	2,555	2,555
Totals	$25,822	$26,324	$52,146

The fishing multiplier for the Kansas economy is 2.02.

Teal Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 10,556	$ 10,556
2. Mining	0	6,417	6,417
3. Construction	0	2,108	2,108
4. Durable-goods manufacturing	0	8,470	8,470
5. Nondurable-goods manufacturing	0	23,052	23,052
6. Transportation and utilities	0	6,454	6,454
7. Wholesale	0	668	668
8. General-merchandising stores and other retail	34,449	238	34,687
9. Travel	40,953	2,006	42,959
10. Finance, insurance, and real estate	0	12,489	12,489
11. Services	0	7,298	7,298
Totals	$75,402	$79,756	$155,158

The teal hunting multiplier for the Kansas economy is 2.06.

Pheasant Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 7,456	$ 7,456
2. Mining	0	4,479	4,479
3. Construction	0	1,405	1,405
4. Durable-goods manufacturing	0	5,980	5,980
5. Nondurable-goods manufacturing	0	16,184	16,184
6. Transportation and utilities	0	4,287	4,287
7. Wholesale	0	443	443
8. General merchandise stores other other retail	19,145	159	19,304
9. Travel	31,187	1,369	32,556
10. Finance, insurance, and real estate	0	8,209	8,209
11. Services	0	4,786	4,786
Total	$50,332	$54,757	$105,089

The pheasant hunting multiplier for the Kansas economy is 2.09.

State Expenditures

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 576	$ 19,687	$ 20,263
2. Mining	0	12,687	12,687
3. Construction	0	3,613	3,613
4. Durable-goods manufacturing	5,910	18,108	24,018
5. Nondurable-goods manufacturing	13,436	32,382	45,818
6. Transportation and utilities	6,333	9,022	15,355
7. Wholesale	23	858	881
8. General merchandise stores and other retail	26,932	352	27,284
9. Travel	28,974	2,740	31,714
10. Finance, insurance, and real estate	10,265	15,378	25,643
11. Services	17,089	9,077	26,166
Total	$109,538	$123,904	$233,442

The state spending multiplier for the Kansas economy is 2.13.

Total Impact

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 576	$197,811	$ 198,387
2. Mining	0	120,460	120,460
3. Construction		38,385	38,385
4. Durable-goods manufacturing	5,910	161,005	166,915
5. Nondurable-goods manufacturing	13,436	420,441	433,877
6. Transportation and utilities	6,333	115,345	121,678
7. Wholesale	23	11,856	11,879
8. General merchandise stores other other retail	558,860	4,281	563,141
9. Travel	741,561	36,135	777,696
10. Finance, insurance, and real estate	10,265	220,298	230,563
11. Services	17,089	128,716	145,805
Total	$1,354,053	$1,454,734	$2,808,787

The total-impact multiplier for the Kansas Economy is 2.07.

The multiplier and average daily expenditures for user groups found above can be used to estimate the economic impacts of different numbers of users in a group, assuming the same ratio of Kansas to non-Kansas residents using the Bottoms. For example, we can compare the impacts of duck and goose hunting for a poor season, 1981-82, and for a good season, 1977-78, using hunter/days from Kansas Fish and Game Commission records. The product of hunter/days and average daily hunting expenditures from table 19.4 is the primary impact. Primary impact times the duck and goose hunting multiplier from table 19.7 yield the total impacts (table 19.8). Total impact less primary impact is the secondary impact.

Table 19.8--Estimated impacts of different waterfowl hunting opportunities on the Kansas economy.

	Number of Hunter Days	Primary Impact	Secondary Impact	Total Impact
A good waterfowl year:				
1977-78	11,675	$440,211.71	$457,820.17	$898,031.88
A poor waterfowl year:				
1981-82	2,260	$ 85,214.43	$ 88,623.01	$173,837.44

AN INPUT-OUTPUT MODEL FOR BARTON COUNTY

It is possible to adapt the Kansas model to Barton County using the location quotient method. The location quotient is a number used to compare the relative importance of an industry in one region to its relative importance in a larger region. We used Commerce Department employment data (U.S. Deptartment of Commerce, 1986), which breaks employment down into sectors for each county and the state, to compare the structure of the Barton County economy with the structure of the Kansas economy. The location quotient for industrial sector i in Barton County is defined as

$$LQ_i = \frac{E_{ib}}{E_b} - \frac{E_{iks}}{E_{ks}}$$

where

LQ_i = location quotient for industry I

E_{ib} = employment in industry i in Barton County

E_b = total employment in Barton County

E_{iks} = employment in industry i in Kansas

E_{ks} = total employment in Kansas.

This method indirectly shows the adequacy of production in the county by Kansas standards: when the quotient for a given sector equals or exceeds one, we can assume that local requirements for that sector's production are met locally, at least to the same degree that requirements for state production

are met within the state. In this case, we do not alter the Kansas model; i.e. if $LQ_i > 1$ then $a_{ij} = a_{ij}$. When the quotient is less than 1, it indicates that that sector in Barton County employs a relatively smaller proportion of workers than the comparable state sector, indicating that the county is less self-sufficient than the state and therefore will have to import more of that good from outside the county. In such a case the model must be adapted for Barton County by deriving new regional coefficients for the sector. Barton County production coefficients, a_{ij}, in row i are computed as: Barton County a_{ij} = LQ_i times Kansas a_{ij}, where Barton County coefficient, a_{ij}, equals the product of the location quotient for sector i, LQ_i times the Kansas coefficient a_{ij}, for all j's. This equation will derive all of the appropriate row coefficients for industrial sector i in the Barton County coefficient table. Table 19.9 sets out the primary, secondary, and total impacts of Cheyenne Bottoms use on Barton County.

Table 19.9--Primary, secondary, and total impacts on the Barton County economy of user and State expenditure. Discrepancies are due to rounding.

USER EXPENDITURES
Birdwatching

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 71,007	$ 71,007
2. Mining	0	41,173	41,173
3. Construction	0	12,684	12,684
4. Durable-goods manufacturing	0	44,954	44,954
5. Nondurable-goods manufacturing	0	141,719	141,719
6. Transportation and utilities	0	45,000	45,000
7. Wholesale	0	4,628	4,628
8. General merchandise stores and other retail	128,911	1,548	130,460
9. Travel	477,284	14,573	491,857
10. Finance, insurance, and real estate	0	42,772	42,772
11. Services	0	45,727	45,727
Total	$606,195	$465,784	$1,071,980

The birdwatching multiplier for the Barton County economy is 1.77.

Deer Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 121	$ 121
2. Mining	0	80	80
3. Construction	0	35	35
4. Durable-goods manufacturing	0	77	77
5. Nondurable-goods manufacturing	0	258	258
6. Transportation and utilities	0	127	127
7. Wholesale	0	13	13
8. General merchandise stores and other retail	1,192	4	1,196
9. Travel	417	33	450
10. Finance, insurance, and real estate	0	129	129
11. Services	0	140	140
Total	$1,609	$1,017	$2,626

The deer hunting multiplier for the Barton County economy is 1.63.

Duck and Goose Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 9,586	$ 9,586
2. Mining	0	5,601	5,601
3. Construction	0	1,768	1,768
4. Durable-goods manufacturing	0	6,070	6,070
5. Nondurable-goods manufacturing	0	19,206	19,206
6. Transportation and utilities	0	6,294	6,294
7. Wholesale	0	648	648
8. General merchandise stores and other retail	21,578	216	21,794
9. Travel	62,746	2,004	64,750
10. Finance, insurance, and real estate	0	6,015	6,015
11. Services	0	6,442	6,442
Total	$84,324	$63,850	$148,174

The duck and goose hunting multiplier for the Barton County economy is 1.76.

Environmental Study

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 2,086	$ 2,086
2. Mining	0	1,230	1,230
3. Construction	0	400	400
4. Durable-goods manufacturing	0	1,321	1,321
5. Nondurable-goods manufacturing	0	4,199	4,199
6. Transportation and utilities	0	1,429	1,429
7. Wholesale	0	147	147
8. General merchandise stores and other retail	5,829	49	5,878
9. Travel	13,195	446	13,641
10. Finance, insurance, and real estate	0	1,374	1,374
11. Services	0	1,475	1,475
Total	$19,024	$14,156	$33,180

The environmental study multiplier for the Barton County economy is 1.74.

Fishing

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 2,086	$ 2,086
2. Mining	0	1,300	1,300
3. Construction	0	493	493
4. Durable-goods manufacturing	0	1,323	1,323
5. Nondurable-goods manufacturing	0	4,322	4,322
6. Transportation and utilities	0	1,792	1,792
7. Wholesale	0	185	185
8. General merchandise stores and other retail	12,751	59	12,811
9. Travel	10,396	506	10,902
10. Finance, insurance, and real estate	0	1,773	1,773
11. Services	0	1,921	1,921
Total	$23,147	$15,759	$38,906

The fishing multiplier for the Barton County economy is 1.68.

Teal Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 5,072	$ 5,072
2. Mining	0	2,951	2,951
3. Construction	0	919	919
4. Durable-goods manufacturing	0	3,211	3,211
5. Nondurable-goods manufacturing	0	10,139	10,139
6. Transportation and utilities	0	3,264	3,264
7. Wholesale	0	336	336
8. General merchandise stores and other retail	10,154	112	10,266
9. Travel	33,710	1,049	34,759
10. Finance, insurance, and real estate	0	3,109	3,110
11. Services	0	3,327	3,327
Total	$43,864	$33,490	$77,355

The teal hunting multiplier for the Barton County economy is 1.76.

Pheasant Hunting

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 0	$ 4,071	$ 4,071
2. Mining	0	2,343	2,343
3. Construction	0	704	704
4. Durable-goods manufacturing	0	2,577	2,577
5. Nondurable-goods manufacturing	0	8,095	8,095
6. Transportation and utilities	0	2,488	2,488
7. Wholesale	0	256	256
8. General merchandise stores and other retail	5,643	86	5,729
9. Travel	28,072	820	28,893
10. Finance, insurance, and real estate	0	2,351	2,351
11. Services	0	2,509	2,509
Total	$33,715	$26,301	$60,017

The pheasant hunting multiplier for the Barton County economy is 1.78.

State Expenditure

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 576	$ 15,164	$ 15,740
2. Mining	0	9,927	9,927
3. Construction	0	2,944	2,944
4. Durable-goods manufacturing	5,910	10,532	16,442
5. Nondurable-goods manufacturing	13,436	21,059	34,495
6. Transportation and utilities	6,333	8,030	14,363
7. Wholesale	23	754	777
8. General merchandise stores and other retail	26,932	288	27,220
9. Travel	28,974	2,295	31,269
10. Finance, insurance, and real estate	10,265	6,888	17,153
11. Services	17,089	7,488	24,577
Total	$109,538	$85,369	$194,907

The state spending multiplier for the Barton County economy is 1.78.

Total Impact

Sector	Primary Impact	Secondary Impact	Total Impact
1. Agriculture	$ 576	$109,193	$ 109,769
2. Mining	0	64,604	64,604
3. Construction	0	19,945	19,945
4. Durable-goods manufacturing	5,910	70,064	75,974
5. Nondurable-goods manufacturing	13,436	208,997	222,433
6. Transportation and utilities	6,333	68,425	74,758
7. Wholesale	23	6,965	6,988
8. General merchandise stores and other retail	212,991	2,362	215,353
9. Travel	654,795	21,726	676,521
10. Finance, insurance, and real estate	10,265	64,412	74,677
11. Services	17,089	69,030	86,119
Total	$921,418	$705,723	$1,627,141

The Cheyenne Bottoms multiplier for the Barton County economy is 1.77.

ECONOMIC IMPORTANCE OF TRAPPING

Existing information on the trapping of furbearers at CBWMA does not lend itself to a complete analysis. However, trapping activities over the years at Cheyenne Bottoms merit some discussion.

Furbearer populations, fur-market prices, and condition of the marsh (e.g., wet year) are some of the factors affecting trapping intensity and use at CBWMA. An examination of table 17.2 in Chapter 17 shows how trapping activities fluctuate at this marsh under existing conditions. Wet marsh conditions occurred during the 1976-78 period and were reflected, in part, by the high trapping success for muskrat, mink, and raccoon. Conversely, marsh conditions in dry years (e.g., 1984 and 1985) negatively impact trapping success.

Data obtained from the Kansas Fish and Game Commission and CBWMA management personnel also show that annual trapping activities at this area are highly erratic. Information for the 1977-78 through 1983-84 trapping seasons indicate that the mean number of trappers utilizing the Bottoms area was 28. However, trapper numbers and calculated man/days of use varied greatly. The number of trappers using the marsh during this 7-year period ranged from a seasonal low of six to an all time high of 52. Trapping use in man/days for this same period varied from a low of 150 to a high of 1,300 (pers. comm., Darrell Montei-KFG, 1986).

Individual income estimates for trappers at the Bottoms were calculated from seasonal harvest data and the concurrent market values associated with each species. Trapper income in dollar values ranged from $279 to $6,475, while the mean income for the seven-season period was $3,142. Unfortunately expenditure data for trapping activities at CBWMA are not available, and the

overall economic impact of this activity on the Kansas or Barton County economy are not quantifiable.

COSTS AND BENEFITS

These figures represent the economic impact of the Bottoms on Kansas and Barton County. This type of analysis shows, given the structure of the Kansas and Barton County economies, what a dollar of expenditures in a given sector will generate in terms of financial wealth for the county and state. An impact study acknowledges that state expenditures, which could in another type of analysis be viewed as a cost of operating the Bottoms, generate wealth for society. Clearly the issues relating to the maintenance and continuing existence of Cheyenne Bottoms could be seen in terms of costs and benefits to society rather than in terms of the financial impacts of Bottoms-related expenditures. Other investigators, people from Kansas Fish and Game Commission, from the Great Bend Chamber of Commerce, and from the Bottoms vicinity suggested the following possible costs and benefits of Cheyenne Bottoms:

Costs of Cheyenne Bottoms:

* Opportunity loss--some wetlands can be drained and plowed
* Flood control--eliminates redeposition of topsoil
* Habitat for nuisance plants and wildlife
* Diminished tax base--state-owned land is not taxed
* Difficulties of farming on acreage interrupted by Cheyenne Bottoms

Benefits of Cheyenne Bottoms:

* Flood control--potential for water diversion, storage and controlled release
* Water quality control--wetlands allow contaminants to settle out
* Maintenance of connecting road system
* Hunting and related consumptive use opportunities

* Gene pool maintenance--unique wildlife habitat contributes to genetic diversity
* Aesthetic enjoyment and other nonconsumptive uses
* Retention and attraction of tourist dollars for the state
* Site for scientific research and instruction
* Forage and wildlife production
* Habitat for migratory waterfowl including endangered and threatened species
* Preservation of a diminishing national and state natural resource.
* Enhanced hunting opportunities on surrounding private lands.

CONCLUSION

A large part of the total impact of Cheyenne Bottoms derives from expenditures of birdwatching, which is by far the most popular activity at the Bottoms. Since the primary impacts for all usage activities are confined to the retail and travel sectors, the secondary impacts of the uses are a reflection of how these sectors interface with the Kansas economy. A relatively large percentage of the inputs to retail and travel sector products comes from the agriculture; durable-goods manufacturing; nondurable-goods manufacturing; and finance, insurance, and real estate sectors. Therefore, the secondary impacts from increased demand in the travel and retail sectors are greatest in those four sectors. Since birdwatching is the predominant use, when we look at the total economic impact of Cheyenne Bottoms, we also find large secondary impacts in these four sectors.

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_____, 1980, Cheyenne Bottoms Wildlife Area 1980 waterfowl harvest summary: Kansas Fish and Game Commission.

U.S. Department of Commerce, 1986, County business patterns 1984--Kansas: U.S. Department of Commerce, Bureau of the Census.

U.S. Department of the Interior, 1982, 1980 national survey of fishing, hunting, and wildlife-associated recreation: U.S. Department of the Interior, Fish and Wildlife Service.

Appendix 19.1

SURVEY

This survey was prepared by the Institute for Public Policy and Business Research to help in identifying the uses of Cheyenne Bottoms and to help in estimating the economic impact of Cheyenne Bottoms on the state and the region. To assure that all answers remain anonymous, please do not write your name on this survey.

1. What is the purpose of your visit to Cheyenne Bottoms?
   A. ___ hunt ducks
   B. ___ fish
   C. ___ trap
   D. ___ collect bait
   E. ___ hunt teal
   F. ___ hunt deer
   G. ___ hunt quail
   H. ___ hunt pheasant
   I. ___ bird watching
   J. ___ environmental study
   K. ___ other (please specify: _____)

2. About how much of your total time spent on the activities that you checked above is spent at Cheyenne Bottoms? (Please give a percentage)_____

3. Where are you from?
   A. City_____ B. County_____ C. State_____

4. How did you get to Cheyenne Bottoms?
   A. ___ car
   B. ___ bus
   C. ___ airplane
   D. ___ other (please specify: _____)

5. For how long will you be visiting Cheyenne Bottoms?
   Days_____

6. A. Have you come to Cheyenne Bottoms in past years for the purposes that you checked in question one?
   ___ Yes
   ___ No

   If yes,
   B. For approximately how many years have you come?_____
   C. Approximately how many trips per year do you make?_____

7. Do you expect to return to Cheyenne Bottoms in future years for the same purpose?
   ___ Yes
   ___ No

8. What were your approximate expenditures in preparing for and making this trip to Cheyenne Bottoms?

Type of Expenditure	Approximate Amount Spent
A. Hotels and Motels	_____
B. Eating and Drinking Places	_____
C. Entertainment	_____
D. Food, Drug and Liquor Stores	_____
E. Gas Stations	_____
F. Ammunition	_____
G. Film Developing	_____
H. Other (please specify)	
1) _____	_____
2) _____	_____
3) _____	_____
4) _____	_____

9. Did you make some purchases this year that were used in part for your purposes at Cheyenne Bottoms?

Type of Expenditure	Approximate Amount Spent
A. Auto and/or Truck Parts	_____
B. Camper and/or Trailer	_____
C. Tent	_____
D. Special Clothing	_____
E. Camping Equipment	_____
F. Guns	_____
G. Camera	_____
H. Other (please specify)	
1) _____	_____
2) _____	_____
3) _____	_____
4) _____	_____

CHAPTER 20: ENGINEERING ASSESSMENT

Dave Parr

This chapter will consider the current condition of Cheyenne Bottoms relative to the effective storage and transfer of water and to the stability of dikes. In discussing these items, methods for improvement will be presented qualitatively in this section and quantitatively in the next chapter.

TRANSFER OF WATER BETWEEN POOLS

The principal method for water transfer between pools at the Bottoms is by gravity flow through concrete channels with gated outlets. Unfortunately, the bottom elevation of the channels was designed and constructed at the original elevation of the borrow ditches which were at a lower elevation than the natural bottoms of the pools. Consequently, siltation rapidly filled the open-channel approaches and drastically reduced the rate of water conveyance by blocking the outlets. The desired two-week period allotted for draining pools 3, 4, and 5 into Pool 1 cannot be met. A further problem exists because the borrow pits also have filled with silt and do not serve as effective channel components in the drainage of pools as initially intended. This siltation of borrow ditches also creates a problem in the transfer of water from pools 3 and 4 to Pool 1 through the pumping station since the drainage from the perimeter pools is too slow to keep up with the pumps. Consequently, the pumps cannot be operated continuously at full capacity since the inlet "goes dry."

Methods for alleviating the problems and augmenting the transfer capability at the Bottoms include:

1. Construction of new gated outlets with bottom elevations equal to the natural bottom of the pools.
2. Purchase of portable pumps to supplement gravity flow and the existing forced (pumped)-transfer components.
3. Adoption of a continual-maintenance program to keep outlet channels and borrow ditches clean.

WATER STORAGE

In the hydrology portion of this study, it was determined that on the order of 95% of the water supply to the Bottoms is lost to evapotranspiration. Consequently, storage methods designed to minimize evapotranspiration stand to significantly increase the amount of water that can be used for management.

The rate at which water is lost to evaporation is proportional to surface area. Therefore, for a fixed volume of water stored on a flat surface, doubling the water depth while halving the surface area halves the rate of evaporation. Although transpiration doesn't exactly follow this proportionality, since the principle component of evapotranspiration at the Bottoms is evaporation, deep-water storage can result in considerable reductions in water loss.

Currently Pool 1 serves as a single 3,300-acre storage pool. In dry periods this pool is far too large to fill, and low-depth/high-evaporation storage is dictated. Even during wet periods storing water in Pool 1 to the design depth of 4.5 feet is not recommended due to the potential failure of the unprotected dikes by water-wave erosion. Given the typical water supply

to the Bottoms, Pool 1 is not an ideal storage area during dry, wet, or even normal periods. The perimeter pools also are too large to be efficiently managed given the current and projected water-supply scenarios.

Deep-water storage can be achieved by partioning Pool 1 into smaller pools by diking if rip-rap is used for dike protection. Although rip-rap is quite expensive, it is necessary to ensure the integrity of the dikes and to adopt a management scheme based on deep-water storage.

Pumping will be necessary at times to fill the central storage pools with water from perimeter pools and the inlet canal. Raising the dike elevations and/or lowering the bottom elevations of the storage pools would increase the allowable-storage depth and further decrease evaporation rates.

WAVE PROTECTION

Historically and according to a 1961 study by Appel, Jones, and Yu, wave protection is needed for the interior of Pool 1 dikes if water is to be safely stored at the design depth of 4.5 feet. While various methods exist for providing erosion protection from waves (see the 1961 study) dumped rip-rap is considered superior for most cases. Table 17 of the book Design of Small Dams by the Bureau of Reclamation (1960) shows that for fetch lengths of 2.5 miles, the nominal thickness of dumped rip-rap on 3 to 1 slopes is 2 feet. The gradations of stones are 25% greater than 600 pounds, 45 to 75% from 30 to 600 pounds, and 25% less than 30 pounds. Using a bulk specific weight of 110 pound/foot^3, it would require about 13,800 tons per mile to protect one 3 to 1 side of a 7.5-foot-high dike. Therefore a 10.5-foot-high dike would require approximately 19,300 tons per mile.

SITE SURVEY

An engineering company (Landplan Engineering of Lawrence, Kansas) was hired to perform a sparse survey of the Bottoms in order to determine the stage versus storage capacity relationships for each of the pools and the extent of siltation. To date, the elevations of all the dikes have been measured, but high water elevations have prevented the completion of the pool measurements. The work will be done when conditions are suitable.

FLOOD CONTROL

The inherently poor design of the gravity-flow outlets from the perimeter pools to Pool 1 requires that additional outlets be constructed if significant improvements are to be made in moving floodwater through the Bottoms. In addition, improvements in the outlet canal should be made to increase its capacity. Since the flatness of the area in and around Cheyenne Bottoms does not, nor has it ever, facilitated the rapid conveyance of floodwaters these changes will not insure that flooding problems will be alleviated.

REFERENCES

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CHAPTER 21: OPTIONS FOR IMPROVING FACILITIES AND MANAGEMENT

Leigh Fredrickson, Wayne Hoffman, Donald G. Huggins, Thomas McClain, David Parr and Lynn Vogler

INTRODUCTION

This chapter attempts to identify and describe various approaches that might be utilized in the decision making process regarding the enhancement and maintenance of Cheyenne Bottoms Wildlife Management Area (CBWMA) as a natural resource of state and national importance. The majority of this report is dedicated to the establishment of an environmental data base necessary to develop viable and rational responses to the problems facing the Cheyenne Bottoms Wildlife Management Area. During the course of this study, existing environmental information was gathered, while new studies were initiated to supplement or enhance existing data and to fill data gaps identified during this study period. An integration process (figure 21.1) was utilized by the interdisciplinary study group to help direct the input of information from the various areas of concern toward the development of management goals and actions necessary to address these goals. Development of the individual actions (termed modules because of their "building block" characteristics) included identification, formulation, and evaluation as to their potential in addressing specific problems associated with present management and maintenance of the marsh. The actions which appeared more viable were then integrated into an engineering appraisal phase in which possible physical alterations or changes were evaluated and initial cost estimates were made. This integration process resulted in the development of a series of options that exemplify various combinations of managerial and physical actions. These options should serve as examples to help the Kansas Fish and Game Commission formulate its own courses of action to address the current problems at Cheyenne Bottoms. It should be noted that, although each module/action can be implemented individually (and probably have some beneficial impact),

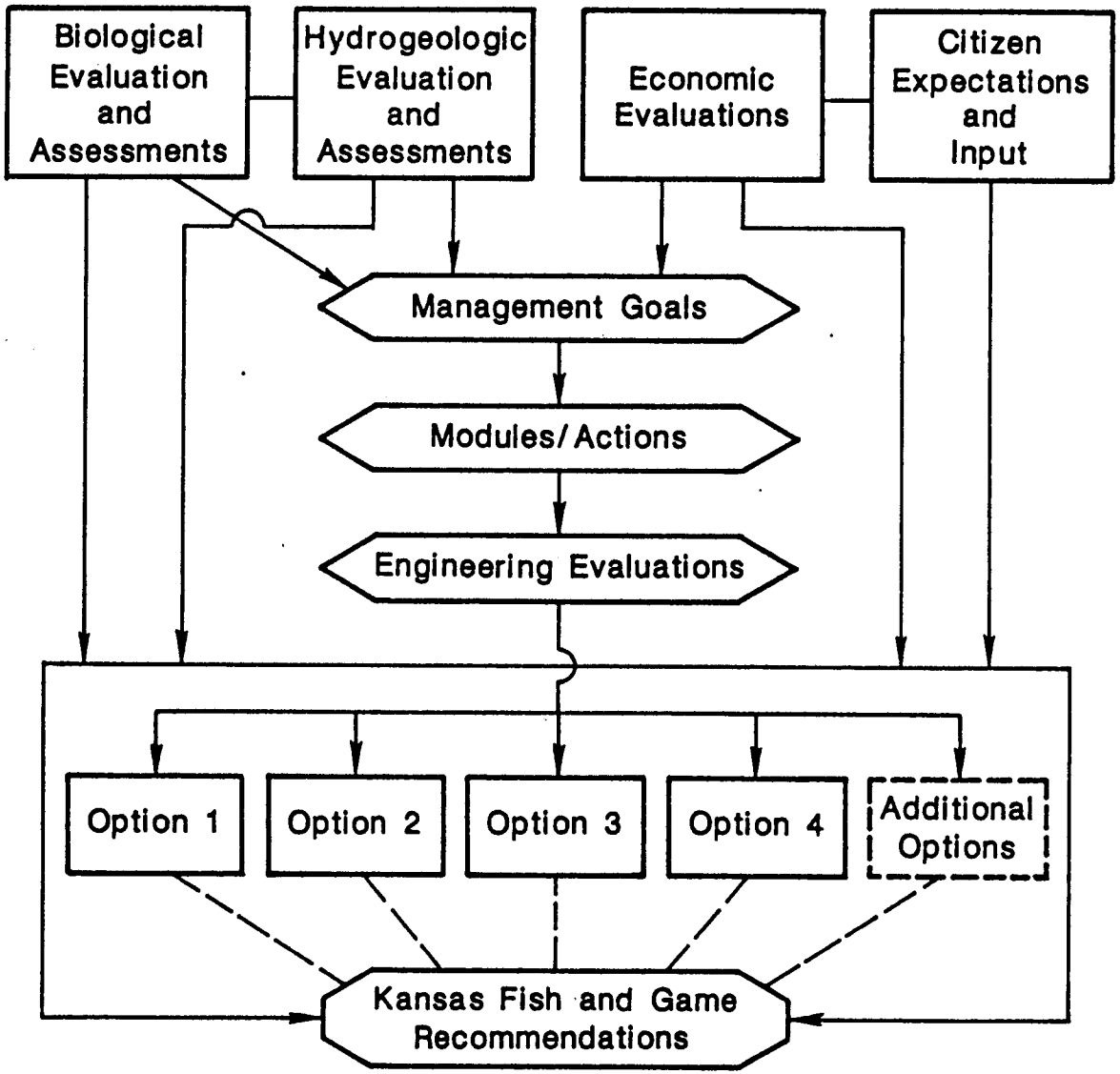


Figure 21.1 - The integration process and information flow.

additional benefits can be realized by the enhanced interactions from combining several modules (as exemplified by these options). Public input was integrated into the evaluation process (figure 21.1) in a number of ways. At various points in the investigation, study personnel worked closely with members of the Cheyenne Bottoms Task Force, a private organization responsible, in part, for the initiation of this study. Members of this task force included but were not limited to the Kansas Wildlife Federation, Wildlife Society, Northern Flint Hills Audubon Society, Kansas Audubon Council, Kansas Ducks Unlimited Council, Kansas Natural Resource Council, Kansas Ornithological Society, Nongame Wildlife Advisory Council, Kansas Chapter of the Sierra Club, and Kansas Chapter of the American Fisheries Society. A final meeting to discuss the study group's findings was held in Moore Hall at the University of Kansas, Lawrence, Kansas, on December 16, 1986 (see appendix 21.1 for roster). Wherever possible, their concerns, comments, and specific needs were incorporated into the study plan or addressed in the integration process of this study. In addition, an open public meeting was held in the Fine Arts Building at Barton County Community College on November 22, 1986. Initial study findings were presented and a public comment and question period was held at the end of the presentation (see appendix 21.2 for meeting agenda and public comment).

This study was designed to investigate as fully as possible the functioning of this wetland system. An interdisciplinary approach was adopted that considered the biotic and abiotic components as well as those human factors that have or could have an impact on the Bottoms. The individual actions, combined actions (options), and supportive assessments of these proposed activities are based on the data presented in this report, public input, and the collective professional judgment and experience of both

individual contributors and the options committee. The options committee was responsible for integrating all aspects of this study into definable and potential answers to existing problems facing this Kansas resource. Committee membership was composed of the following individuals and disciplines: Donald Huggins (Chairman), aquatic ecologist; Dr. Wayne Hoffman, ornithologist; Thomas McClain, hydrologist; Dr. Leigh Fredrickson, wetland ecologist; Lynn Vogler, hydrologist; Dr. David Parr, civil engineer; and Shirley Sicilian, research economist. This committee was guided by the desire to present options that were both realistic and defensible, and illustrative of the various levels of development and cost. Determination of the final courses of action will depend not only on the provision of timely and essential data, but also on the establishment of clear long-term objectives regarding the role and function of Cheyenne Bottoms. Any physical alterations and/or management procedures that are ultimately adopted and employed must be in accord with long-term objectives and functional ideologies. It was not (nor should have been) the charge of this study group to develop those objectives or dictate future long-term management plans for CBWMA. However, based on the information available to this study group, specific management goals were developed so that appropriate and meaningful assessments could be made for proposed alternatives and options.

DEVELOPMENT OF MANAGEMENT GOALS

The cyclic nature of precipitation in Barton County and the dependence of Cheyenne Bottoms Wildlife Management Area on rainfall within the 154,000-acre drainage basin indicate that water levels within the management area will fluctuate dramatically between wet and dry cycles. Such natural fluctuations maintain the productivity of marsh systems because of changes in vegetation structure as well as the production and availability of invertebrate and plant

foods. Likewise, vertebrate populations fluctuate seasonally and among years in a healthy marsh system as food and cover conditions change. As wetland habitats throughout Kansas and the Central Flyway have been lost or degraded, the importance of managed wetland areas has increased tremendously because they offer sites where wetland species can meet their needs on an annual basis. Thus, implementation of management actions to assure the availability of wetland resources throughout the wet and dry cycles is essential to maintain continental populations of migratory species with wetlands needs. The management goals for CBWMA are geared to assure the production and availability of food and cover for wetland wildlife annually, but particularly during the drier portion of the precipitation cycle. This need to provide habitats and resources during dry periods was recognized as early as the 1940's and the Arkansas River and Walnut Creek were identified as potential sources of water during the dry years. Modification of the marsh system resulted in the current configuration of the CBMA system, which included construction of the diversion structure on the Arkansas River, the 22-mile inlet canal, a diversion structure on Walnut Creek, the construction of a levee and water-control system resulting in five pools, and an outlet system. Despite structural limitations of the system (e.g., decreased storage capacities due to increased dike erosion at high storage levels), the modifications were successful in enhancing the wetland values of Cheyenne Bottoms. Thereafter, as the flows of the Arkansas River and Walnut Creek diminished, the potential to provide water during the dry portion of the annual and long-term water cycles was reduced to such a low level that the reliability of the water supply was no longer sufficient to provide management benefits. The major changes in water use and flow in the Arkansas River and Walnut Creek drainages no longer make these sources of water of sufficient

reliability for wetland management purposes. Thus the problem of enhancing marsh values for wildlife use and wetland recreation during the dry portion of the annual and long-term water cycles led to the need for this study. This chapter will identify biological and recreational goals in order to focus on the range of management actions and/or options that will once again enhance wetland productivity even though the Arkansas River and Walnut Creek drainage no longer represent sustained, dependable sources of water for the area.

MANAGEMENT GOALS

Biological and recreational goals are proposed as a means to identify management actions that will meet the needs of the wildlife populations and provide recreational benefits for Kansas. The development of management goals for wetland systems requires an understanding of abiotic and biotic components and a historical record of variability among these components. The quality and quantity of historical information available for Cheyenne Bottoms is highly variable. The best historical perspectives include information on birds in the biotic arena, and for weather (precipitation and temperature), Arkansas River discharge, and ground water supplies among the abiotic components. This study was designed to fill some critical data gaps among the biotic and abiotic components in order to identify limiting factors and to establish realistic goals. Interest in Cheyenne Bottoms is largely related to bird populations (e.g., hunting and other recreational uses). Thus the development of goals is centered around species that are important because of 1) their numbers, 2) endangered-species status, 3) energetic influence on the marsh system, or 4) recreational value. In many cases, selection of management goals and development of alternatives required use of professional judgment because data bases were lacking or were of insufficient quantity or quality. The time period for field investigations and subsequent analysis of

information was limited by the time constraints of the study. Likewise, data that were collected are relative to the rainfall cycle during the course of the study and may not necessarily reflect conditions throughout the long-term precipitation cycle. The following management goals were formulated for the most part from the data contained in this report and reflect the study group's interpretation of this information. It was never our intention nor prerogative to develop a well-defined management plan to attain these goals. As already stated, these goals were established to provide a "benchmark" from which various assessments could be made.

Management Goals for Cheyenne Bottoms

- Provide 4 million pounds of seed crops and minimally 5,000 acres of seasonally flooded habitat for waterfowl.
- Provide a minimum of 3,000 acres of shallow open water and mudflat habitat for shorebird feeding.
- Maintain species diversity and habitat diversity for a healthy marsh system.
- Provide increased opportunity for quality waterfowl hunting.
- Provide increased recreational opportunities and access for birdwatchers and other users.

It should be noted that the first two management goals were established with respect to waterfowl and shorebird use experienced in 1985 at Cheyenne Bottoms. These values were determined based on 1985 field data, available literature, and best professional judgment (see Chapter 16). Kansas Fish and Game target populations for the Bottoms call for a waterfowl population of 240,000. Higher projected waterfowl and shorebird populations, however, may never be experienced at Cheyenne Bottoms, since North American populations have been declining due to reduced habitat in both northern breeding grounds and southern wintering areas. Management goals such as these serve as

benchmarks that should be strived for, not necessarily reached. Failure to attain these goals does not imply failure of this or any other management scheme.

These management goals represent the ideal situation to assure adequate nutrition for the approximately 100,000 waterfowl that used Cheyenne Bottoms in 1985, assuming that these birds obtained 100% of their food within the mangement area. However, it can safely be assumed that about half of total seed and browse needs might be supplied by the surrounding agricultural lands (pers. comm., Dr. Leigh Fredrickson, 1986). Under this assumption, then, Cheyenne Bottoms could accommodate approximately 200,000 ducks and 40,000 geese, provided that about 500 acres are irrigated for especially high productivity yields (see table 21.1)

Table 21.1-Small grain production estimates for CBWMA based on generalized productivity rates for small grains grown under similar conditions (pers. comm., Dr. Leigh Fredrickson, 1986).

	Wet[a]		Dry[b]	
	productivity rate	total productivity	productivity rate	total productivity
500 acres (irrigated)	2000 lbs/acre	1,000,000 lbs	1500 lbs/acre	750,000 lbs
4500 acres (non-irrigated)	800 lbs/acre	3,600,000 lbs	300 lbs/acre	1,350,000 lbs
Total		4,600,000 lbs		2,100,000 lbs

[a]Wet = water supply for management during the wetter portion of the long term water cycle.
[b]Dry = water supply for management during the dryer portion of the long term water cycle.

MODULES OR ACTIONS

The following modules/actions are considered to be the smallest units of action that can be implemented toward helping achieve specific management goals. Categorically and in an elemental physical sense they attempt to

enhance: 1) external water supplies; 2) internal water storage; 3) internal water use or management; and/or 4) management potential. The first six modules (1-6) are directed toward increasing the amount of management water available to the marsh from external surface water or ground water sources. Modules 7 through 14 call for configuration changes within the management area to help achieve better storage potential, water manipulation, and management potential. The last modules address equipment purchases for marsh management and maintenance.

Module 1--Inlet-Canal Reservoir. A reservoir was considered for placement in the inlet canal system between the Walnut Creek diversion dam and Cheyenne Bottoms. It would be located immediately upstream of the drop structure, 1 mile west of the CBWMA headquarters facilities (figure 21.2). The reservoir would be formed by constructing an earthfill dam across the valley that the canal occupies. Two different dams were considered (figure 21.3). The respective storage volumes for the reservoirs created by dams 1 and 2 (to the maximum surface elevation of 1,860 feet) are 470 and 640 acre-feet as shown by storage versus stage curves (figure 21.4). The dam length and estimated volume of fill needed to construct the small dam (dam 1) is 1,300 feet and 49,000 cubic yards while an 1,800-foot dam of 135,000 cubic yards of fill would be required for the larger reservoir dam (dam 2). At $1 per cubic yard, the estimated earthwork costs for dams 1 and 2 are about $49,000 and $135,000 respectively. In addition, each dam would require a water control structure with an estimated cost of $100,000 and riprapping at costs of $66,000 and $92,000 for dams 1 and 2, respectively. Land purchases would be necessary to site the proposed reservoirs. The cost estimate presented in table 21.2 was based on costs associated with the larger of the two dams (dam 2) and does not include land purchase costs.

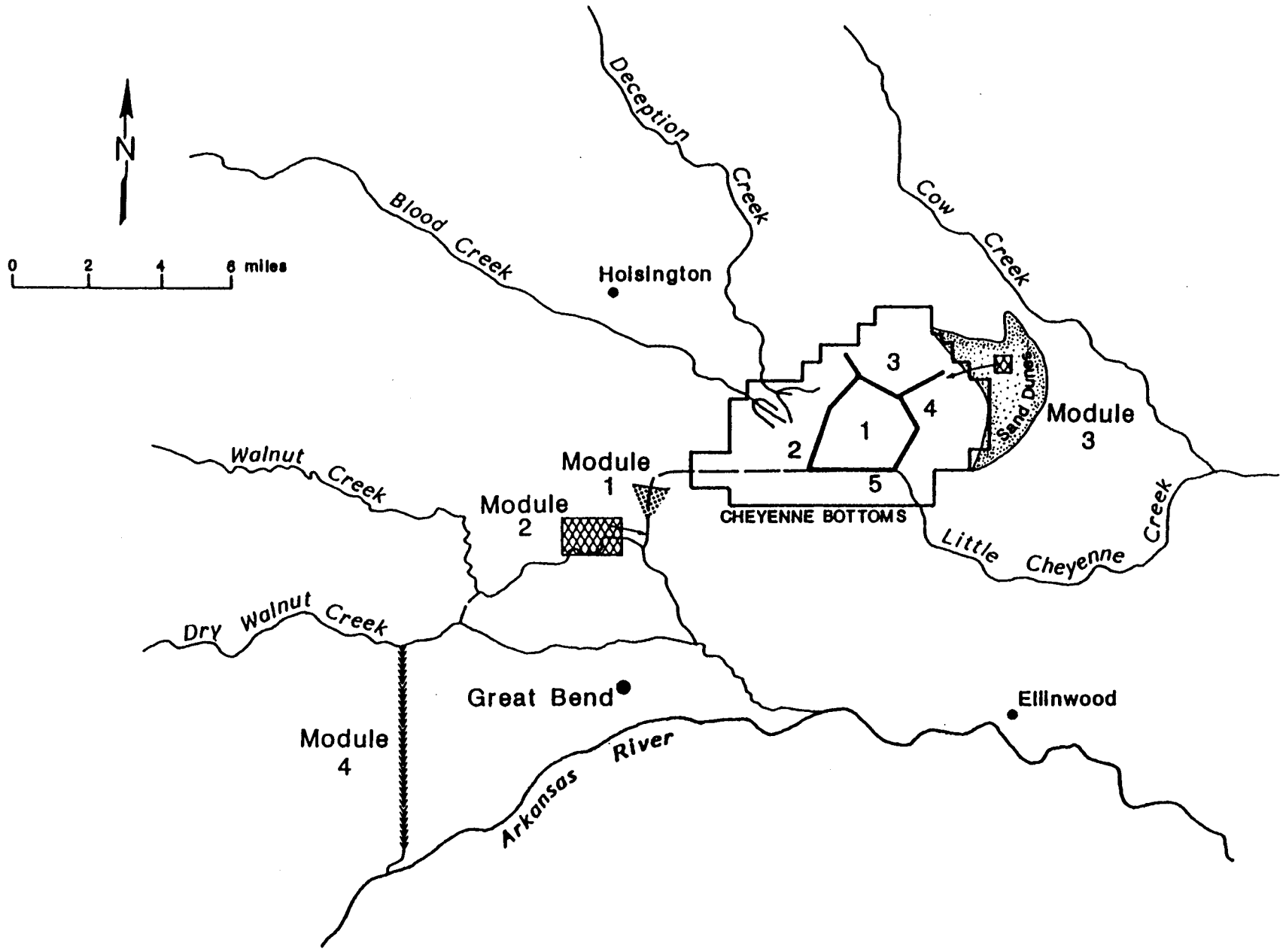


Figure 21.2 - The Cheyenne Bottoms regional area with the approximate locations of Modules 1-4.

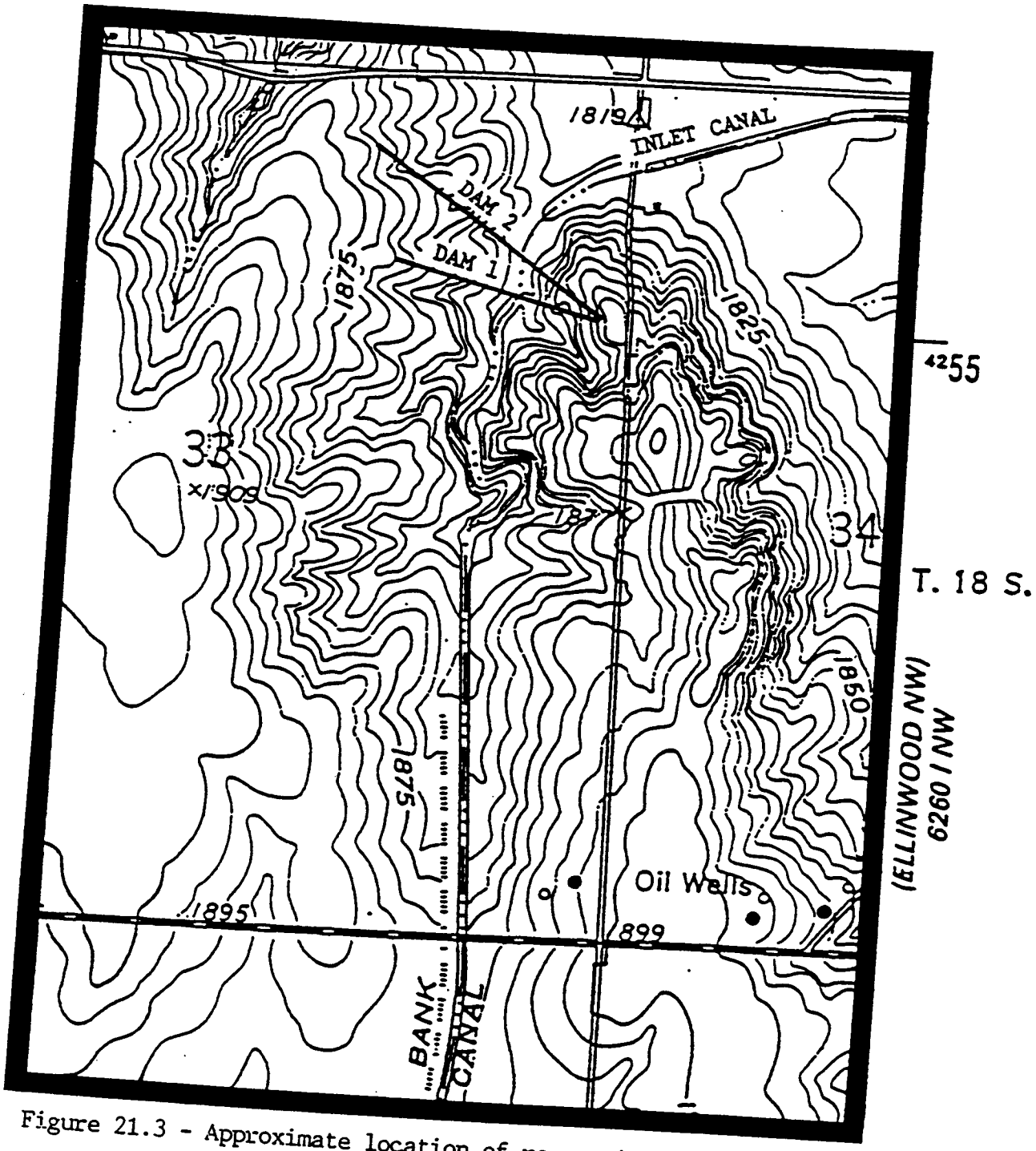


Figure 21.3 - Approximate location of reservoir dam sites proposed in Module 1. The location is within Township 18 South, Range 13 West.

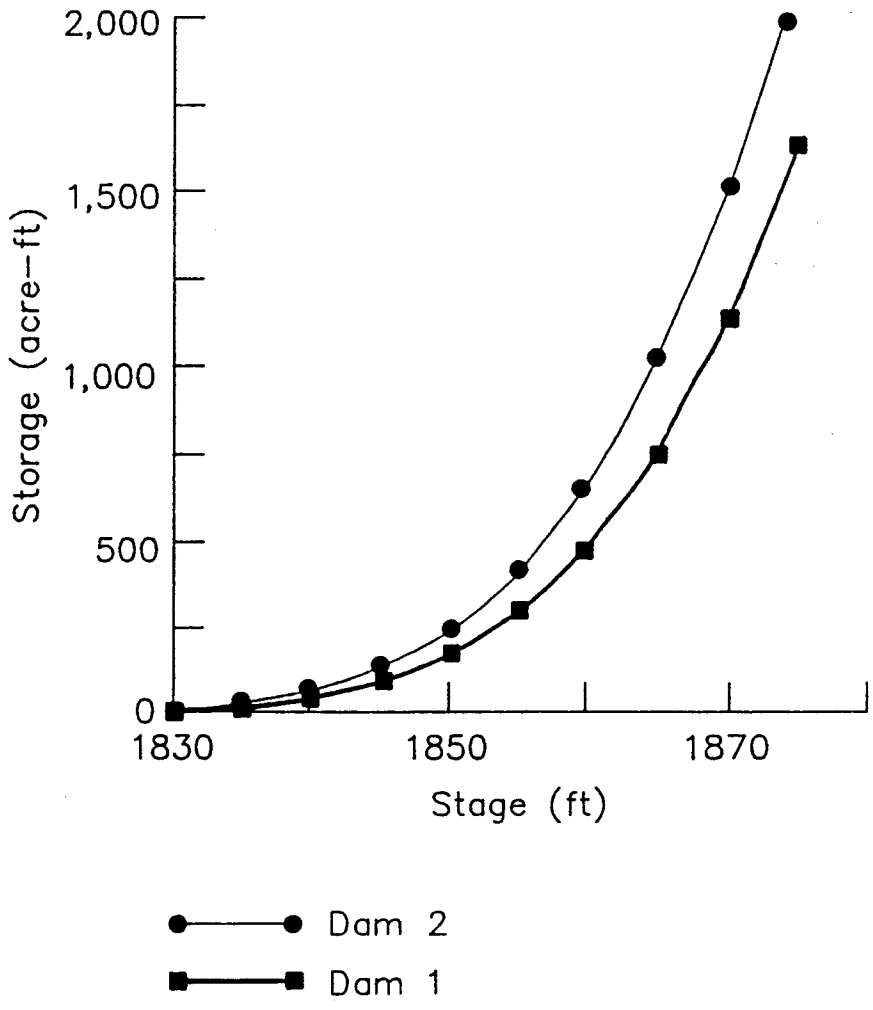


Figure 21.4 Stage vs. Storage for Proposed Module 1 Reservoirs

Table 21.2. Economic considerations and assessments of proposed modules.

Action/ Module	Economic Considerations			Engineering Assessment			Management Benefit Assessment			
	Purchase and/or Construction Cost	Operation & Maintenance Cost/yr	Longevity Year	Performance	Reliability	Implement-ability	Water Storage	Water Supply	Water Manipulation Capability	Vegetation Management
1. Inlet Reservoir	327,000[a]	2,000	50	moderate	moderate	good	+	0	+	0
2. W. Walnut well field	?	5,000	?	good	?	good	0	+	++	+
3. Sand dune well field	600,000[a]	15,000	?	moderate	good	good	0	+++	++	+++
4. Improve I. Canal	2,500,000	0	30	good	good	good	0	++	0	0
5. Enhance Blood Ck.	63,000[a]	3,000	20	moderate	good	good	0	++	0	0
6. Enhance Deception Ck.	28,000[a]	1,500	20	moderate	good	good	0	+	0	0
7. Add Dike Pool #2	131,600	1,700	30+	good	moderate	good	+	0	+++	++
8. Add Dike Pool #3	136,800	1,800	30+	good	moderate	good	+	0	++	++
9. Add Dike Pool #4	111,450	1,400	30+	good	moderate	good	+	0	++	++
10. Add Dike Pool #5	62,050	600	30+	good	moderate	good	+	0	+	++
11. Add Dike Pool #1	1,705,900	1,700	30+	good	moderate	good	++	0	+	++
12. Deep Water[b] Storage	4,605,900[c]	1,700	30+	good	moderate	good	+++	0	++	+++
	2,414,300[d]	1,700								
13. Finger Dikes	3,000/each	20	15	good	moderate	good	+	0	0	++
14. Dbl. Dike[b] & Canal	686,000	4,000	30+	good	moderate	good	0	0	+++	+++
15. Mobile Pumps (3)	118,500[e]	7,000	20	good	good	good	+	0	+++	+++
16. Dragline	180,000	10,000	20	good	good	good	+	0	+	+++

a = does not include potential easement or land purchase costs.
b = not functional without implementing Module #11.
c = includes cost for excavation of subpool 1a by dredging.
d = cost for elevating and riprapping dikes around subpool 1a.
e = does not include pump site development costs.

0 = no change in benefits.
+ = enhancement of benefits.
- = deterioration of benefits.

This module is intended to impound the water received from Walnut Creek and the Arkansas River until it is needed at CBWMA. Ideally, water would be kept in deep storage, thus greatly reducing evaporative losses. Under normal operation and climatic conditions, water would be received during late spring and summer, then transferred by gravity to the Bottoms in fall, and utilized to flood areas kept dry through the summer. Originally conceived as a means of providing more efficient water storage, the proposed reservoir could be of value in controlling water import under exceedingly wet conditions, or whenever situations at the Bottoms require better control of water from outside the basin. However, once the reservoir is filled to capacity, excess water would have to be passed through to the Bottoms regardless of existing water conditions at CBWMA. Secondary benefits of an inlet reservoir might be obtained by the limited habitat provided to waterfowl and sport fishes. Recreational use of such a reservoir would be limited by water requirements at the Bottoms.

The effectiveness of this module is limited by the capacities of the proposed reservoirs. The estimated storage capacities of 470 and 640 acre-feet (dam 1 and 2, respectively) are too small to favorably impact the water budget or water management of Cheyenne Bottoms. Also, the reservoirs would fill rapidly if the inlet canal were flowing full for several days. Additional reservoir storage could be created by excavation of the site at an estimated cost of $1,600 per acre-foot of new storage.

Module 2--Walnut Creek Well Field. The limited nature and high value of ground water in the region demand that its use in any management scheme be one that restricts its loss and contributes directly to satisfying a management need. The use of ground water for direct flooding of pools for the creation of marsh habitat is not recommended. The large quantities of groundwater

necessary to inundate desirable acreages and the costs associated with achieving this are extreme considering the potential losses from evapotranspiration. Ground water, however, could provide a highly dependable source of water for irrigation purposes. Results of small grain crop (e.g., millet) irrigation in central California marshes similar to the Bottoms indicate that as much as a 4-fold increase in yield can be achieved by timely but limited flood irrigation (pers. comm., Dr. Leigh Fredrickson, 1986). Significant increases in crop yields have been experienced by many Kansas farmers utilizing similar irrigation practices on small grains. Thus the potential exists for producing sustained high yields of seed crops for waterfowl food with relatively small quantities of supplemental irrigation water. Modules 2 and 3 are aimed at exploiting local ground water supplies and would greatly assist reaching at least one or two of the specified management goals.

The first of the ground water sources to be considered is in the Walnut Creek area. In this module, existing water rights would be purchased from right holders to supply irrigation water for small grain crops within the basin. Existing wells and pumps would be used to supply water to the inlet canal for transport to the Bottoms. Optimum locations would be those areas at or near the Walnut Creek diversion dam (figure 21.2). The cost of a delivery system connecting the wells to the existing canal system could be reduced by selecting wells near the canal. In addition, ground water losses caused by pumping in this area would be partially offset by recharge caused by ponding of surface water behind the Walnut Creek diversion dam.

It is recommended that water obtained from a Walnut Creek well field be exclusively used for irrigation purposes and not as a supply for maintaining pool levels. In addition to those reasons already cited for not using ground

water for surface water maintenance, the present reserves of ground water in the Walnut drainage are insufficient to support continued pumping over long periods of time. There is some apprehension on the part of the study group to promote the further use of a limited resource which is already suffering from over exploitation. Currently this drainage is under restrictions prohibiting new well development. This is a strong indication of the type of problems already facing this ground water source.

Little information is available on the cost of acquiring water rights or the legal or moral ramifications of implementing such a system. However, we do recognize the potential of obtaining limited irrigation water from the Walnut Creek drainage. Irrigating marsh areas in Pool 5 is most convenient, but potential management conflicts must be considered.

Module 3--Sand Dune Well Field. A tract of sand dunes, located on the east-northeast side of the Bottoms (figure 21.2), consists of windblown sand that readily allows recharge of the underlying aquifer by precipitation. Available data indicate there is a layer or lens of fresh water overlying the poorer quality ground water in this region. This lens is not sufficient to yield enough water to fill or even partially fill any existing pool at the CBWMA. However, there could be enough to irrigate feed crops such as millet, to augment food supplies for waterfowl at the Bottoms. Due to the lack of available subsurface data in the area, only estimates of the available ground water were made.

It has already been pointed out that the fresh water in the dunes comes from recharge by precipitation. Since recharge is not great in this area, the amount of water pumped out should be no more than annual recharge to avoid depletion of this localized water supply.

Available drilling data and reports from local landowners suggest that the saturated thickness of the fresh water lens ranges from zero to possibly a few tens of feet. Our limited observations also indicate that the lens thickness is highly variable in this region. An analysis of a water sample from well T.18S., R12E, Sec. 25 addd, shows that this water is very low in dissolved solids (see discussion in Chapter 3). Ground water quality below this lens is reported to be so poor that it is not usable for domestic purposes.

Based on the characteristics of similar material, the specific yield of the sand in the area should range from 7 to 15%. If the lens were 10 feet thick, then a half section (320 acres) would contain 3,200 acre-feet of water. Thus by taking the calculated amount of ground water in acre-feet per half section times the minimum expected specific yield (.07), approximately 224 acre-feet of water would be available for use. However if the specific yield were as high as 15% then as much as 480 acre-feet of water could be available.

Recharge to the dunes is estimated to be between 3 and 6 inches of precipitation per year based on work by Marios Sophocleous (pers. comm., 1986) on similar soils in southern Barton County. Recharge on a half section would then range between 80 and 160 acre-feet on the long-term average (320 acres times the recharge rates). Therefore even if 224 to 480 acre-feet of water were available, only 80 to 160 acre-feet should be pumped in order not to deplete the freshwater supplies.

As in Module 2, available ground water would be utilized for irrigation purposes only. Assuming that at least 125 acre-feet of water was available annually for use from the sand dunes, a viable irrigation plan could be implemented. Ideally, a well field would be sited such that a delivery system

would convey water to the areas adjacent to the peripheral dike separating pools 3 and 4. We envisioned the development of two 500-acre areas that could be flood-irrigated with 1-1.5 inches of water several times during the growing season on an annual alternating basis (figure 21.5). It was assumed that this amount of water would result in saturated soil conditions conducive to good plant growth. The fallow acreage resulting from a yearly shift between irrigated parcels is expected to produce desirable native plants as well as any carryover of planted crops. Water required to flood-irrigate 500 acres with 1.5 inches of water twice a year was calculated to be 125 acre-feet (.25 feet of water times 500 acres). Thus, 125 acre-feet of available ground water from the sand dunes would make the development of a well field worthwhile.

Approximate costs of implementing a well field in the sand dunes would include the following major costs: 9-7/8 inch drilled hole at about $7/ft including 5-inch casing, screen, and grout; 50 gallon/minute pumps at $550 each; electric cable cost and installation; supply pipe; and delivery system including delivery pumps to maximize delivery rate. Several assumptions concerning number of wells, depth of wells, configuration of well field and size and length of delivery systems were made to derive a well-field cost estimate for this module. These assumptions were necessary because of existing data gaps. However, the inherent value of this module dictates that some estimate of cost be made. The cost estimate in table 21.2 was based on the following assumptions: the location of the well field is reasonably close to the dike dividing pools 3 and 4, the number of required wells is approximately 20, and the wells are shallow in nature.

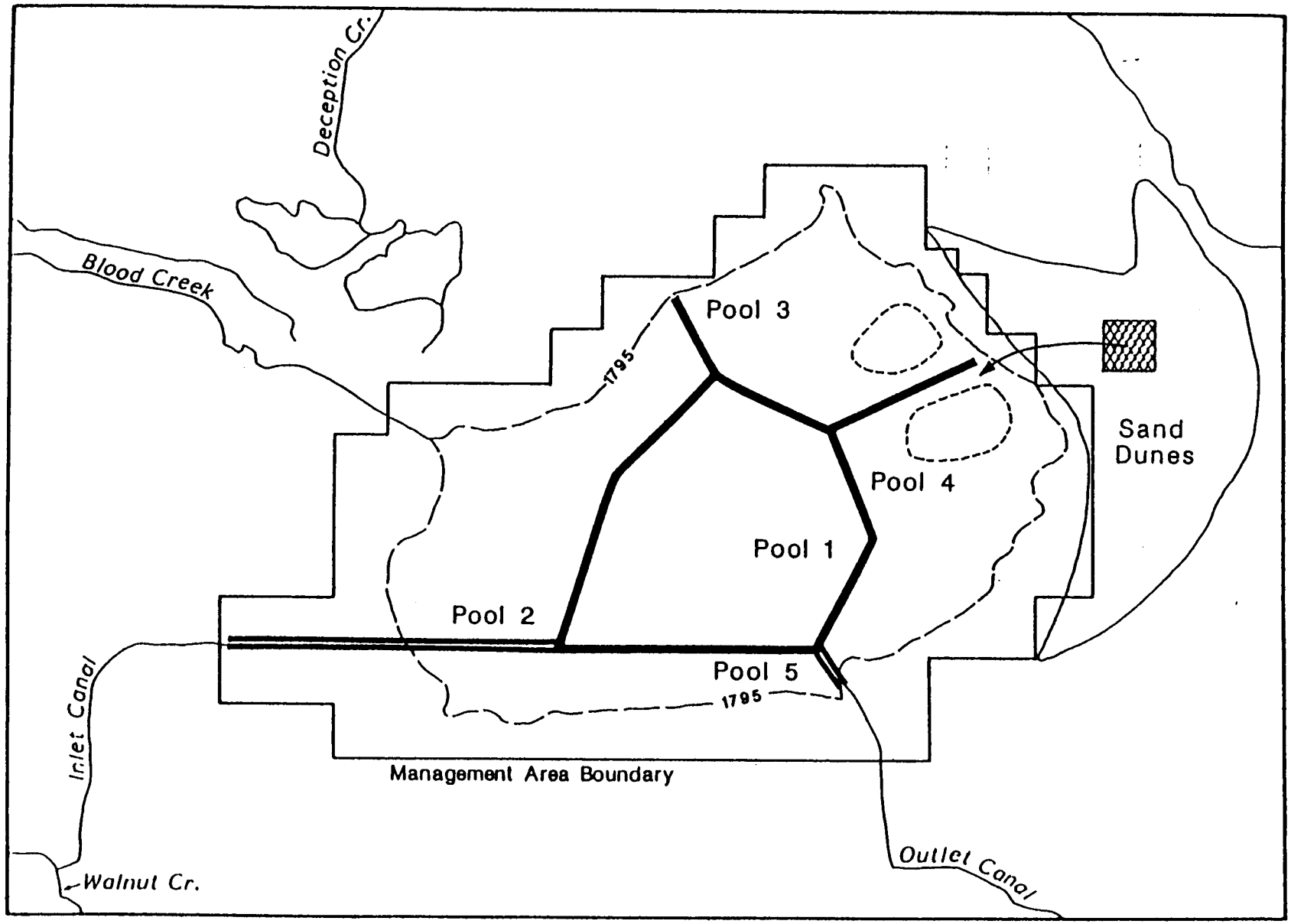


Figure 21.5 - Cheyenne Bottoms Wildlife Management Area with the proposed Sand Dune well field (Module 3). The actual location, size and configuration of the well field would be determined by future study.

Obviously additional field investigations are necessary before a complete evaluation of the available ground water in the sand dunes is possible. Once this information becomes known, a more meaningful assessment of this module can be conducted.

Module 4--Improve the Inlet Canal. Both visual observation and indirect flow measurements (Chapter 8) indicate that significant seepage losses occur in 5 of the initial 7 miles of the inlet canal (figure 21.2) during periods of major diversion. The losses in this reach could be largely eliminated by lining the canal. Consequently, a 6-inch-thick formed concrete liner was considered for the 5-mile length. The trapezoidal canal would have a 12-foot base width, a 5-foot depth, and 1.5:1 (horizontal to vertical) side slopes. At a cost of $120 per cubic yard, the cost is $352,000 per mile or $1,760,000 for the entire 5-mile length.

The value of this module is uncertain. It assumes the continued availability of significant and timely amounts of water from the Arkansas River. Water losses in the inlet-canal system downstream of the stretch to be lined may be great enough to offset the possible benefits of the module. Improved gaging, as described in the Additional Considerations section, would be necessary to generate the data needed to fully evaluate this module.

Modules 5-6--Enhance Water Delivery from Blood Creek and Deception Creek. Water reaching the floor of the Cheyenne Bottoms basin from the Blood and Deception Creek watersheds (figure 21.6) often has difficulty reaching the Pool 2 area at CBWMA. Moderate to heavy streamflows overtop the existing channels and spread onto private land northwest of the management area, where much is lost to infiltration, evaporation, and plant transpiration. Module 5 considers channel modifications on the existing section of Blood Creek from

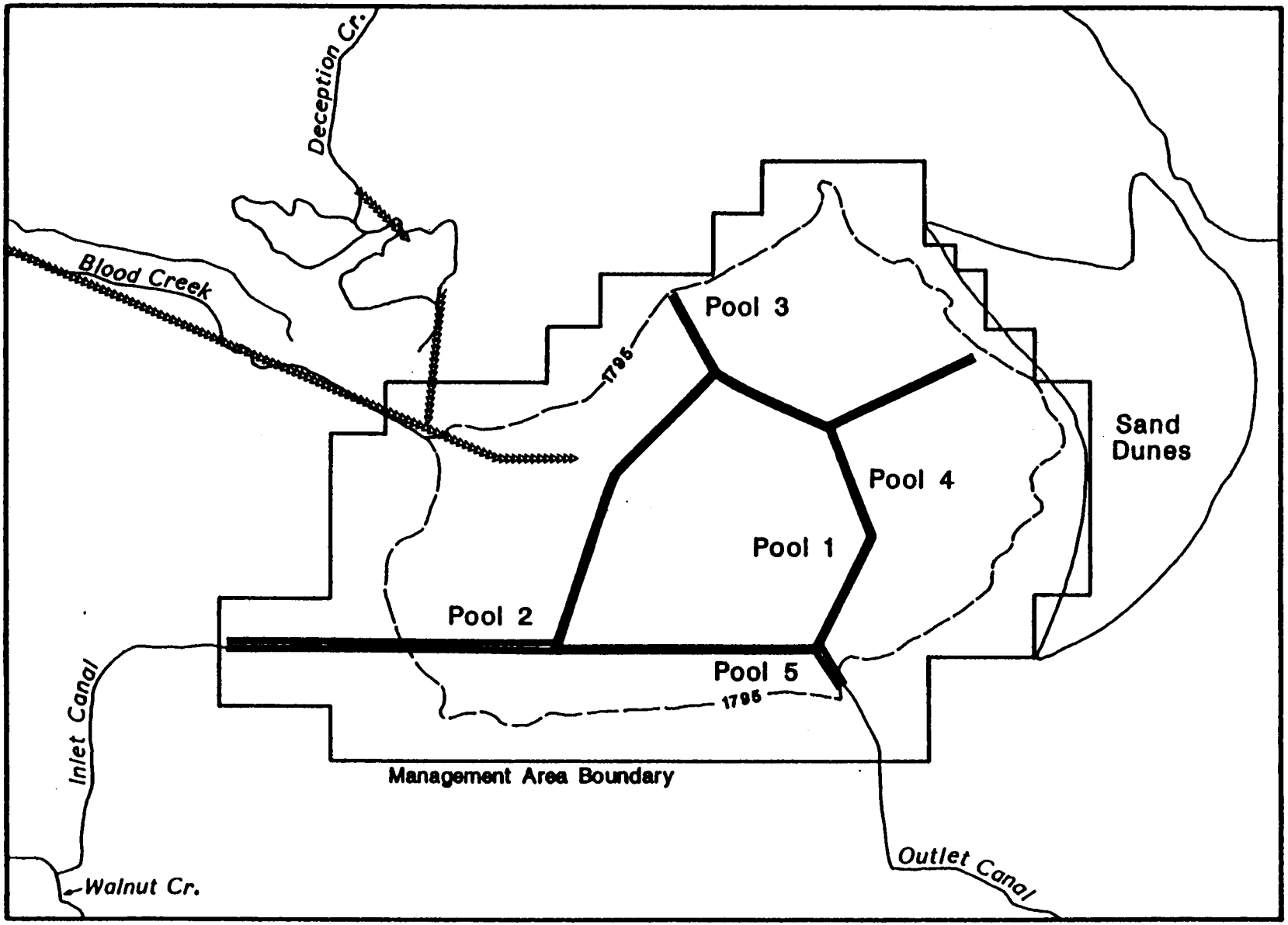


Figure 21.6 - Blood and Deception Creeks (Modules 5 and 6) proposed flow enhancement of lower Cheyenne Bottoms.

Highway 281 to the management area. Module 6 involves the stretch of Deception Creek from just south of Highway 4 to the management area. The proposed unlined trapezoidal channels (20 feet wide at the base, 3 feet deep, and with side slopes of 1.5:1) would cost $14,000 per mile and have a capacity of 150 cfs or 300 acre-feet per day. The Blood Creek flow-enhancement project (Module 5) would involve 4.5 miles of channel for an estimated cost of $63,000. The 2 miles of proposed channel work on Deception Creek (Module 6) would cost $28,000. These modules are intended to enhance water delivery to Cheyenne Bottoms, but they may also enhance land management adjacent to the Bottoms by reducing flood frequency.

Implementation of these modules will require landowner agreements, easements, and a variety of permits. The loss of some small, poor-quality wetlands might result if flood frequency or intensity are modified by these channel enhancements.

Modules 7-10:--Modifications of Peripheral Pools. These modules propose that various new dikes and their associated control structures be constructed to divide peripheral pools 2 through 5, respectively (figure 21.7). The dikes would extend from the perimeter of Pool 1 and bisect the existing peripheral pools into approximately equal subpools. Each dike would be about 7.5 feet high with side slopes of 3:1 and possess the same design characteristics as the original dikes. The per-mile cost of these dikes is based on the placement of 65,000 cubic yards of material per mile of dike at an estimated cost of $1 per cubic yard. Since riprapping of dikes was a suggestion brought out in the public meeting, table 21.3 outlines the cost of dike construction (without control structure) and the cost of riprapping each. However, because we did not consider riprapping essential for any of these peripheral dikes, riprapping costs were not included in table 21.2. In addition, each of these

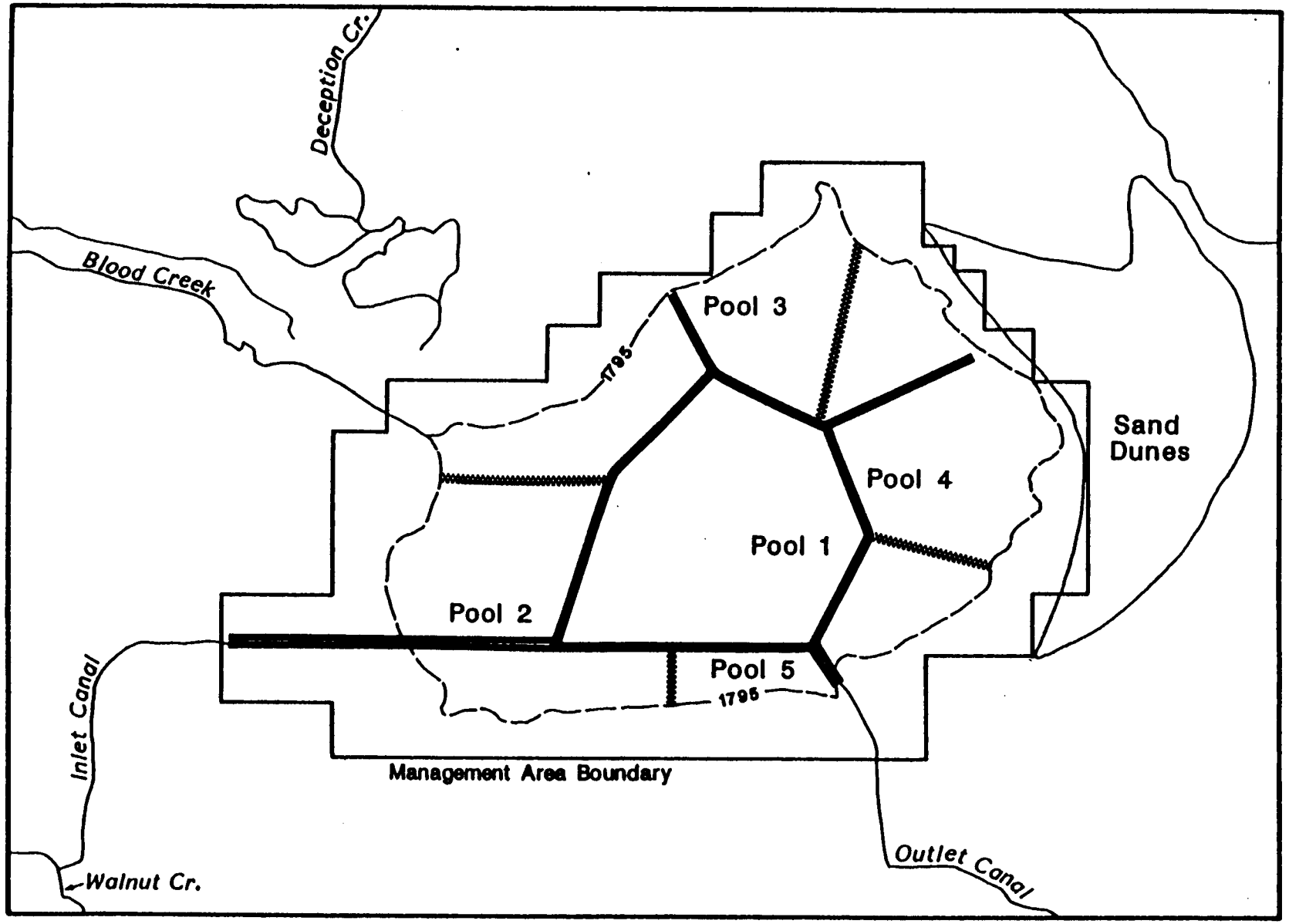


Figure 21.7 - The proposed division of the peripheral pools by earthen dikes. Module 7 proposes the division of Pool 2; Module 3 divides Pool 3; Module 9 divides Pool 4; and Module 10 divides Pool 5.

dikes would have a two-barrel, 6-foot by 8-foot gated box culvert with the bottom set at the elevation of the pool adjacent to the culvert. Control structures cost an estimated $25,000 each when built into new dikes.

Table 21.3--Construction and riprapping costs associated with peripheral dikes. Cost estimates based on 7.5-foot dike-height design.

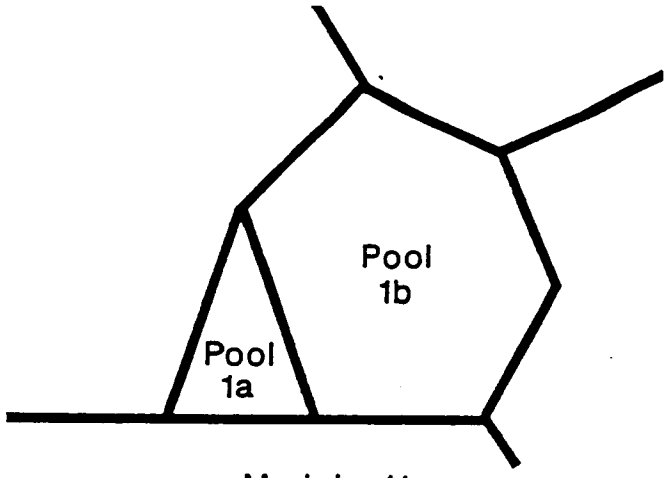
Module #	Length in Miles	Estimated Dike Cost b	Estimated Riprap Cost c
7	1.64	106,600	995,808
8	1.72	111,800	1,042,384
9	1.33	86,450	807,576
10	0.57	37,050	346,104

b = does not include control-structure cost.
c = calculated at $303,600 per mile.

These dikes are intended to improve the efficiency of water storage by creating smaller units that would provide deeper storage. They should improve management flexibility, because these new individual subpools could be dedicated to specialized purposes in a given year. In addition, vegetation management should be enhanced since the smaller sub-units would be easier to dry or flood as needed. The dike dividing Pool 2 (Module 7) has the added function of improving control over the storage and distribution of water received from Blood and Deception creeks. The dikes dividing pools 3 and 4 (Modules 8 and 9) may be important in managing the irrigated areas proposed in Module 3.

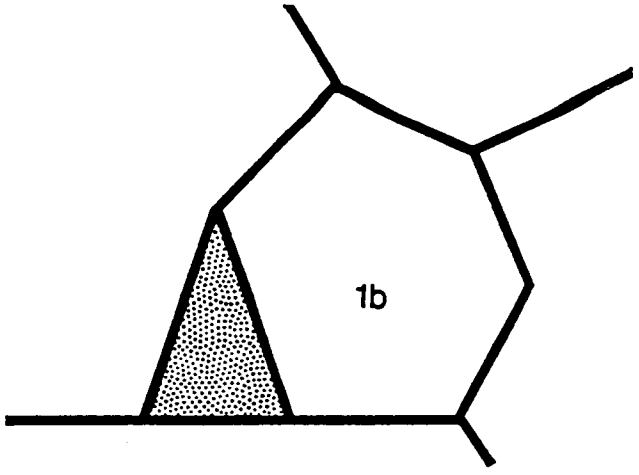
Module 11--Dike Dividing Pool 1. This dike (figure 21.8a) would divide Pool 1 into two subpools, Pool 1a and Pool 1b, with surface areas of 600 acres and 2,700 acres, respectively. Design characteristics for this new dike would be similar to the existing dikes around Pool 1, but would have 10:1 slopes on both sides if riprap were not used. The module construction cost of $356,600 is based on the placement of 140,000 cubic yards of dike material per mile at $1 per yard for a length of 1.69 miles and the cost of four control systems and other water conveyance structures. Control structures constructed on existing dikes were estimated at $35,000 each and $25,000 each for new dikes. The 600-acre pool (Pool 1a) would have a storage capacity of about 2,700 acre-feet at maximum design level (4.5 feet). Daily evapotranspiration losses could be reduced by about 80% if this volume were stored in the 600-acre subpool rather than allowing this volume of water to be spread over Pool 1 (3,300 acres) as a whole. Pumping would be required at various times to operate this type of deep storage.

However, because of the increased potential for dike erosion by storage of water at design levels (4.5-foot level in 7.5-foot dikes), we are recommending the riprapping of the interior sides of the containment dike. The use of riprap would allow the use of 3:1 slopes on the new dike and reduce required fill to 110,000 cubic yards per mile. Approximately $1.4 million would be needed to riprap the internal slopes of the containment dike. Riprap-cost estimates were calculated to be $22/ton delivered and placed. This was derived from the following projected costs: riprap rock at $5/ton, placement at $5/ton, and a hauling charge of $12/ton. The haul-charge estimate is based on informal-quote values for a 50-mile hauling distance from quarry to CBWMA. New dike construction (3:1 slope) costs ($185,900), riprap



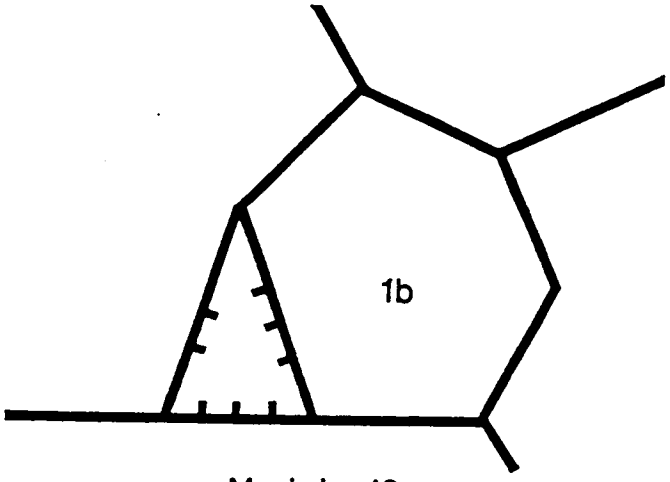
Module 11

Figure 21.8a



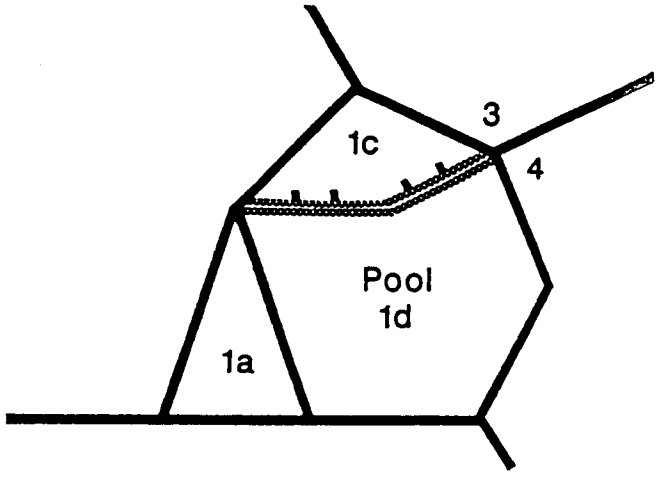
Module 12

Figure 21.8b



Module 13

Figure 21.8c



Module 14

Figure 21.8d

Figures 21.8a,b,c and d - Proposed central pool (Pool 1) modifications and resulting subpools associated with Modules 11 through 14.

needs ($1.4 million), and costs associated with appropriate water-conveyance structures (e.g., control structures) are reflected in the Module 11 cost estimate found in table 21.2.

This module has a variety of management benefits in addition to reducing evaporative losses. It should be useful for vegetation management within Pool 1 by providing more flexibility in storage of water received through the inlet canal system. In low water years the remainder of Pool 1 (Pool 1b) could be dried to condition the soil, grow waterfowl food crops, and/or discourage cattail growth. Drainage ditches associated with the new dike might provide refugia to improve fish survival through winter and through dry years. The increased efficiency of water storage in the 600-acre subpool would allow longer term planning for management of the peripheral areas, because water availability could be guaranteed further in the future. The reservoir area would provide good nesting and brood-rearing habitat for waterfowl.

Module 12--Deep Storage in Subpool 1a. A greater volume of water could be stored in the 600-acre subpool by increasing the storage depth of the subpool, which would result in increased management benefits (figure 21.8b). The depth of stored water in this subpool could be increased by excavation of the existing pool bottom or by elevating the containment dikes.

The existing bottom could be excavated or dredged (Module 12a) to accommodate an additional 1,800 acre-feet with no additional evaporative loss. This would involve removing approximately 2.9 million cubic yards of material and disposing of it. Pumping would be required to move the additional stored water out into other management areas. Riprapping the interior of the containment dikes would also be required at an estimated cost

for riprap in place at $22 per ton. This module is estimated to cost $4.6 million, which does not include spoils removal if off-site removal is necessary.

A second method (Module 12b) of increasing water-storage depth in Pool 1a was also considered. The dikes surrounding the 600-acre subpool could be raised 3 feet to accommodate an additional 1,800 acre-feet of storage. The incremental fill material would amount to about 33,000 cubic yards per mile and cost about $33,000 per mile. The interior face of the elevated portion of the containment dikes would also need to be riprapped at a cost of about $556,600 for the 4.6 miles of dike. Pumping would be required to fill the reservoir to its design capacity. Modules 12a and 12b have essentially the same management benefits. The reservoir would provide habitat for fish, fish-eating birds and diving ducks, and brood-raising waterfowl in general. Management of the rest of the marsh would benefit as described for Module 11, but with increased storage capacity the potential benefits can be greater.

Module 13--Finger Dikes. Finger dikes are short sections of dike extending out into the deeper pools of the Bottoms (figure 21.8c). They would have the same cross-sectional dimensions (10:1 slopes) as the dike dividing Pool 1 and would cost $3,000 per 100 feet of dike. Finger dikes would lengthen the shoreline of the pools, providing more nesting sites for waterfowl. Finger dike construction could involve excavating material adjacent to the dikes, thus creating borrow ditches next to the dikes. The drainage ditches would provide the benefits of deeper water areas in the pools. Finger dikes would also be useful recreation sites, providing access for fishing and for viewing the wetland wildlife.

Module 14--Double-dike/Canal across Pool 1. This module would be functional only if Module 11 is built and would be enhanced greatly by implementation of Module 12a or 12b. This module consists of an excavated canal with a dike on each side that divides Pool 1b into two subpools (figure 21.8d). The proposed canal begins at the north end of subpool 1a and terminates at the point where the dike separating pools 3 and 4 contacts Pool 1b. This will divide Pool 1b into two subpools, Pool 1c of approximately 660 acres to the north, and Pool 1d of about 2,040 acres in the south. The canal would be trapezoidal in cross-section. The bordering dikes would have 10:1 slopes on their exterior faces and 3:1 slopes forming the canal walls. These dikes are estimated to require 208,000 cubic yards of fill material per mile, and with associated control structures would result in a total constuction cost of $686,000 including canal-excavation costs. This module allows rapid and efficient transfer of water from the deep storage pool (Pool 1a) or Pool 2 to the east side of the marsh (pools 3 and 4).

Module 15--Mobile Pumps and Pump Stations. Effective wetlands management often requires the ability to transfer water among pools over relatively short periods of time. Currently, the water-transport system at Cheyenne Bottoms is predominantly gravity flow through gate culverts. The original design placed the bottom of the culverts below the natural elevations of the pool bottoms, at the original elevations of the local borrow ditches. Unfortunately, siltation from sediment-laden inflow and from dike erosion has filled the drainage ditches to a great extent, partially blocking the dike culverts. This results in a significant reduction in the water-transfer capability at the Bottoms.

To increase the water-transfer capability, with or without new dikes, it is proposed that three portable pumps be purchased. Our recommended pump

model has a capacity of 33 cubic feet per second (65.3 acre-feet per day) at a TDH of 5 feet. Larger capacity pumps are available, but the increased pumping rate may create a large cone of depression that can effect pumping performance. These pumps are trailer-mounted, transportable by pickup truck, and operable by one person (appendix 21.3). A pumping station is required at each dike pumping location. A station consists of two 60-foot long by 18-foot wide wooden piers, two excavated sump pits, one buried concrete culvert, and two discharge structures for dike-slope protection. The cost of one pump is $39,500 (delivered) and the cost for the construction of one pumping station is about $13,000.

Module 16--Amphibious Dragline. The maintenance of Cheyenne Bottoms and, particularly, the existing gravity-flow system should include regular removal of silt from the dike culverts and their adjacent drainage ditches. The lack of drainage-ditch maintenance on the existing system has resulted in an inability to thoroughly drain the marsh even under ideal conditions. This problem compounds the emergent vegetation problem as sheet water on extensive mud flats stimulates cattail-seedling production. The task could be handled by an amphibious dragline costing about $180,000. This piece of machinery is capable of operating in water, on mud, or on dry land, and has a 1/2-cubic-yard bucket (appendix 21.4). The dragline would also be useful in making moderate-size physical modifications, such as constructing finger dikes and digging deep-water areas for wildlife management purposes.

MODULE ASSESSMENT

Each of the proposed module/actions was evaluated in terms of economics, engineering considerations, and management capabilities (table 21.2). The criteria used for module assessments are outlined below.

Economic Considerations--Purchase and/or construction costs were derived from discussions with estimators from regional engineering firms or manufacturer's quotes and estimates. Operation and maintenance costs (O and M) were assigned on an annual basis. These costs were assessed on actual or expected replacement or repair costs and manpower needs (based on percentage of salary) to maintain and/or repair structures and other items. The longevity of a module is based on the expected life of the most functional and/or most expensive component(s). These values were derived from engineering estimates, standard historical information, and best professional judgment.

Engineering Considerations--Performance evaluations were based on both effectiveness and projected useful life of the module. Effectiveness was either determined from design specifications or assessed on the basis of best professional judgment. Useful life estimates were assessed in terms of the projected service life of the module's technological components. The reliabilty of a module/action was assessed on the basis of two factors: 1) operation and maintenance requirements of each technology; and 2) demonstrated performance of the same or similar technology at other sites. The implementability of a module refers to the ease of installation and the time element required to become operational. These criteria include on- and off-site circumstances that may directly or indirectly affect the construction and implementation of each module/action (e.g., availability of equipment; physical site conditions).

Management Capabilities--Assessments of the water-storage efficiency of each module/action were based on projected increases in water volume. Storage efficiency refers to those conditions that would reduce evapotranspiration losses per unit volume of water. Water-supply enhancement was evaluated with respect to whether or not the module will directly affect water input into the management area from external sources. Water-manipulation capability evaluations involved two elements: 1) rapid and flexible movement of water within and between pools; and 2) independence of delivery systems to allow direct movement of water from one specific pool to another. Evaluations were made with respect to the existing pool delivery system. The criteria for vegetation management was whether or not the module/action might aid in the control of monoculture vegetation, enhance interspersion of emergent vegetation, provide diverse plant communities, and/or improve seed production (for waterfowl consumption).

OPTIONS

Examination of the potential management benefits associated with various modules (table 21.2) clearly indicates that no single module or action can produce desirable benefits in all management categories. This reflects, in part, the inherent limitations of individual modules and suggests that the use of combinations of modules could greatly increase their usefulness in addressing various management needs. For example, deep-water storage may enhance the availability of more water during drier time periods but beneficial use of this water might then be limited by existing water-manipulation capabilities. However, if appropriate modules were combined, their overall value in marsh management would be greatly enhanced by increased flexibility in the use of stored water. The following options were developed to illustrate both the potential use of module combinations and to offer a

more definitive evaluation and assessment of these combinations. Time and resource limitations precluded the presentation of the obviously numerous potential options that could be developed from those modules that were evaluated. Rather, the study group has selected a series of options that reflect the various potential approaches that are available to solve many existing problems and, in most cases, strive to meet the management goals we have established.

The options are briefly outlined below and list the modules that are the essential components and their associated costs. Increased operation and maintenance costs for an option were generated additively from the operation and maintenance estimates for each appropriate module included in the option (see table 21.2). These module O and M estimates include both parts and replacement costs and increased labor costs. Therefore, the increased operating costs listed below have possibly been overestimated, since incorporated labor costs in each module were not adjusted to offset increased labor availability provided by additional manpower. However, the study group felt that a straightforward presentation of cost estimates was the best approach and that more detailed development of potential costs could be addressed once a particular course of action has been chosen. Detailed descriptions of additional manpower needs and associated salaries and benefits are found in table 21.4. These salary estimates were based in part on current Kansas civil service information on positions with similar duties and responsibilities. It should be noted that increased costs and additional manpower needs are over and above the current status. The sections that follow this outline describe in more detail both the proposed changes and the rationale for these suggestions.

Table 21.4. Estimated manpower needs associated with proposed options.

Option	Position	Duties	Salary + Benefits
II, III IV and V	Manager Upgrade	An upgrade of manager's position to accommodate increased administration, budgeting, planning of usage needs developing from increased operations and manpower additions and to address other user needs recognized by the study.	$ 5,000 (increase)
II, III IV and V	Biologist	Biologist responsible for short-term and long-term wildlife planning and development; continuous on-site evaluation and assessment of wildlife and non-game needs; develop and execute management strategies; address day to day biological management functions; and provide habitat improvements where possible.	$27,000
II, III IV and V	Mechanic	Position to address intensified use of existing and potentially new farm equipment, heavy equipment, pumps and other mechanized equipment.	$24,000
II, III IV and V	Farm Manager	Supervise and participate in intensified farm practices.	$24,000
III	General Laborer (half-time)	A laborer position to meet the needs of additional farm practices, recreation facilities and other labor intensive needs.	$12,000
IV, V	General Laborer (full-time)	A laborer to carry out increased farming and facility needs plus additional dike and other structural maintenance.	$24,000
V	Heavy Equipment Operator and Laborer	A position needed to maximize dragline operations and assist in up-keep of physical structures.	$24,000

OPTION I. No changes

Costs and Needs

Capital Improvements:	None
Current Operating Costs:	$171,084 for FY 1986
Additional Manpower Needs:	None

OPTION II. A. Increased manpower and operating budget
B. Mobile pumps and pump-site development (6 pump sites)
C. Amphibious dragline

Costs and Needs

Capital Improvements:	$376,500
Increased Operating Costs	97,000
Additional Manpower Needs:	3

OPTION III. A. Increased manpower and operating budget
B. Sand dune well field
C. Mobile pumps and pump-site development (6 pump sites)
D. Amphibious dragline

Costs and Needs

Capital Improvements:	$976,000
Increased Operating Costs:	124,000
Additional Manpower Needs:	3.5

OPTION IV. A. Increased manpower and operating budget
B. Peripheral dike in Pool 2 and associated control structure
C. Divide Pool 1, additional control structures
D. Mobile pumps and pump-site development (10 pump sites)
E. Blood and Deception Creek flow enhancement
F. Amphibious dragline

Costs and Needs

Capital Improvements:	$2,357,400
Increased Operating Costs:	112,400
Additional Manpower Needs:	3.5

OPTION V. A. Increased manpower and operating budget
B. Sand dune well field
C. Blood Creek and Deception Creek flow enhancement
D. Peripheral dikes in pools 2, 3, 4, 5 and associated control structures
E. Deep storage area in Pool 1
F. Division of Pool 1 into 3 sections, with double-dike canal to Pool 3/4 intersection
G. Mobile pumps and pump-site development (16 pump sites)
H. Finger dikes (20 each)
I. Amphibious dragline

Costs and Needs

Capital Improvements:	$4,799,700
Increased Operating Costs	179,800
Additional Manpower Needs:	5

Option I.

Option I represents the "do nothing" approach. This option is included to present current conditions and to provide a basis for the evaluation of the other four options. No changes would be made with respect to operation/maintenance budgets or manpower, and no capital improvements would be proposed. The operating budget for fiscal year 1986 was $171,084 (see appendix 21.5).

Cheyenne Bottoms would continue to exist as an extremely dynamic and often undependable resource for both man and nature. This is not to say that the wetland would consistently be of poor quality, but overall conditions of this resource will worsen with time. The cyclic and extreme climatic nature of this region would result in years with adequate and timely water supplies, years with moderate water conditions, and years with very poor water supplies. However, given current conditions and apparent future trends, the cyclic extremes experienced at Cheyenne Bottoms in the recent past will most likely become more severe.

The current operation and maintenance and manpower budgets are viewed as inadequate for the management of a productive and balanced wetland system, considering the current problems that exist and the projected decline in

available water. Similarly, the lack of allocations for structural improvements and equipment purchases ensure that the full value and benefits of this resouce would not be realized by the people of Kansas.

Option II.

The basic philosophy in the development of Option II was to provide the means to return the current configuration of the marsh to its design capabilities and when possible enhance those capabilities. Better marsh management could be accomplished by increasing both the O and M budget and staff. It is the opinion of the study group that funding and staffing at this 19,000-acre facility, currently and perhaps even historically, have been inadequate to optimize management and/or address water problems associated with the marsh and the resulting extremes in marsh dynamics. Presently, three full-time Kansas Fish and Game employees plus some part-time help are responsible for maintaining and managing this wetland. Intensified vegetation management, waterfowl-food production, and structural maintenance are but some of the exemplary needs that could be better addressed with increased resources. Within the constraints of available water, the current marsh configuration could be brought closer to design capabilities by increased maintenance of existing physical facilities (e.g., drainage ditches, gated culverts).

Overall, Option II calls for increased manpower and O and M budgets along with the purchase of an amphibious dragline, three mobile pumps, and the development of six pump sites. The potential uses and nature of an amphibious dragline have already been outlined (see Module 16 description). The purchase of this piece of equipment is recommended for this option and all succeeding

options. The role of this dragline becomes more important as more physical facilities are proposed and the mileage of drainage ditches (associated with suggested new dikes) is greatly increased.

The second major equipment purchase called for in this and all other options is that of mobile pumps. We have recommended the addition of three mobile pumps and suggest that three pumps be considered the minimum desirable number. It was thought that, minimally, three pumps could provide the type of flexibility and capability for water manipulation necessary for better management of the area under current and proposed marsh configurations. Portable pumps could be effectively used at various sites throughout the marsh provided that suggested pump sites were developed. Thus a few mobile pumps and a network of pump sites could accomplish the same work as a larger number of fixed pumps at permanent sites.

The purchase of three mobile water pumps and the construction of pump-site platforms at strategic locations would: 1) increase efficiency of spring drawdowns of peripheral areas, thus conserving water while providing migratory shorebird habitat; 2) provide a means of water recovery from deep storage areas; would assist in flood control; 3) increase the efficiency of fall flooding in areas with waterfowl-food crops; and 4) increase the overall flexibility of water manipulation within the management area.

Detailed descriptions of the duties of the increased staff are presented in table 21.4. In general, the rationale for these positions stems from the activities included in the options and the philosophies behind the management goals.

Option III.

Option III is identical to Option II but with the addition of the sand dune well field (figure 21.5) and the expansion of the proposed staff to include a half-time general laborer position. The well field would be used to irrigate approximately 500 acres for small-grain crop production. A series of shallow wells would tap high-quality ground water at a controlled rate to match recharge and meet irrigation needs. A delivery system would convey water to grain crops located at the east side of the Bottoms. Timely irrigation would help guarantee a dependable and productive waterfowl-food source. The new half-time laborer's position would help meet the needs of new farming practices, vegetation management and other labor-intensive needs.

In general, Option III would provide an opportunity to return the marsh to a more productive state and increase water availability to the wetland. This additional water would be utilized to enhance and stabilize on-site waterfowl-food production and help meet at least one or more of the established management goals.

Option IV.

Aside from the increased budget necessary to address the following proposed additions, this option exemplifies substantial changes to the configuration of the management area (figure 21.9). The division of Pool 2 introduces several of the integral elements directed toward achieving some of the management goals. This division would not only provide better control of water entering the marsh through Blood and Deception Creeks, but could improve both water-storage efficiency and water-manipulation capability in Pool 2. The resulting subpools should make vegetation-management practices and wetland-avifauna food resource development more practical and easier to implement.

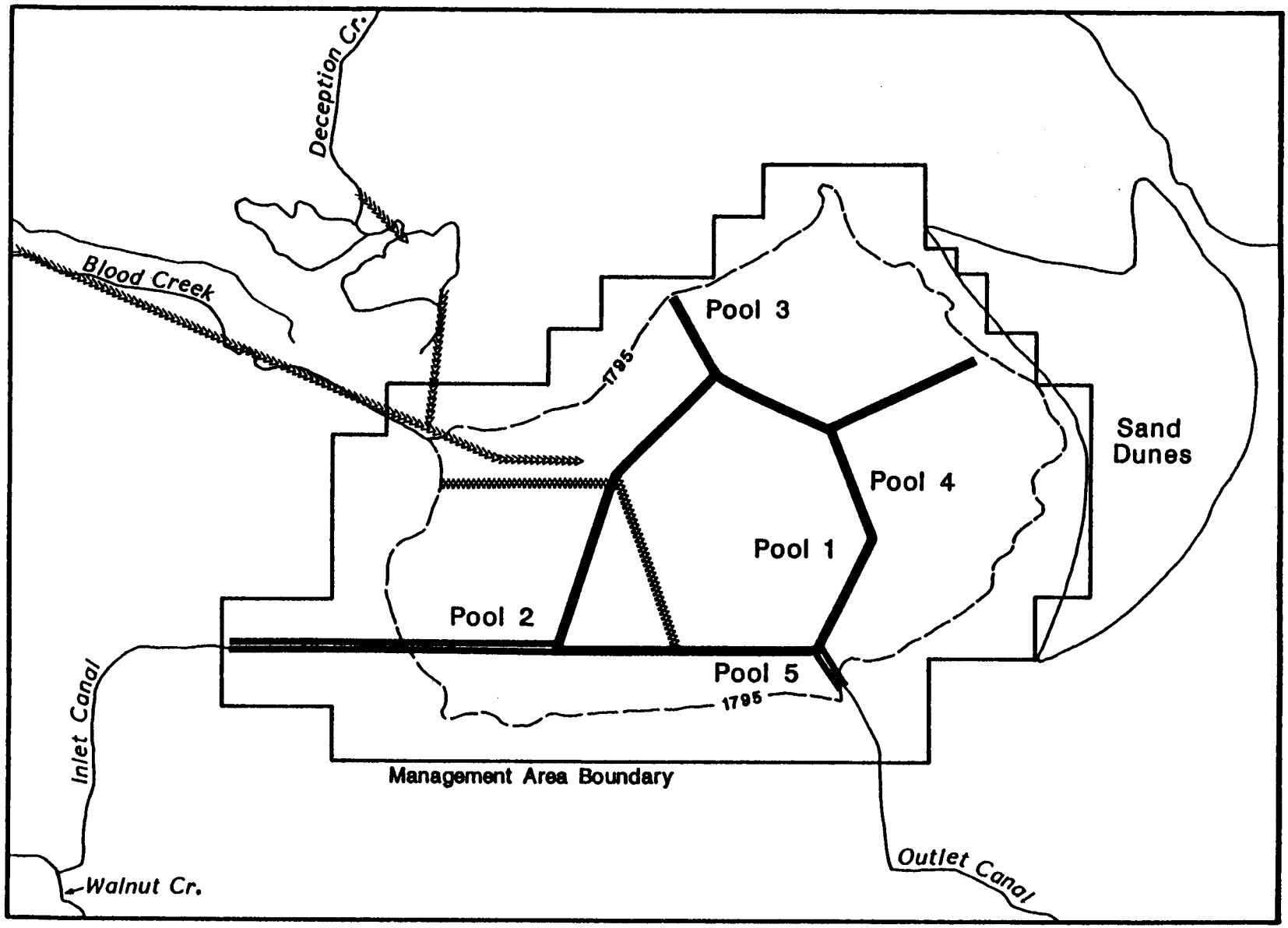


Figure 21.9 - The physical enhancements of the Cheyenne Bottoms Wildlife Management Area proposed in Option IV.

This option also includes the division of the large central pool (Pool 1). This modification would create a 600-acre subpool that would provide an efficient deep-storage situation. The principle behind this element is the reduced potential for water loss due to evapotranspiration. The reduced surface area-to-volume ratio would reduce evaporation rates, and transpiration losses would be greatly decreased since the pool could be managed to reduce and control emergent vegetation.

Enhanced water delivery to Pool 2 from Blood and Deception Creeks would also be accomplished through channel modifications. Water loss due to evapotranspiration and infiltration associated with many high-streamflow events would be reduced, allowing more water to enter the management area.

As a result of the construction of the additional dikes in Option IV, four additional pump sites would be required for increased water-manipulation capability.

These proposed marsh reconfiguration projects are expected to have greater impacts on user activities than any previous option. Gains in nonconsumptive and fishing uses are anticipated if this option were implemented.

Option V.

This option (figure 21.10) represents the integration and implementation of most of the more viable modules that would enhance external water supply, internal water use, water storage, marsh maintenance, and marsh-habitat diversity. Increases in available water could be expected by development of the sand dune well field for irrigation use and enhancement in the quantity of water delivered into the management area from Blood and Deception Creeks. Irrigation water would again be used to stabilize small-grain crop production for waterfowl independent of overall climatic conditions. This would largely

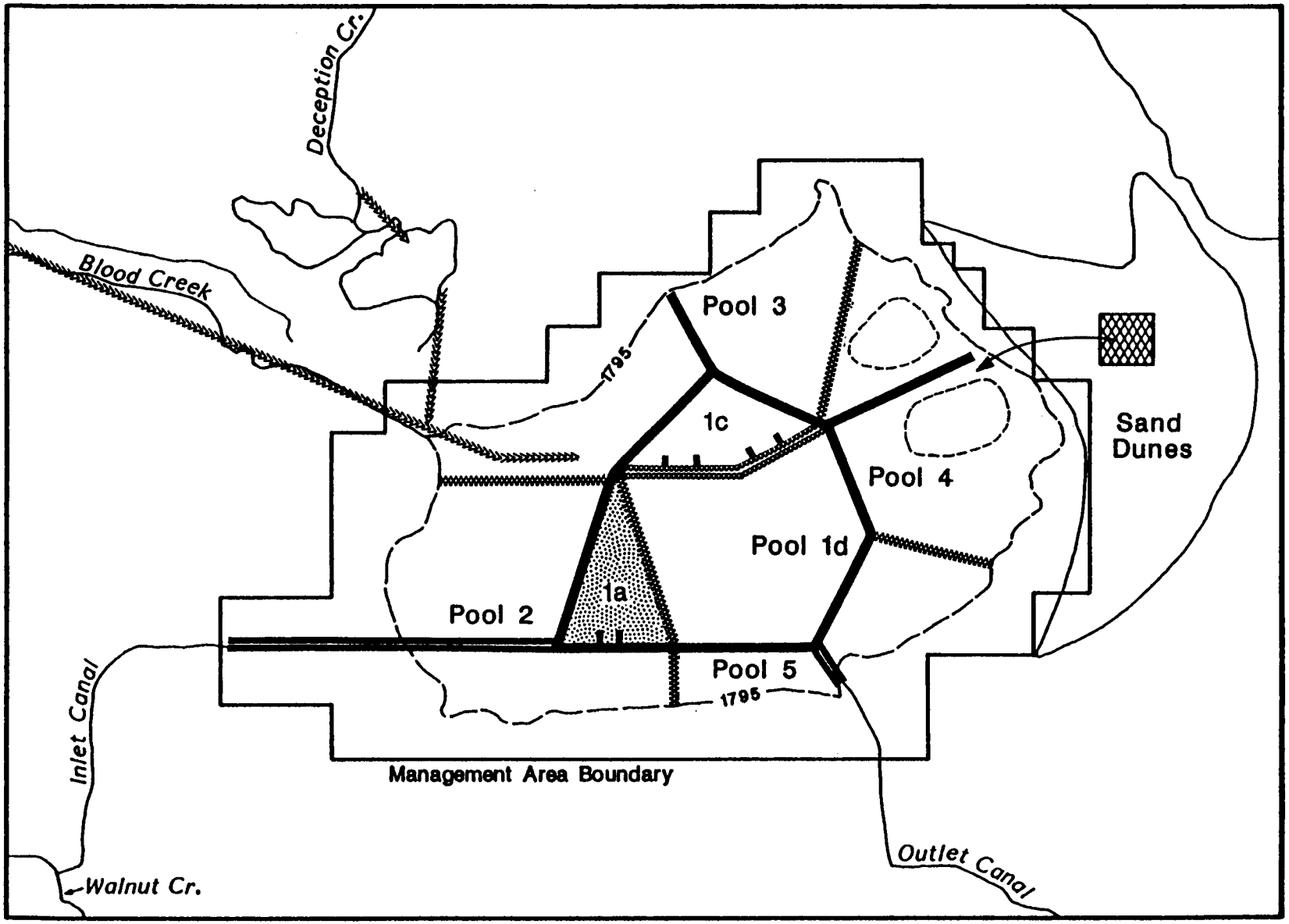


Figure 21.10 - The physical enhancements of the Cheyenne Bottoms Wildlife Management Area proposed in Option V.

help satisfy one or more of the established management goals. Secondly, under various climatic conditions, enhanced delivery of creek water to the basin could be possible and this water would help supplement pool waters.

Construction of all peripheral dikes would substantially increase the versatility, capacity, and usefulness of internal water storage and management in all areas of the marsh. Individual and general peripheral dike benefits are discussed within the appropriate module descriptions. The subdivision of the central pool and construction of a canal system across this pool to pools 3 and 4 would help mitigate several existing problems. Deep-water storage and better water management within the central pool would reduce evapotranspiration losses, preserving more water for later use. Water conservation would be improved by individual subpool storage and deep-water storage by dike elevation (Module 12b). The manipulation of available water for management purposes is maximized by the creation of additional subpools and the ability to move water between central subpools and most peripheral pools in the double dike/canal system and associated subpool control structures.

Finger dikes would create more stable deep water habitats and add diversity to the marsh environment. Favorable muskrat habitat would result from the construction of finger dikes. Increases and/or stabilization of muskrat populations is deemed desirable. Among other things, muskrats help maintain more "open" marsh conditions.

Lastly, the amphibious dragline would provide needed increases in maintenance capabilities. This module is essential in maintaining the vast structural modifications (i.e. canals, control structures, pump sites, and finger dikes) outlined in this option. Approximately 18 miles of new drainage

ditch would be created under this option. Increased manpower and O and M expenditures similarly reflect needs to maintain the complex configurations of this option.

OPTION ASSESSMENT

Cost estimates and assessment of proposed new manpower and resource needs can be found in summary form in table 21.4. Capital-improvement costs were basically generated by the strict addition of module purchase and/or construction costs. In addition, the costs associated with the construction of mobile pump sites was included in each appropriate option. Operating costs were derived from projected O and M costs for each module (table 21.2) and additional costs (e.g., salaries, fringe benefits) associated with proposed new manpower needs. While we have provided specific breakdowns of manpower needs with each option, it is important to realize that these assessments are somewhat subjective. Since we have not developed a specific management plan, our manpower estimates represent a cursory evaluation. Ultimately, the responsibility for development of an appropriate CBWMA budget, in terms of money and staff, will rest with the Kansas Fish and Game Commission. However, our proposed manpower needs and their associated salaries (including fringe benefits) should be of value in helping recognize costs associated with any positive action taken at the CBWMA.

In addition, it should be noted that increases in budget, staff, equipment, and activities will eventually, at some point, require secretarial and/or clerical support at the management headquarters, as well as a larger shop facility. Final budget considerations should include Kansas Fish and Game Commission insights, comments, and recommendations.

Although not discussed outright, the modular nature of option elements allows for phased and flexible implementation of those elements over time. In fact, phased implementation of actions would probably be advantageous, allowing conscientious application of management practices in a dynamic system. Staged implementation would also allow for the appropriation of funds to be spread out over longer periods of time.

POTENTIAL RESPONSE OF TARGET ORGANISMS TO OPTIONS

An assessment of the responses of a variety of target organisms to the five options described above is provided in table 21.5 for wet and dry climatic conditions. Responses were assessed for migrant and breeding ducks and geese, pheasants, migratory shorebirds, endangered species, carnivorous mammals, muskrats, fish, seed-crop plants, emergent nesting cover, and invertebrates. Assessments were made on a qualitative basis in relation to the current performance of the marsh in meeting the needs of these organisms. In many cases, each option should create specific conditions that would be different than those presently found at the marsh, thus causing each target organism to respond to these new conditions. Response by these organisms includes such things as use of the area, productivity (reproduction or growth), and survival. A minus (-) indicates the organism is expected to fare more poorly than at present under a particular option. A zero (0) indicates the organism's response is not expected to change from its present state. Predicted improvements in response are indicated by plusses (+, ++, +++). One plus implies a slight improvement over current conditions, two plusses indicates a moderate improvement, while three plusses indicates a potential major improvement, and where appropriate, achievement of the proposed management goals. The plusses are comparable only within rows: two plusses for Bald Eagles may mean something very different than two plusses for

Table 21.5. Potential Responses of Target Organisms to Proposed Options

	OPTIONS									
	I		II		III		IV		V	
Organisms	Dry[a]	Wet[b]	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Gamebirds										
Geese										
Migrant	-	o	+	+	++	++	+	+	+++	+++
Breeding	-	o	-	o	-	o	++	+	+++	++
Ducks										
Migrant	-	o	+	+	++	++	+	+	+++	+++
Breeding	-	o	-	o	-	o	++	+	+++	++
Pheasants	+	o	+	o	+	o	o	o	+	+
Migratory Shorebirds	-	-	-	+	o	+	++	+	+++	+++
Endangered Species										
Whooping Crane	-	o	+	o	+	o	+	o	+	o
Piping Plover	?	o	?	o	?	o	+	+	++	++
Snowy Plover	-	-	-	+	+	+	+	+	++	++
Least Tern	?	?	?	?	?	?	+	+	++	++
Peregrine	?	?	?	?	?	?	+	+	+	+
Bald Eagle	-	-	-	-	-	-	++	+	++	+
Mammals										
Carnivores	+	o	+	o	+	o	+	o	+	+
Muskrats	-	o	-	o	-	o	++	+	+++	++
Fish	-	-	-	-	-	-	++	+	+++	+++
Seed Plants	-	o	+	+	++	++	+	+	+++	+++
Emergent Nesting Cover	-	o	+	+	+	+	++	+	+++	+++
Invertebrates	-	o	+	o	+	o	++	+	+++	+++

a Dry = water supply for management during the dryer portion of the long term water cycle
b Wet = water supply for management during the wetter portion of the long term water cycle

o = no change from present numbers and/or production of organisms
- = decreasing numbers and/or production of organisms
+ = increasing numbers and/or production of organisms

invertebrates. Thus, adding the plusses for a particular option is not a valid way to assess the option's overall performance. Instead, performance must be considered separately for each target organism.

The predictions of target organism response were deduced by Drs. Leigh Fredrickson and Wayne Hoffman, based on their 29 years of combined experience with marsh systems, their recent work at Cheyenne Bottoms, and with the known ecology of the target organisms. Predictions were made separately for dry years and wet years, to assess the ability of each option to perform in the variable environment of central Kansas. These predictions are based on several assumptions about the optimum performance of the options.

First, it was assumed that Cheyenne Bottoms will be managed in an enlightened manner consistent with the management goals outlined earlier. Second, it was assumed (for all but Option I) that manpower, operational budgets, and equipment would be adequate to fully realize the option's potential. Obviously, if the facility were understaffed or poorly managed, these projections of response might not be realized. Third, it was assumed that the water available to Cheyenne Bottoms from the Arkansas River and Walnut Creek would not increase, and in fact is likely to decline further.

The predicted responses are explained first for each species or category of target organism. These responses are then summarzied for each option.

For migratory geese and ducks, declines in use under Option I are expected in dry years, as food crops would be adversely affected by decreased soil moisture. Improvements are expected in both wet and dry years under options II through V. The modest improvements in options II and IV would accrue primarily from increased farming activity and enhanced water management due to increased staff and equipment. The more substantial response expected for Option III results from the food provided on the proposed irrigated

croplands. Option V provides irrigated cropland, improved water availability for fall flooding, and enhanced vegetation management throughout the marsh.

For the resident Giant Canada Geese and the breeding ducks, nesting and brood-rearing habitat seems to limit population growth. Options IV and V, with their modifications of Pool 1, will provide better summer habitat in both wet and dry years.

Pheasants are expected to respond positively in dry years to irrigated crop availability. The drying of the marsh provides more suitable pheasant habitat. However, little change in their status is expected to result from any of these options.

Migratory shorebirds are attracted to the habitats created as open-water pools dry or are drawn down. This habitat is expected to continue declining under Option I and in dry years under Option II. The irrigation in Option III concentrates seed production, providing flexibility for management of other areas as shorebird habitat, thus alleviating some of the potential losses associated with continued water decline. Increased water storage and manipulation capabilities associated with options IV and V should provide suitable shorebird habitat.

Whooping Cranes are not expected to show strong responses to any of the options. They use Cheyenne Bottoms mainly as roosting habitat during brief migratory stopovers. Suitable roosting sites should be available under most options. Piping Plovers require bare mud (or sand) habitats that can best be provided with the manipulation capabilities inherent in options IV and V. Manipulation capabilities that create habitat for migratory shorebirds also provide suitable mudflat areas and nest sites required by Snowy Plovers. Currently, Least Terns do not utilize the Bottoms as a breeding area but have been known to have bred there in the past. Least Terns require suitable nest-

sites and abundant populations of small baitfish. Islands could easily be constructed using the amphibious dragline, providing suitable nesting sites in options IV and V. Baitfish populations would also be expected to improve. Peregrine Falcons are attracted to Cheyenne Bottoms primarily by the migratory shorebirds they eat and are best managed by providing shorebird habitat. In winter, Bald Eagles are dependent largely on fish and waterfowl populations for food. Options IV and V should improve winter habitat for large fish and ducks, thereby increasing food supplies for eagles.

Fish require reliable aquatic habitat. The water must be deep enough so that in the winter it does not freeze all the way to the bottom and in the summer provides refuge from high temperatures. Fish populations are expected to continue to decline except under options IV and V, where deeper water storage should provide refugia under extreme environmental conditions. Under Option V, the deep-water reservoir is expected to provide habitat suitable for maintaining channel catfish populations, as well as populations of a variety of forage fish.

The seed-crop plants will exhibit a positive response to both the additional cultivation possible with increased manpower (options II through V) and the irrigation in options III and V.

The nesting cover for waterfowl can be improved with increased vegetation-manipulation capabilities. The additional dikes in options IV and V especially improve nest-site availability.

The invertebrate populations that constitute shorebird and spring waterfowl food resources are expected to increase with increased capabilities for water-regime management, particularly under Options IV and V.

Summarizing for Option I (no change), negative responses are expected for virtually all target organisms in dry years. Under these conditions, only

pheasants and carnivores are expected to prosper as the marsh takes on more upland characteristics. Although waterfowl food production may not suffer greatly, availability of the food will be compromised without adequate water for fall flooding. In wet years, Cheyenne Bottoms is expected to perform approximately as it does now. Infrequent flood events will undoubtedly have some effect on target organisms. However, this is not considered a serious problem, since high-quality marsh habitat can be expected to develop as the water recedes.

Option II is expected to significantly enhance marsh conditions when compared to Option I. Increased manpower and additional equipment would allow the staff to conduct more intensive agricultural activities and to better maintain the structural components of the marsh. Enhanced water-manipulation capabilities would increase the quantity and quality of waterfowl food and would allow more effective vegetation control. Waterfowl nesting would continue to be poor in dry years. Fish and nongame wildlife would probably not benefit very much in this option.

Option III will provide subtantial benefits in waterfowl food production due to irrigation. In general, Option III will do little more to improve conditions for fish and nongame wildlife than Option II. However, Snowy Plover habitat might be improved. Waterfowl food production will be concentrated into smaller areas, allowing other management practices to be employed at other sites throughout the marsh.

Option IV is predicted to provide modest benefits to virtually all target organisms. Most of the benefit derives from the creation of the 600-acre reservoir in the southwestern corner of Pool 1. The reservoir should improve habitat for nesting waterfowl, greatly improve the capability to flood seed crops in dry years, and provide refugia to maintain fish populations (thus

improving the food supply for Bald Eagles and other fish-eating birds). The flow enhancement of Blood and Deception Creeks should modestly enhance the water delivery to the Bottoms and ameliorate conditions in dry years.

Option V greatly improves habitat for most of the target organisms, in both wet and dry years. The benefits derive from the reservoir and from the increased capacity for manipulating water levels in the peripheral pools. Under this option, the management goals should be achievable in most years.

USER-BENEFIT ASSESSMENT OF OPTIONS

The type and degree of impact that each option could have on the various types of use-activities is evaluated in table 21.6. Once again, assessments were made for both wet and dry years. However, the only assessment that differs between these extremes is under Option I for non consumptive uses (e.g., birdwatching or environmental study). Otherwise, options II through V all exhibit increased user benefits in all activities except for fishing under options II and III where no modules are employed that increase the type of habitat reliability needed by fish populations.

The most substantial increase in use benefits for the primary activities pursued at Cheyenne Bottoms (i.e. waterfowl hunting and birdwatching) are projected under Option V. It is the opinion of the study group that Option V exemplifies the combination of modules that most effectively provides conditions toward achieving ideal management goals.

These gains in user-activity benefits under Option V would be directly attributable to similar biological gains shown in table 21.5 for this same option. Substantial increases in potential responses of gamebirds, shorebirds, and the provision of improved habitat (i.e. food resources and cover) should translate to increased opportunity for these particular user activities.

Table 21.6 Assessment of potential user benefits associated with proposed options.

	Options									
	I		II		III		IV		V	
	Dry[a]	Wet[b]	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Waterfowl Hunting	-	-	+	+	++	++	++	++	+++	+++
Other Hunting	0	0	+	+	+	+	+	+	++	++
Fishing	-	-	-	-	-	-	++	++	++	++
Non-consumptive uses	-	+	+	+	+	+	++	++	+++	+++

a = water supply for management during the dryer portion of the long term water cycle.
b = water supply for management during the wetter portion of the long term water cycle.

0 = no change predicted from present user benefits.
- = deterioration from present user benefits.
+ = improvement from present user benefits.

ADDITIONAL CONSIDERATIONS

INTRODUCTION

The purposes of this study were, initially, to evaluate the most important biotic and abiotic elements of the ecosystem of Cheyenne Bottoms and secondly, to identify a range of actions that could be implemented to maintain or enhance conditions.

Given the scope of the project and the huge array of enhancement possibilities, it was virtually impossible to consider every aspect of the ecosystem or to evaluate every possible impact that might arise. Thus, many elements either were not considered or considered superficially. The following sections provide some insight into the types of elements the study group feels would merit additional consideration depending on actions that might be proposed in the future. In other words, whatever courses of action are chosen for Cheyenne Bottoms will, in part, determine what kinds of additional studies will be required. These elements include considerations outside the management area proper, the identification of recreational needs, and various gaps in the current data bases.

Land acquisition and/or easements

Original land acquisition and development present certain physical limitations on vegetation management by water-level manipulations. Water depths necessary to control or eliminate undesirable growth and stands of emergent vegetation can result in some flooding of adjacent private land. In addition, current and proposed configurations involving more dikes or subpools do not adequately address the potential for uncontrollable flooding outside the confines of CBWMA during periods of heavy and intense rainfall within the basin. The study group has considered the potential for flood damage outside of the Bottoms area and many flood alleviation approaches were incorporated

into the various proposed physical alterations or additions. Increased pumping capacities, enhanced on-site storage capabilities and improved water manipulation associated with various options may help relieve minor flooding problems. However, infrequent but major flood events can occur within this basin as exemplified by the flood in June 1981. While recognizing this fact, the study group felt that addressing this problem through over-design of proposed physical alterations was beyond the scope of this study and represented high-cost solutions and compromises in management capabilities under "normal" wet and dry years. The most direct and perhaps least costly solution to major flooding of private land adjacent to the CBWMA would be the purchase of the property or acquisition of flood easements to areas known to flood under historic conditions. In order to better evaluate the possibility of such actions, an inventory was made of all adjacent private property located below the 1,800-foot contour interval. It was determined from past flooding records and the personal accounts of some local residents that floods do not occur above this contour. This determination was largely speculative and was not quantified but appears to offer a very conservative measure of flood limitations. The results of this inventory are presented in table 21.7 and identify approximately 5,523 acres potentially in need of direct acquisition or easement purchase. Land prices are highly dependent on current real estate values, existing property development, and land characteristics. The study group did not investigate individual land and easement costs. Private land acquisition or purchase of flood easements would offer a solution to the potential flooding problems associated with CBWMA and enhance the implementation of existing and proposed management goals.

Figure 21.7--Land outside of the CBWMA and below 1,800 foot elevation.

Township	Section	Area (acres)
Cheyenne Bottoms R12W,T18S	2	9.48
	3	138.25
	4	353.92
	5	41.87
	6	57.28
	7	355.90
	8	292.70
	9	162.74
	11	3.95
	12	39.50
	13	19.36
	18	252.80
	25	33.97
	35	213.30
	36	64.39
Total		2039.41
Logan R11W, T18S	18	0.79
	19	85.72
Total		86.51
South Homestead R13W, T18S	1	17.38
	2	116.13
	11	92.43
	12	499.28
	13	433.71
	14	337.73
	23	250.43
	26	229.10
	27	334.17
	34	94.41
	35	127.59
Total		2532.36
Lakin R12W, T19S	2	40.29
	3	188.81
	4	171.43
	5	135.09
	6	229.89
Total		765.51
Great Bend R11W, T18S	1	98.75
Total		98.75

OVERALL TOTAL = 5,522.54 ACRES

Outlet Canal

The inadequate nature of the current configuration and structure of the outlet canal from the CBWMA has long been known. The climatic extremes that can occur in this basin, the size of the area, the capacities of individual pools, and the occasional high volume of unregulated basin inflows contribute

to the outlet-canal discharge limitations (pers. comm., Kansas Fish and Game, 1986). Proper marsh management sometimes dictates quick and dramatic drawdowns, which are not always possible with current discharge capabilities. While beyond the scope of the study, this problem and other problems associated with the outlet canal have been addressed by M. A. Wilson (Engineer) in an undated memo to Kansas Fish and Game Commission (appendix 21.6). We suggest that if problems associated with the existing outlet-canal system remain an area of concern, a follow-up study be conducted based on the suggestions and opinions of Mr. Wilson in his letter to Kansas Fish and Game Commission.

Recreational Needs

During the course of this study it became apparent that this natural resource currently and historically provides opportunities for a large and diverse range of users and activities. While the primary objectives of this study were to identify, quantify, and assess problems and solutions associated with this management area, it is important to note that proposed solutions will probably enhance user opportunities. Thus, we must assume increased demands for recreation facilities. The study group respectfully suggests that at some point in the decision-making process, the ramifications of potential increases in recreational use be addressed.

Data Gaps and Refinement of Data Base

This study has resulted in the development of a rather extensive data base that addresses many aspects of the ecology, hydrology, geology, management, and use of CBWMA. It is inevitable that during the course of any study, data gaps are discovered that can not be resolved because of imposed time and/or financial limitations. In addition, refinement and better

quantification of some parts of the data base are desirable so that better assessments or evaluations are possible. The following topics briefly address some of these data concerns:

1. Development of a flow-gaging system to monitor water import to and export from the Cheyenne Bottoms basin is desirable. The monitoring of flows derived from Dry Walnut, Walnut, Blood, and Deception Creeks along with gaging stations along the inlet canal would provide needed data regarding inflow quantities (and losses in some cases) reaching CBWMA. This information would be useful for Cheyenne Bottoms management and provide data for better determining water budgets.
2. More accurate determination of water quantity and quality associated with the shallow- and deep-water aquifers located in the sand dunes area is necessary. While some predictions have been made on the quantity and nature of potentially available water for irrigation purposes in Module 3, a number of assumptions were necessary because of data limitations. A better measure of available freshwater would be desirable so that more precise information regarding water yields, well-field development, and costs could be generated.
3. The water budget presented in this study was estimated using the best available data. When more complete data are available from the climatologic instrumentation at the Bottoms, more accurate estimates of the annual water budget can be made. This refinement is scheduled for spring, 1987 in an additional study by the KGS.
4. Most of the ecological processes occurring in the marsh have been outlined in Chapter 18, but our knowledge of many of these processes is limited. A better understanding of the energetic relationship between living plant material, detritus, invertebrates, and waterfowl would provide wildlife

biologists and ecologists with practical data concerning marsh functioning and management strategies.

5. Development of definite shorebird management strategies is suggested because of the importance of this resource to many of North America's shorebirds. It is already known from this study that many shorebirds are dependent upon aquatic invertebrates as a food resource at CBWMA. Currently, we suspect that invertebrate production is correlated with water regimes. The resulting physical, chemical and biological conditions associated with various water regimes have a great impact on the kinds and numbers of invertebrates found there. Those factors affecting both invertebrate production and shorebird-feeding habits need to be defined so that specific management strategies or techniques could be determined.
6. The relatively recent and expansive invasion of CBWMA by narrowleaf cattail has created problems for both water and wildlife management. Therefore, control of the plant must be considered in future management practices for the area. While a number of ecological studies have been made of the plant, most have been conducted in regions not comparable to the central Great Plains. Therefore, a good case can be made to examine growth parameters of this cattail at the CBWMA to facilitate the control and/or use of this plant in managing the habitat for the future. The impact of the marsh moth caterpillar foraging on cattail populations should also be investigated. In addition, the effects of other invading plant species, such as salt cedar, should be more clearly identified. This and other introduced species can be very difficult to control once they are firmly established.

Appendix 21.1

Attendance roster for Task Force meeting held in Moore Hall, University of Kansas, Lawrence, Kansas on December 16, 1986

Name	Agency	Phone
Wayne Hoffman	Kansas Biological Survey	913-864-4775
Don Huggins	Kansas Biological Survey	913-864-4775
Paul Liechti	Kansas Biological Survey	913-864-4775
Tom McClain	Kansas Geological Survey	913-864-3965
Lynn Vogler	Kansas Geological Survey	913-864-3965 x 346
Joe Kramer	Kansas Fish and Game Commission	316-227-8609
Darrell Montei	Kansas Fish and Game Commission	316-672-5911
Kent Montei	Kansas Fish and Game Commission	316-672-5911
Stan Wood	Kansas Fish and Game Commission	316-872-3551
Jerry Horak	Wildlife Society	316-342-0658
Jerry Hazlett	Kansas Wildlife Federation	913-266-6185
Tom Mosher	Kansas Chapter Amer. Fish. Soc.	316-342-0658
Larry Kramer	Ducks Unlimited	913-294-2102
Dave Ranney	Harris News Service	316-947-2567
Elmer J. Finik	Kansas Ornithological Society	913-532-6629
Dave Parr	KU Dept. of Civil Engineering	913-864-3807
Tom Kneil	KS Chapter Sierra Club	316-744-1016

Appendix 21.2

SAVING CHEYENNE BOTTOMS II

November 22, 1986

Great Bend, Kansas
Fine Arts Building
Barton County Community College

8:15 - 9:00 a.m.	Registration and coffee
9:00 - 9:20	Welcome and overview Jan Garton, Kansas Audubon Council Jerry Hazlett, Kansas Wildlife Federation
9:20 - 9:30	Introduction to feasibility study Ed Martinko, Kansas Biological Survey
9:30 - 9:50	Continental perspective on wetlands and wetland problems, an introduction to Cheyenne Bottoms Leigh Fredrickson, University of Missouri
9:50 - 10:20	Hydrology and related studies Tom McClain, Kansas Geological Survey
10:20 - 10:35	BREAK
10:35 - 11:30	Hydrology (continued)
11:30 - 1:00 p.m.	LUNCH
1:00 - 1:30	Vegetation and invertebrate studies Leigh Fredrickson, University of Missouri
1:30 - 2:45	Vertebrate studies Wayne Hoffman, Ornithological investigator
2:45 - 3:00	BREAK
3:00 - 3:20	Economic study Shirley Sicilian, Institute for Public Policy and Business Research
3:20 - 4:00	Overview of tentative options Don Huggins, Kansas Biological Survey
4:00 - 5:30	Public comment and questions Darrell Montei, Kansas Fish and Game Ed Martinko, Kansas Biological Survey
6:00	BANQUET
	Keynote speaker: Joe Kramer, Southwest Regional Wildlife Supervisor, Kansas Fish and Game

CHEYENNE BOTTOMS FEASIBILITY STUDY - PUBLIC MEETING

On November 22, 1986 a public meeting was held at the Barton County Community College to discuss aspects of the Cheyenne Bottoms Feasibility Study. Approximately 75 people were in attendance to hear reports on various components of the study. A public comment and question period was held after the presentations. The following discussions took place:

Question: It was stated that the goal would be to manage 3,000 acres of wetlands, but the area now has about 12,000 acres of wetland. Why is the wetland area to be decreased?

Answer (KBS): I would like to begin by saying I think you have a little misconception of what we intend. We talked about having at least 3,000 acres devoted specifically to providing the kinds of marsh land habitat that is good for waterfowl on a predictable basis. That is not our intention as a maximum for marsh management. In a managed marsh at any given time, there may be some areas of deep water storage, some areas drained to grow crops, and some areas drained to control cattails. We are still considering a 12,000 acre marsh in our options.

How much is marsh, how much is wet and how much is dry would be determined by the annual water supply. There would be some dry years when there is not much marsh there no matter what is done.

Question: You're saying there's 3,000 acres of minimum pumping less evaporation all the time we hold it for each spring migration, that's the goal thats set?

Answer (KBS): No that's not the intention. We haven't set a specific goal, we think that at least 3,000 acres is necessary and we think that a migration wetland habitat may not be quite as difficult to provide in the rotation of other management goals and therefore is not so necessary to set specific acreage goals up front. We do feel the marsh is far more important for high quality waterfowl food during spring and fall migration.

Question: Could you show us how you arrived at that goal once again?

Answer (KBS): 3,000 acres was the minimum. Even in dry years, we would like to at least have 3,000 acres of managed marsh. The bottom line is that goal No. 2 would provide at least 3,000 acres of managed marsh. That is a minimum, obviously the area may be quite larger depending on the total amount of water available. But as a worst case scenario, there would be

a 3,000 acre area that would be intensively managed to provide the continuity that's necessary to maintain the area.

Comment: I think you should change the No. 2 goal statement to more accurately state what you have explained.

Answer (KBS): We can certainly do that. The other thing to consider is that we want to maintain these 5 goals simultaneously, these are not alternatives, but 5 goals together. For example, we may be talking about 3,000 acres of mud flat habitat for spring use and at the same time using 5,000 acres that we want to flood for waterfowl. Obviously, that implies that we have to have a reservoir or some sort of water storage to have water to flood back with. All of these things should be working together.

Question: On the possible use of the sand dune field and for the Wet Walnut well field currently used for irrigation, wouldn't it be more sensible to just purchase those grains from existing farmers than try to irrigate at the Bottoms?

Answer (KBS): The point was that natural foods are irreplaceable and critical for waterfowl management and the goal was to irrigate natural vegetation. We know that by irrigating natural vegetation and other area environments we can greatly enhance two things. We can enhance litter production which will then give us more invertebrates and we can enhance seed production. And for example, in the Sacramento refuge we can produce over 2,000 pounds of millet per acre with a single irrigation and in the San Joaquin Valley, which has conditions more similar to what we have at Cheyenne Bottoms. Given that we have suitable soils and nutrients available, I think with the correct timing of irrigation, we could greatly enhance production of these wild foods. We are talking about doing this on a rather small acreage, which would match the recharge available from the sites. In that small area, we could flood it using minimum water amounts and be assured that we have a large amount of food available on an annual basis during the dry part of the cycle. That's the rationale behind using that particular site.

Question: My understanding is that the estimate that is made for that option includes the cost of purchase of some parcel associated with the sand dune land, is that what you related?

Answer (KBS): No, actually we were looking primarily at leasing water rights and developing a field, but outright purchase of a parcel of land to put the field on is a possibility.

Question: If an option is chosen to improve Cheyenne Bottoms, will the funding be expected to come from the Fish and Game budget?

Answer (KBS & KFGC): I think the expectations of where the funding will come from vary depending on which audience you're talking to. Obviously, I think there will be an inclination for the expectation that funding would come from Fish and Game, because it is a Fish and Game managed area. On the other hand, I think that quite often the area has been perceived as an area that has been predominantly used if not mostly used by the sportsmen. I think particularly some of the usage data indicate that there are many other uses of the area other than for just hunting purposes. Consequently, that opens further the question of who should provide the funding to implement some of these options. Needless to say, that will be addressed by the legislature and, again, its anyone's guess how they will proceed with that.

All along there has been talk about if anything is possible and anything is desirable to be done to the Bottoms, how is it going to be funded? Much of our energy has been channeled so far in how to come up with answers regarding is there even a future for the Bottoms and is there a need to do something? First, we all have to agree that there is a need; secondly, some kind of plan of action developed and then identify some kind of funding source. There really has been no detail work gone into that. I would say at this time the door is open for about any discussion on any type of funding.

Question: We keep talking about these dunes and wells east of the Bottoms, I've been involved in this area for 28 years. I've got customers out there and there have been 3 homes that they couldn't build out there because they couldn't get suitable water and I know of 4 wells that were drilled that was too salty. I'm wondering where we are getting this kind of water from, because we are right east of pool 3 right now with one well that's less than 3/4 mile from the east edge of pool 3, and its so salty that the cattle won't even drink it.

Answer (KGS): When we drilled our original observation well that we had on the east edge of the Bottoms, we picked up some very high quality recharge water from precipitation. There is a thin lens of only a few feet of fresh water on top of the poor quality water that you describe that could possibly be tapped with some small wells. Our concept is not to provide thousands of acre-feet of water. We're looking at a minimal amount of water to irrigate some millet for feed crops on the Bottoms. This would involve only a few hundred acre-feet and no more than that, pulled off the top of this fairly thin lens. I can't tell you that I know exactly how thick that lens is or what the extent of it is at this time. We are fairly sure that its there. Our observation wells plus others in the area shows that to be true. What we are talking about is a number of shallow wells of fairly low capacity that would tap the top of that fresh water lens and provide a small

amount of water for irrigation. More exploratory work would be necessary to determine how much water is available.

Question: Well I'm the new kid on the block, I just moved to Kansas a couple of months ago and I'm going to ask the embarrassing question. It looks from my point of view, seeing everybody talking about a technological solution to a problem because nobody wants to go after it. The real problem is that the water has been stolen from Cheyenne Bottoms and used by irrigators primarily. Why not go in there and fight for what is yours, instead of listening to these technological solutions that may not be the answer anyway. You may have to end up going in there and fight for what belongs there and has belonged there all along. It's like the sacred cow you can't touch.

Answer (KBS & KGS): First of all the answer to your question on the surface may seem that that's the obvious route to take. However, the question that you're asking and the answer in terms of going after the irrigators and those who have used the water is a much more complex issue. First of all, I think it would be very difficult to make a case that this water has been stolen. It all goes back to water law and water law in Kansas which has a very long historical aspect to it that is not likely to be solved very easily. Addressing that kind of a problem, which again relates back to these water laws for an area this size, becomes a very complex issue, and one which I would assure you would not be solved very shortly. In the meantime, of course, the Cheyenne Bottoms is confronting problems of a much shorter term nature that needs some action that addresses them early on.

Kansas presently has a case before the Supreme Court to try to ajudicate some of the water problems with Colorado. I can't tell you what will happen there. Kansas has tried before to take Colorado to court and it may take 10 years or more to get the case through court. The results--that I can't tell you either. It may be a very long, difficult process.

I think the point is that not only will it be long and difficult as with the case of Colorado results have shown, but again I would emphasize that the kinds of problems we are confronted with at Cheyenne Bottoms are problems that we need to address now. While on a long term basis, as you point out, perhaps some of those need to be addressed. I think our most immediate concern here is what kinds of actions should be taken now.

Question: It seems to me that a philosophical contradiction to irrigate and save Cheyenne Bottoms when irrigation is part of the problem, that is just a comment question. The question I have is, if we are losing so much water in the inlet canal, why wasn't that considered in any of the options?

Answer (KGS): Part of the answer is that the inlet canal was considered. The problem is not only the cost of providing an impervious surface, but the fact that the impervious surface for the route we are talking about would not necessarily solve the problem.

There was water loss throughout the whole inlet system. We estimated was the cost to do the first seven miles of the inlet canal would be about 2.5 million dollars. We don't have the data available to say how much value would be gained by lining the inlet canal.

Question: What you are telling me is the study didn't find out enough about the inlet canal to consider lining as an option. It was an option that was considered based on that first seven miles. The problem was the rest of the miles we don't know enough at this point to go forward on inlet canal improvement.

Answer (KGS): We looked at this fairly seriously, about the losses in the canal and looked at liners, we looked at concrete, looked at plastic, looked at PVC pipe, we looked at a whole bunch of options. The canal as it is now is 22.7 miles, lets call it 23 miles, something like that. If we looked at concrete liners, which was about the cheapest of the options we had, we're talking about $300,000 a mile for a ditch large enough to carry that kind of water. So $300,000 times 23 equals a pretty sizeable investment in ditching. At that point, we tried to weigh whether the amount of water we were getting from the Ark and the Walnut, which is decreasing every year, on the long term average, was worth the investment. At that point we felt there were other options we could consider that would be more economically feasible. We did consider this fairly seriously and if you are interested we can put that in there. It added up to so much money that it made it very difficult to justify.

And in addition, you should keep in mind that not only is that expenditure of concern, but also the efficiency with which the water would be used when it got there. We attempted to take the approach of how much water do you really need to maintain the biological integrity of this area. Improvements to the inlet canal will result in a certain amount of additional water coming into the Cheyenne Bottoms. But that doesn't address the very serious problem of evapo-transpiration and the efficient management of the water once it gets there. It is a complex issue and I think the cost of providing somewhere in the range of $7 million to do that entire 23 mile area becomes problematic when you are not exactly sure how much water you are going to net at the Bottoms when you haven't addressed the other problems of evapo-transpiration.

Question: You don't show us which one of those options address these goals. The reason I want to throw this out so I know which one of these options the people should be for.

Answer (KBS): That is the intention of these tables to address that to a certain extent.

Could I say one thing about the canal. In 1961, a very good hydrologic study was done and one of the options that was considered at that time was improvement of the inlet canal. In 1961 there was far more water in the Arkansas River that there is now, but at that time they said that it was not a feasible option and its much less feasible now than it was then. There is not that much water anymore.

Comment: There is a viable option, purchase the water rights of irrigators.

Answer (KGS): Yes, that is a viable alternative. I think one thing that was confusing that I was talking about the inlet canal. We talked about significant losses, but that's only relative to the total flow that comes down the canal. I don't think there are significant losses relative to how much water comes into the Bottoms because we don't get much down the canals.

Question: Everybody says that we should study the wetlands because of the big losses occurring. You have talked today about the big losses, yet I never hear about Quivira. I know that Rattlesnake Creek was dry a couple of times or at least I'm told. I was curious if any of your studies show the feasibility of managing Quivira in cooperation with the Bottoms.

Answer (KBS): I think I can answer that question by saying no. I think we all recognize that we have problems with wetlands both throughout the United States and in Kansas.

Quivira is a great marsh as it is productive and useful. It is a different kind of a marsh and some of the things that Cheyenne Bottoms can do, Quivira can not, and vice versa. In particular, because of the difference in soil types, Quivira will probably never provide the densities of spring invertebrate food that Cheyenne Bottoms does. In answer to your question, I think yes, it would be very nice and may well be feasible to sort of split responsibilities, some kind of organisms in one place and some kinds in the other. This would require a great degree of cooperation from the federal government and the state. Perhaps more than is available now, but certainly not impossible. I hope we don't get into the idea that if Cheyenne Bottoms drys up we still have Quivira. They are very different kinds of places and Cheyenne Bottoms

does a number of things that the soils at Quivira just won't support.

Question: I didn't see any information presented on your channelization option. Surely there would be an ecological effect for those flood plains outside of the Bottoms area. I'm also sure you are aware that Fish and Game has cooperated with the Water Authority and the Water Office to generate a proposal for the upcoming legislation on channelization in the State of Kansas. Where is the data to back up this option?

Answer (KBS): We presented this as a potential mechanism of getting water onto the basin and reducing some of the water infiltration during moderate flooding on Blood and Deception Creeks. We realize and actually stated that this involves the need to address the kinds of things that you are suggesting in terms of 404 permitting, state regulations and the other requirements. During the time period that we had, we certainly could not approach it in the detailed manner that you are suggesting. I think the type of channelization that we were looking at is different than one normally associates with major channelization programs.

Question: Does this presentation today complete the survey or study?

Answer (KBS): The answer to that question is that the presentation today is an effort to give the public some indication of where we are at this point before we begin putting the final report together. The questions and comments that are raised today and even after that will help us put together the final report.

We are required by the legislation to deliver a report to the legislature at the beginning of the 1987 legislative session. We can go ahead and continue some items if we can find the resources and the people available to do the work. However, for most part, the results of this eighteen month study will be completed in early January of 1987. Now, I might add at this point a little bit about that. There will be a fairly sizable report that will be generated it will present in detail all of the information that was given here today. In conjunction with that report there will be a executive report that will be widely disseminated and that report will have an overview and summary of the kinds of information presented here plus additional amplifications that result from this meeting and any other public input or comments that we receive. That report will be more widely disseminated. The full report will be available, but there will be a cost associated with the actual full report. In other words, the full report will not be disseminated free of charge because of the reproduction costs.

Question: Who do we direct our requests for reports to?

Answer (KBS): For the full report you can direct inquiries to Biological Survey or the Kansas Geological Survey and executive reports will also be available through us or the Fish and Game Commission.

Question: Option 4 on the potential responses on target organisms - Option 1 through 4. When I look at that, option 4 is a pretty good option. This essentially works all the problems that you have listed here. In fact, it enhances the Cheyenne Bottoms in practically every category except pheasants which its not supposed to do anything with them anyway, and whooping crane habitat will at least remain constant so that looks to me like a pretty good option. To add on the cost of those options that you have on this other page (less than the cost of option 3), it says $676,000 plus the increase in operations, is that right?

Answer (KBS): I'll have to look myself. This says that with $780,000 you can really do a major improvement at Cheyenne Bottoms, plus the increase to operate the improvements.

Question: Where sir are you getting the $676,000?

Answer (KBS): Well, I go over to the cost of such proposed module and add the dike in pool 2, $105,000, add dike in pool 1, $362,000. Mobile pumps and stations $118,000, Blood and Deception flow enhancement $91,000 and that adds up to $676,000. So you are concerned about the cost difference?

Question: No, I think that's great. I just want to know if I understand what's proposed.

Answer (KBS): Basically yes, if you look at the next page, of the economic assessment, we come up adding those figures plus a few more that are not included for $780,000. The difference between the number you got and this number is in development of 8 mobile pump sites at $13,000 each. Those didn't get listed specifically because we did not have the price per each as when this set of figures was prepared.

Question: You're saying for less than $1 million you can do some improvement. It'll be better than it is now.

Answer (KBS): I think essentially what we are saying there is going to a much more efficient utilization of the water that will be available to that area. So even during the dry periods the more efficient operation of that area from a management standpoint will improve the overall condition of the area.

Question: Along that line, if you look at the goals up here, the first 3, probably would be the optimal management to get what you want to get. I would take it that option 5 would get you to that. If that's the case, if you chose option 2 you get 30% to that, option 3 would get 40% to that, option 4 would get 70% to that, and option 5 would get 100% to that. Is my understanding right? How are you getting these percentages. From your + and - on here. You got 10 on option 5, 7 on option 4, 4 on option 3. Are the + and - judgments of the potential of your goal?

Answer (KBS): They can't be added to that precisely. For example if we look at this chart of responses of the target organism.

Comment: If it doesn't, you ought to try to do that in your final report.

Answer (KBS): The problem is how do we compare a dollar value helping habitat for whooping cranes to helping habitat for geese, to helping habitat for pheasants, to helping habitat for muskrats. Those are things that there is just no real validity to saying a whooping crane is worth 15 muskrats, or anything like that.

I understand what you are saying, you're saying that it would be nice to have some indication of the degree to which each option would address the overall goals. I think that is something we can take into consideration when we are putting the report together, that is a very good point.

Question: Is this going to be only a band-aid or is it going to be a long term solution depending on the controlling use of ground water by irrigators?

Answer (KBS): I don't think at this point we can plan in the near term for any increase in ground water flow in two major streams, the Ark and Walnut from cessation of irrigation, not unless wheat goes to fifty cents a bushel and corn goes to a quarter.

What this will do will help us manage and conserve what water we do get at the Bottoms. That's the best way I can put it. It will allow us to, remember that pie diagram, it will allow us to cut some of the evapo-transpiration. It might allow us to help cut some of the seepage and expand that little narrow 3% maybe up to 4 or 5%. At this point, I think that we have talked about this for quite a while and we really don't have any magic solutions to water resources which seem to be the cause of the problem. We are going to have to bite the bullet and make do with less.

Question: Assuming that we spent this $780,000, how long do you think that this will provide a solution?

Answer (KGS): I think that our estimates of surface water supply for the Ark and Walnut particularly, are equal to or less than what we have now over the long term average. Now if we get 3 years of increased rainfall, then we might get some more flow. Looking at the statistics at this point, I can't see any reason why we would get increased flow in the Ark or the Walnut so we're dependent pretty much on runoff from Blood and Deception Creeks to add water to Cheyenne Bottoms. We take water from the Ark and Walnut when its there. We talked in the discussions of setting up the options about the lifetimes of the engineering options. We brought in the dikes and the pumps and all those sorts of things and that lifetime on those engineering monuments is fairly limited so we are talking about long term maintenance. I don't know if that answers your question or not.

Question: Isn't the principles gone from the contributing channels in general? Basically.

Answer (KGS): The irrigators have lowered water levels greatly. Once you get the baseflow, the ground water level, low enough then you can take it another five feet and it doesn't affect flow anymore. I think that is where we are now so we should be relatively constant. Our supply mostly comes from surface water: precipitation and then runoff into the Bottoms. Statistically it is going stay about the same. The problem now is that we have a wetlands area designed to function on more water than we are going to have in the future because the pools are so large. We take a certain amount of water and put it in pool one for storage now and it is only six inches deep. If you put the same amount in the six hundred acre compartment, and it's two and a half feet deep, you reduce your evapo-transpiration maybe on the order of seventy or eighty percent. We are trying to reduce our losses. New water supply is limited. We can increase it a little, but nothing significant.

Question: I have one more question. If you are talking about the ground water level and the relationship with the ground water to rivers it translates in my mind that when you have lower levels in the Bottoms, ground water levels are also lowered.

Answer (KGS): The Bottoms is pretty much like a bowl and relatively impermeable. It's filled with silt and clay primarily. What's in there hasn't changed. We looked at some records for the Wilson Company from when they built some of the original dikes and their depths to water in quite a number of observation wells (test wells) that they had around the

Bottoms were on the order at the land surface one or maybe two feet below the land surface and that hasn't changed. The instrumentation that we have at the Bottoms now near the office indicates that when it rains the ground water level comes right up the land surface and when it stops raining, ET takes over and the ground waters decline very rapidly. You can see them decline diurnally. Each day when the sun comes up, plants transpire and ground water levels drop. At night, that slacks off a little bit and it comes back. But, we haven't lost much, if anything, of the ground water resources that were already there at the Bottoms.

Question: Two years ago when I came up here, I had visions of artesian wells sprouting out of Cheyenne Bottoms and ducks flying through the air and all of this. I think that I have a new perspective on this thing and I'd really like to give you guys an okay early. I think that I was looking down the road for something that really wasn't there and your presentation today has really brought me back to earth and made a really realistic picture of present conditions.

I have a question relative to the channelization of Blood and Deception Creeks.

The channelization of Blood and Deception Creeks is going to shoot the water down here a little bit faster. But, I believe in your presentation earlier you said the water that percolates into the ground eventually moves towards Cheyenne Bottoms anyway. Is the channelization essentially going to be putting water on top of the bowl whereas if you didn't do anything it would go into the bottom of the bowl anyway. Will the same thing occur with or without any channel work?

Answer (KGS): Well probably the whole point in this channelization was to try to get the water which is restricted from going down the channel and getting to the Bottoms now to get to the Bottoms quicker and be able to use it for management purposes.

Question: My question, though, is that water really lost or is that water that is percolating in actually becoming part of the Bottoms, the whole alluvial type Bottoms area?

Answer (KGS): Loss in this case is defined by whoever uses the word, so I would have to agree with you there.

Question: Taking water away from the alluvium and Blood and Deception Creeks and putting it in the Bottoms a little bit faster will still have some percolation down. Would you be just reversing the cycle here?

Answer (KGS): No, I don't think so in this case. Particularly for the channelization, we are looking at it from a very short term effect. The amount of precipitation and recharge that we get on the Bottoms basin I think will probably keep groundwater full in that area and our assumption was by channelizing we would get the water into the pools a little faster. But you are correct in that we would pass up some of the seepage that might get into the groundwater system to start with.

We would reduce the spreading a great deal and as you increase the surface area of a parcel of water you increase the evapo-transpiration. But, if this same parcel of water is channeled you can get more of it into deep pool storage. Thus, water surface and evapo-transpiration is reduced.

Question: So you are saying you are not going to be losing the water that is already flowing in through the alluvium, there has got to surely be water flowing in through the alluvium.

Answer (KGS): Yes there is. Early in Tom's presentation this morning, he talked about the Ark River and the pumping test. The alluvium in Walnut Creek valley and the Ark Valley is very different from the alluvium in Cheyenne Bottoms. Ark River and Walnut Creek Valleys are gravel and sand. It holds a lot of water. But, the alluvium in Cheyenne Bottoms basin is composed of clays and silts, much less permeable with very slow movement of water up, down or sideways.

Question: Would someone want to comment on the difference between options 4 and 5 in long term prognosis for Cheyenne Bottoms? Option 5 is about 6 times as much. Sounds like it does everything. Could you please translate that into what happens if you do one versus the other?

Answer (KBS): One thing that we have not talked about in terms of cost is the way we approached this. We called this whole process modules, or actions, or a bit of machinery, or some discrete thing that we thought would help. Because it's approached in that manner, we feel that you can actually implement this type of program over a period of years. You can coast in to it. So I don't think any of us came here with the idea asking for $1 million or $5.7 million right now because that's what it takes to get something moving on this. What we would hope to address further down this whole process is that we are early into this whole assessment process. We came here with ideas but not final products because we felt this was the place we wanted to be at when we began to talk to you folks. We hope to go home and begin to finalize some of these things. So we have heard some of your concerns and one of the things I think we will address in the report is cost incrementing into these approaches.

I also would add, that the idea here was that 5 is perhaps what we would foresee as the most that we could see economically that could be done to incorporate many of these actions. That is not to say that you couldn't do more, but what we are saying is that if you decide to do this over a period of time, we would probably look at 5 as a culmination of actions that could be taken. Hopefully you could implement the actions that would have the greatest impact. That isn't to say that others might not also have an impact.

We offered 5 options and 5 is no magical number. We offered 5 options because of the time limitations. Because we have to go through a total assessment process, we begin to think of these things working together. And to do some kind of biological evaluation assessment and then look at that in terms of gains or losses and user needs, and expectations, we ended up with 5 options. We are here to consider the need for more options or at least consider your opinions of this approach and the practicality of some of these modules.

Question: How do you envision this being presented to the legislature, a series of options or what?

Answer (KBS): Our presentation is to Fish and Game.

Question: How does the Fish and Game address this? Is it better to give the legislature 5 options, or one or how do you plan to go about that?

Answer (KFGC): These are going to be conceptual thoughts. Quite frankly, we've been exposed to this the same time as you have today, for the first time. Its kind of on purpose that way, so these people would have the freedom to go ahead and develop things that they best saw fit. We will be working with them closer now. There may be some other options, some mixing of options, some things that will come up today, some thoughts that maybe we had that we'll ask them to look into and then there will be a final report that will address a number of options. It might be premature to say that we will have final recommendations because our Commission is the one that will have to make those final type of answers and there is not a lot of time between now and December. But the report will be made and we are hoping over a short period of time, like at least the next year, sit down and really study the thing, work with the people, see what we want to do, what its going to cost, and where the funding might come from. How the Commission might feel may be different, because they will be exposed to it for the first time Monday at their Commission Meeting. We will brief them at that time a little bit about this meeting and the report.

Answer (KBS): I would like to make a comment concerning your question and a couple of the others on our plus and minus assessment system. A single plus does not mean we are going to meet these goals, a single plus means it will do at least a little better than current. We can provide a little more duck food or a little more goose food, a little better habitat for shorebirds. For the particular things we addressed to really meet these goals is about the equivalent of 3 pluses.

I think what its going to come down to is an overall concept for Cheyenne Bottoms. We are going to get what we pay for. I think that it may be that there are some other combinations of modules that will do about as well as 5 for a little less money. But to really meet the goals is going to probably take something on the order of magnitude of 5. Now there are two particular places where things really change in this table. Table 4 has a whole lot fewer minuses than zeros, or option 4 has a lot fewer minuses than zeros than any of the others. Option 5 has a lot more double pluses. The particular modules in there that seem to really make the difference are the dike dividing up pool 1 and the deep storage in pool 1. That gives you different kinds of habitats, it gives you much better water storage and all sorts of benefits derived from those particular modules. That is the main reason, for example, of the difference between 4 and 3. Its that one dike and control structures that's doing most of that.

Question: I don't know all you people, but I believe its Dr. Fredrickson who talked about wetlands and seemed to have a pretty good background on wetlands. I would like him to give his personal feelings about what he sees in all this.

Answer (Dr. Fredrickson): First of all sir, its a real pleasure to work with the people here in Kansas who got together this information. I don't think we've ever had this amount of abiotic data available to make decisions about biotic management. It's typical that generally one is really flying by the seat of our pants in so many places. The information you have before you today is not all that pleasant in terms of what we have in terms of water, but at least we have it. I think it is absolutely essential that we have these sorts of pieces of information in front of us to make realistic decisions. I think you have to be optimistic and I think as we understand how wetland processees work and as we gain experience in what resources are needed by birds and when they are needed, then we can make better use of scarce resources, water and foods or whatever, to try and better meet the needs of these critters. So that they are out there for us to enjoy either by looking at them or hunting them. I don't have a personal opinion about what way is best to go and that is why we came up with one of these intermediate steps because I think the people of Kansas need to have their own script to

say what kind of options you want to put together. We put those five together which kind of run from nothing to the very best we can perceive and the intermediate ones are flip-flopping different sorts of benefits and hopefully you can then look at the series of modules and say this is doing this or that. You can restructure these in a way that you think might provide better benefits for the state of Kansas with the dollars that you are willing to try to fight for or spend.

Question: Should consideration be given to using waste water from Hoisington or Great Bend to use at the Bottoms?

Answer (KGS): This is a real good point. This is something we considered in the whole realm of possibilities of water supply, ground water, surface water, and everything else. I think that might be a viable option to look at. The city of Hoisington presently disposes of their sewage by putting it into some ponds, it seeps into the ground or evaporates into the atmosphere. Everything comes down to cost/benefit, if it would benefit you enough to put that water over onto the marsh or use it there or whatever you want to do with, then I don't see that there would be any problem negotiating with Hoisington about using some of that water.

Question: Would it be acceptable to use this type of water in the Bottoms?

Answer (KGS): That does bring a question up in terms of water quality. Not that ducks must have high water quality but when you begin to perceive uses for sewage water, then you have to be concerned for the water quality. When you bring that kind of water in, you open up a whole bag of questions that I don't know if we have answers to.

The cities have to have secondary waste water treatment. This question is something we tossed around and generally assumed that the supply wasn 't large enough to really seriously consider, but it could be explored. You would have to look at the quality problems, bacteriological problems, the source of the water and a number of other things.

One comment: since we stuck to water quality in using refuse water and these kinds of things, you can do good treatment and get good quality water. There is also the possibility of an accident such as a plant break down or have something really toxic dumped into the water that the system is not built to handle, like insecticides, and cause all sorts of problems downstream. This is something you want to really watch out for with a natural area or marsh.

The city of Hoisington puts their treated water into the creek and that creek is dammed off so that goes through a private

gun club before it will get to Cheyenne Bottoms. There is another gun club and they have a dam on Deception Creek. They have taken water twice this fall that Deception Creek has been up and only the last time did the water trickle over the dam and come to the Bottoms. There are two private gun clubs above Cheyenne Bottoms and they can get water from Blood Creek or they can get it off Deception Creek.

Question: I think the concept of the deep water storage is going to have to be inevitable at some time but it appears by the data that the cost didn't mean that 600 acre .....

Answer (KBS): That's about right.

Question: I didn't realize it was that much.

Answer (KBS): One dollar a yard it works out.

Question: Why can't you just jack up the dikes a little bit for the same deep water storage. Make your dikes a little bit higher instead of digging down.

Answer (KBS): You could. That's a pretty good point. And maybe could be looked at further. You would just have to pump it a little higher to fill it up. In this deep water storage thing, one thing we haven't brought out is that gravity flow won't get the water in there. When it is only a foot deep on the outside, you will need to pump it up to this 4 or 5 foot level. That is an option we could think about.

One thing was brought to our attention by a gentleman that had to leave early. The actual design of the dike system never stored water at what was considered optimum for storage because of the wave action and potential erosion on the dikes. Rip-rapping and controlling erosion was suggested so we could actually fill deeper and gain a little volume. That's one of the things we'll go back home with and look at.

There has been nothing said about the outlet. There is a lawsuit right now, because landowners had water on their land. Great Bend had 22 inches of rain, part of it was over in the Bottoms watershed. A week later, there's 12-14 inches of rain northwest of Hoisington with 7-8 inches of rain clear around the Bottoms. The Boyd recording station recorded 16,000 acre-feet of water through it in 24 hours without taking any other inflow between Boyd and Cheyenne Bottoms into accounts. We have an outlet that will only let out 400 acre-feet of water per day. I think we need to look at that.

These mobile pumps will help that some, but it won't do enough. If you design it for the 100 year floods, the cost is prohibitive.

We have had that happen 3 times in the last 25 years and we have had water clear up against the boundaries and you have to let it out.

The mission of this wasn't to look at flood control. Flood water is a problem, there's no question about it.

Question: What I'm asking about is when we got high water on peripheral dikes in pools 3 and 4, we lost them both. These dikes that are proposed now, you'd have to leave them pools dry for 5 or 6 years to get them grassed enough to hold. If people right now knew what was under that grass around pool 1, and down some of them roads that the rocks and stuff that was hauled in there to hold them dikes. I hunted that place before the dikes and after the dikes. I saw them about lose the whole place. The people would faint if they knew what was hauled in there right now just to save them dikes from washing out. Because when we get them 30 or 40 mile winds out here and you have water, them dikes are going to go.

Question (KBS): Did you have peripheral dikes out there at one time?

Comment (Audience): There were peripheral dikes in pool 3 and pool 4 behind the blinds. They were made about 4 foot high and about 30 or 40 foot wide at the base. They couldn't hold due to the ice in the winter time working on them and the winds, they couldn't hold them.

Question (KBS): Because the waves took them out?

Comment (Audience): Because the waves took them out. This is why I've been so unhappy, because nobody locally in this area knows the Cheyenne Bottoms--that was born and raised around here and spends so much time in it and why they weren't talked to about some of these things. Because I've worked for farmers out there, I know the place like the back of my hand. And here's the manager sitting right here, that been managing it and he wasn't even there, officially anyway. And the wind out there plays one tremendous part in that Cheyenne Bottoms. You can go out there right now and there will be big white caps on pool 1 and maybe even pool 4.

Question (KBS): Wouldn't dividing pool 1 into the smaller pools help?

Comment (Audience): Not in the perimeter pools it wouldn't affect that, which is what he was talking about. Peripheral dikes, based on this would have to be as high as the dike number 1 and water level would have to be kept down to a maximum required.

Question: Would you address this, your local authorities and individuals that had information, were they consulted, was there nothing done locally? You talk about not having information available for your study and I'd like you to address the gentleman's comment.

Answer (KGS): I'll take a whack at that from a hydrologic view anyhow, and yes we did, we went back and searched through all the records we could find, went to Fish and Game, went to the managers office, got as much as we could to try to do the study. Hydrologically we did that and I know that the KBS did that also from the records they had, birds counts and things like that.

Are there any other questions?

Comment (Audience): I'm going to put my foot in as usual, I think this all boils down to the color of the Bottoms is green in the summer and brown in the fall. We all have to stay interested, green's the color of money. Special interests groups go to the legislature and they have pressure on them by big money groups or special interest groups to cut that money over to what they want, decide what they want, maybe not Cheyenne Bottoms, maybe it falls to the wayside. But green is also the color of grass roots, that's what we are all here about. So we have to not go home from here today and forget about this. Fish and Game is very good to answer any questions, but you have to ask them. The legislators are good to answer any questions, maybe not with the answers you want, but they will answer your questions if you ask them. They won't volunteer very much. And brown is the color you get if you don't ask questions.

I certainly appreciate the data that you have gathered this last 18 months, and I think the audience is very appreciative of the explanation, and the reality that has been put into it on the future of water availability and cost of renovation at the Bottoms. I for one appreciate it, the data that you have put into this and giving the information to us. I thought it was useful.

Comment (KBS): We are pleased with that and again I want to emphasize the fact that we appreciate your comments. Its very difficult to conduct this type of study. As I said earlier, it seems that we've had a cast of many that is involved with this. The people that you see here have had a very, very hectic time the last 3 months trying to pull vast amounts of information together from a lot of people and I simply make the comments because we again are emphasizing that we are not suggesting that this is the ultimate. If you have additional comments, additional concerns, please don't hesitate to send them to us. We will do the best that we can to address them

and I'm sure that if you also send some comments or suggestions to the Fish and Game Commission they will be happy to forward them to us.

Question: In terms of the economic impact of the survey that was done was pointed out as various surveys of people going in and out of the Bottoms. Another aspect of that involved the merchants in the area and the local people by asking what their perceptions of the area are. Were they in favor of improving the area and are they aware that there is this kind of economic impact for them.

Answer (KBS): We have an estimate of the impact on Barton County and we can generalize from that the impact on the vicinity of Great Bend. I've been told that probably much of the retail activity in the county takes place in Great Bend, so I imagine that the retailers are aware of it, the local people are aware of it. Some of the survey material, as I understand it, went to merchants and retailers.

Question: The Chamber of Commerce is getting information also?

Answer (KBS): They are receiving the results of the study. The people that were surveyed for the study were users to find out how much the users spent, but not the merchants. We found out that figure for how much was spent on the user end of this by surveying the spender rather than on the other end of the transaction by surveying the sellers. We did not survey the sellers.

Question: I guess the point that I was trying to make was that surveying and imagining that this impact on Great Bend is probably good information, but politically if we are going to get some action, we want the support of the local people as well as those of us who come from across the state. If Great Bend merchants aren't aware of the impact or not in favor of any action going at there, its going to be rough to be successful in the legislature.

Answer (KBS): I feel real certain that they are. I'm looking around the room to see if I can see the individual from the Chamber of Commerce who arranged for the TV interview this morning. She indicated to us that they are extremely concerned that the results of this study be known to the extent that it helps provide them some additional support. I think the Chamber of Commerce has been very instrumental in how they arranged the conference and I think there has been quite a lot of support at the local level. But in terms of actual documentation, I don't think we have it, I'm sorry to say that.

Along that line, I think it is very important, we brought some handouts with us and I think as far as available information in written form there are quite a few of those handouts still available. We would all appreciate if you could take some of these home and distribute them. The more people that have access to this the better off we all are. I'm suggesting on your way out if you have a friend or merchant friend, someone that you think might be interested, this is one way to get him involved, at least put the material before him and give him a chance to react. That increases the input to us and makes our job a little easier as we come through this assessment process.

Additional comments, questions?

Question: I missed some of the discussion, what I want to know, has anyone proposed anything as far as what can be done to save the Bottoms? Just take the original structures as they are, and maybe just modify some of the gates into the water. Doing something simple like a dragline and going all miles of the dikes as they are now, and putting things as they used to be 30 or 40 years ago. You can take a 5 or 6 foot deep borrow ditch and you got 60 inches of evapo-transpiration that you don't even work with, not to mention a water level, standing water level at the Bottoms that isn't much of a load average in some places. I own some land around it and I dug pits and you can get standing water level in place, not everywhere, but in places at this 5 foot level. I have some ponds I dug last year and they haven't gone dry yet, and I'm not saying they won't but that's something to think about and I just wanted to mention that.

Answer (KBS): That is something that is very similar to our option 2 which is no major engineering changes just more manpower and equipment and pumping to improve the thing. We didn't specifically address enlarging the control structures, those would probably cost on the order of new ones, and might possibly cost about $30-40,000 each. So that's once again within the ballpark of option 2, or rather similar to option 2.

One of the things we did talk about was the last thing about swamp grass or something, because to use the existing gates properly, you have to keep those borrow ditches open, like what you are saying. They were designed at the bottom of culverts for gravity flow below the bottom of Cheyenne Bottoms, and that was a poor design. The 1961 study recommended that they put in new control structures with the bottom at the same elevation as the bottom of the Bottoms. But what you're saying is something we have to consider and maybe that will be the very first thing that should be done.

Question: Have they decided anything on maintenance of the gates that were there but another thing we could look at are culverts. I'm no engineer, I never claimed to be, but when water gets to a certain level, you're talking about some very expensive structures. If they could just get some movement through the dikes it would help. There is only the 2 little openings that are pretty small in size in comparison to the drainage ditch at the Bottoms to get water out of 2 into the other pools when you have an emergency situation. Something as simple as 4 or 5 foot culverts raised 2 foot, 3 foot off the bottom level would relieve the pressure in times the water can't just run off. But there again this borrow ditch thing, put water over that large of an area and have it there all the time would limit the amount of water we are working with that I have experiences with the last studies we've done through the people we've had hired. There just isn't going to be that kind of water there except in times of flooding. If you can just narrow the areas down like these borrow ditches were years ago, my father told me that's where all the ducks were. They just spend time in borrow ditches and you have your shorebirds, and everything because there is water there even though it isn't an over massive amount of area. Wildlife will still more or less remain until the water came just like they showed in the graph earlier today. So the dry period will keep things happening in those deep areas. They contain some water for the animals to stay around, whether it be whatever, not just ducks and geese.

One thing about it that would be really better now than originally is when they built the dikes, they had like a 1/10 slope. Right away the wave action ate that up and it slumped right down in the borrow ditch. Now I think the dikes are much more stable so if the borrow ditches were cleaned I think they might last a lot longer than they did the first time.

In cleaning them, this sediment could also be used to widen your dikes and build them up, to prepare them for your rip-rap otherwise you'd have some sedimentation back again.

Answer (KBS): I think its better to haul away the loose stuff that you get out of there because the sides of your dikes now are somewhat stable and if you go putting soil on there again I believe it will just end up back in borrow ditches.

Question: The rip-rapping is extremely expensive for the kind of area you are talking about around all these dikes. Wouldn't plant growth or full plant growth around the dikes area say 100 feet out, control of wave action? The cattail growth now is out maybe 100 feet or 200 feet from the dikes and it doesn't seem to eroding the dikes even with the higher water level that we had this summer. Also, some equipment is available to the state through surplus. Its already available

and what it would require is just the manpower to operate that equipment and do something within the state itself.

Answer (KBS): Once again that's very similar to what we've described in option 2. You've given a little more details that what we've put in here, but what we are talking about is more manpower, a little more equipment, to do things like that. Higher level of maintenance, more intensive farming for seed crops and basically what you are talking about is a little more detail on that plan that we have in option 2.

Concluding Comment: If not, I would like to thank you all for taking time to visit with us about the course of the study. Again we will now go back and start putting together the report and we again appreciate your comments. If you have comments at times during the next week or two don't hesitate to send them along to us so we might have an opportunity to consider those in putting together these materials. Thank you again for joining us.

Jay Shartran Company, Inc.
Enviro-Reps

-QUOTATION-

BOX 8106
PRAIRIE VILLAGE, KANSAS 66208
913-362-0204

TO: Water Resources
1039 Learned
University of Kansas
Lawrence, Kansas 66045

JOB: Mr. Dave Parr
Kansas Fish & Game Commission
Cheyenne bottoms Wildlife Area
Mobile Pumping Units

QUOTATION NO. 4874
DATE: October 23, 1986
QUOTATION EFFECTIVE: Thirty Days
TERMS: Net Thirty Days After Delivery

QUOTATION SUBJECT TO CONDITIONS ON REVERSE SIDE

Gentlemen:

We propose to furnish the following equipment at the price indicated and in accordance with the terms set forth herein:

ITEM I: Mobile Pumping Unit - 75 HP

One (1) Atlantic Hydrodynamics Model 20 AFMP mobile pumping unit rated 14,500 GPM @ 5' TDH and 10,000 GPM @ 20' TDH. Unit to be trailer mounted with steering tongue. Hydraulic pumping system would be powered by a 75HP Murphy or Deutz diesel engine. Unit to have a 20' long Corten steel pump bowl assembly and 20" discharge tube. Also included would be 50 feet of 20" diameter rubber discharge hose.

Price:----------$38,000.00

ITEM II - Mobile Pumping Unit - 200 HP

One (1) Atlantic Hydrodynamics, Inc. Model 36 AFMP mobile pumping unit rated 43,000 GPM @ 5'TDH and 30,000 GPM @ 16' TDH. Unit to be trailer mounted with steering tongue. Hydraulic pumping system would be powered by a 200 HP Murphy or Deutz diesel engine. Unit to have a 20' long Corten steel pump bowl assembly and 36" discharge tube. Also included would be 50 feet of 36" diameter rubber discharge hose.

Price:----------$90,000.00

Above prices are f.o.b. Pompano Beach, Florida.

Continued.....

THE QUOTATION SUBMITTED HEREON IS SUBJECT TO THE FOLLOWING CONDITIONS

1. Quotation is based on current labor and material costs and is subject to current pricing policies of the Manufacturer.

2. All orders placed for items included in this quotation are subject to final acceptance by the Manufacturer.

3. Quotation will remain in effect for the specified time, and after this expiration date, all prices and discounts quoted are subject to change without notice.

4. Delivery assurance as quoted herein are based on factory's material suppliers' abilities to maintain schedules. Also delivery is subject to Strikes, Accidents, or other unavoidable delays beyond the Manufacturer's control. We assume NO liability for delays in shipment of materials as covered by this quotation.

5. Materials stated to be in "stock" at time quotation is made are subject to prior sale.

6. Orders entered for production are NOT subject to cancellation unless by written agreement with the Manufacturer.

7. Material having been shipped cannot be returned without written permission of the Manufacturer, and any such return shipments are then subject to Manufacturer's return to stock and reconditioning charges.

8. Unless otherwise indicated all prices quoted do not include any tax-assessment or charge upon the Manufacturers' production, sale and/or shipment of said products, now or hereafter imposed by federal, state, municipal and/or other governmental authority. Any such tax, or charge aforesaid will be charged to the Purchaser's Account in accordance with the statutory or other requirements relating thereto.

9. All products are guaranteed in accordance with the Manufacturer's Guarantees, Warranties, or Policies. Any replacement of defective material, or materials, will be made in accordance with such guarantee or warranty policies but, in any case responsibility ends with the replacement of the defective part, or parts, and no responsibility will be assumed for un-authorized repair or replacement of said equipment. Also NO liability, nor any expense, will be incurred due to failure of said equipment excepting replacement of the defective part, or parts, by the Manufacturer and in accordance with said Manufacturer's policies.

10. Should the customer revise operating or installation specifications, after this quotation is made, to other than those originally specified, we reserve the right to revise, or withdraw, this quotation, and to submit prices for the proper equipment which will be recommended to meet revised specifications.

11. Commercial, or Special Export Crating, or Special Boxing or Crating for Domestic Shipment, will be added to regularly quoted prices, unless otherwise indicated in this quotation.

12. Extra or Special Charges imposed by the Manufacturer, and not covered by this quotation, are to be covered by supplemental quotations in accordance with paragraph 2 hereof, or such extra prices, when not covered by a formal written quotation, to be accepted by written or verbal consent of customer.

Notes:

1. Freight would be approximately $1,500.00 for each unit.
2. Other makes of diesel engines would be added cost.
3. All applicable taxes would be added.
4. Descriptive literature is enclosed.

Very truly yours,

JAY SHARTRAN COMPANY, INC.

S. J. Shartran

SJS/bjp

cc: Mr. Maurice Hymes
Atlantic Hydrodynamics, Inc.
1875 N.W. 18th Street
Pompano Beach, Florida 33069

DESCRIPTION

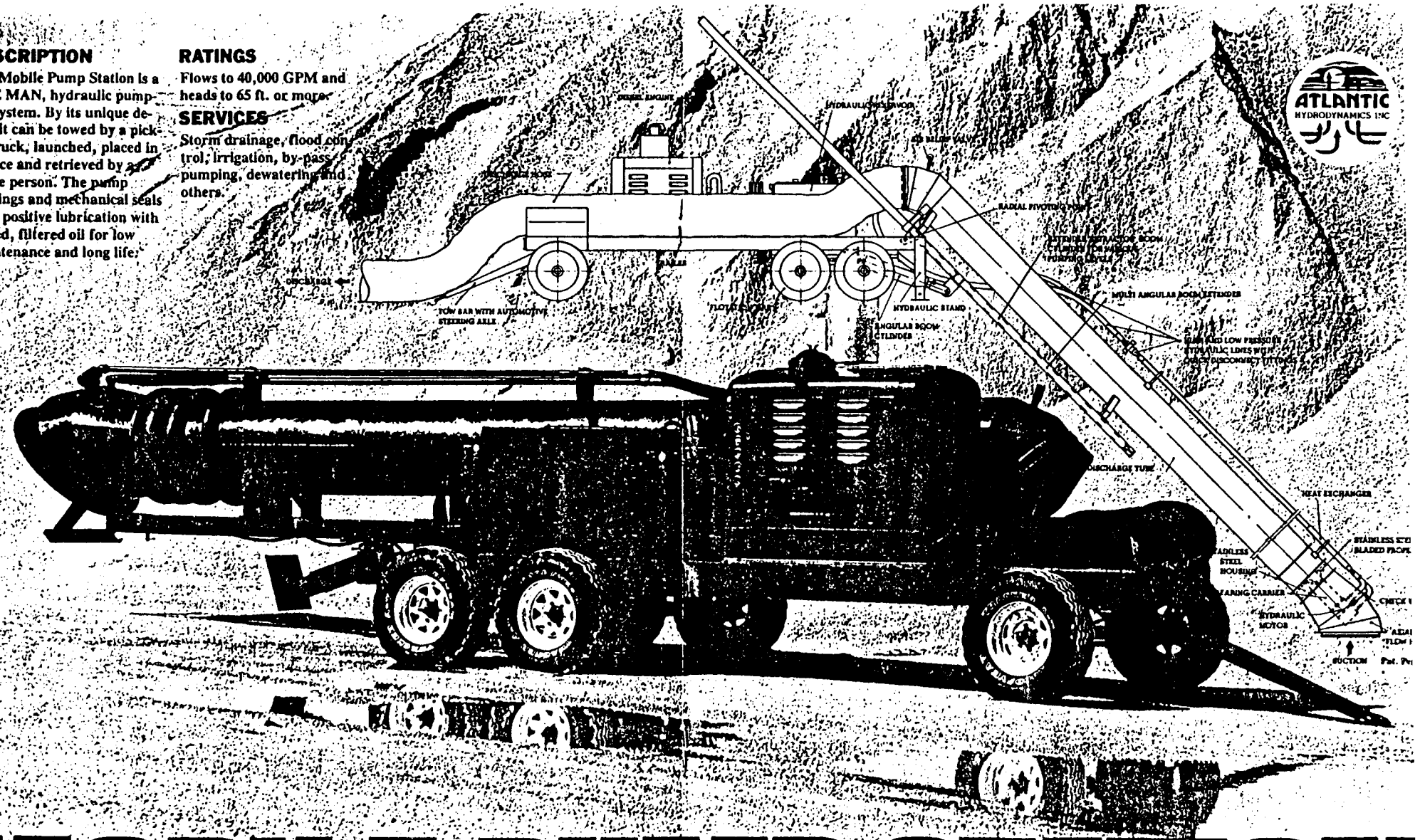
The Mobile Pump Station is a ONE MAN, hydraulic pumping system. By its unique design it can be towed by a pick-up truck, launched, placed in service and retrieved by a single person. The pump bearings and mechanical seals have positive lubrication with cooled, filtered oil for low maintenance and long life.

RATINGS

Flows to 40,000 GPM and heads to 65 ft. or more

SERVICES

Storm drainage, flood control, irrigation, by-pass pumping, dewatering and others.



MOBILE PUMP STATION

QUALITY Industries

Quality Boiler & Machine Works Inc.
Quality Marsh Equipment Co. Inc.
Quality International Sales Corp.

P.O. Box 406 Thibodaux, Louisiana 70302 U.S.A.

November 24, 1986

University of Kansas
Department of Civil Engineering
Learned Hall
Lawrence, Kansas 66045

ATTENTION: MR. DAVID PARR

RE: Quality 100% Amphibious
Construction Equipment
Our Telecon This A. M.

Dear Mr. Parr:

We are enclosing general literature on our line of high mobility, 100% amphibious, construction equipment for your review as dicussed.

We will be most happy to offer our recommendations and proposal for a vehicle to suit your requirements, after you have reviewed this general literature.

Yours truly,

Jay Dornier
New Project Development Engineer
QUALITY INDUSTRIES, INC.

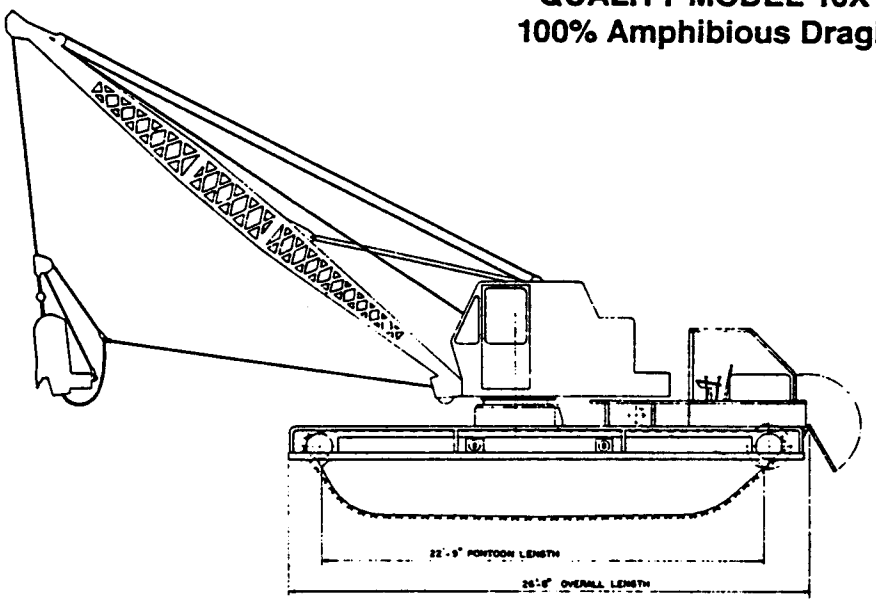
JD/maw
ENCLOSURE

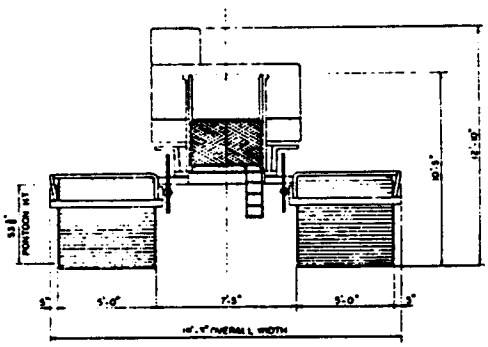
xc: Mr. George Diedrich, President

THE PRESIDENT'S AWARD FOR EXCELLENCE IN EXPORTING.

QUALITY INDUSTRIES, INC.
Exporter: Quality Marsh International Corp.
Post Office Box 406 - Thibodaux, Louisiana, U.S.A. 70302
Telephone (504) 447-4021 Cable Qmeco Telex 70-566

QUALITY MODEL 10XT-HD-59M
100% Amphibious Dragline Carrier





UNDERCARRIAGE SPECIFICATIONS:

BASIC VEHICLE WEIGHT ..... 26,000 pounds
LOAD (CARGO) CAPACITY ..... 14,000 pounds
GROSS WEIGHT ..... 40,000 pounds

SPEED: 3 to 4 MPH - on hard level terrain
1 to 2 MPH - in the water

GRADEABILITY: 60%

ENGINE: Ford 268 cu. in., 4 cylinder, industrial diesel, water cooled, 72 HP @ 2200 RPM

OPTIONAL: GM 3-53, 85 HP @ 2200 RPM

TRANSMISSION: Borg-Warner T-18, 4 speeds forward and 4 speeds reverse

STEERING: "Skid" steering is through an Eaton single reduction differential and a hydraulic steering unit. Turning is accomplished by braking one track while allowing the other to rotate in the required direction

PONTOONS: Dimensions - 22'9" long × 5'0" wide × 4'5" high. C.C. recessed track, all steel construction of 3/16" bottom, 12 ga. sides and 12 ga. top. Three (3) water tight compartments (for safety afloat). All exposed metal sandblasted and sprayed with inorganic zinc, plus painted with one (1) coat of primer and two (2) coats of enamel. Interior is primed with rust preventative.

TRACK: Three (3) strands of special heavy duty 4" pitch track chain. Cleats or shoes of 4" wide, hi-tensile aluminum alloy

OPTION "A": Extreme Service aluminum channel cleats

OPTION "B": Heavy duty track support system for swamp operation

CHASSIS: All steel I-beam and channel welded construction, painted with one (1) coat of primer and two (2) coats of enamel.

REMARKS: The Model 10XT-HD-59M is designed to carry the Little Giant Model 32 Dragline Crane (15 Ton capacity). Other makes and models may be mounted provided their weight does not exceed 14,000 pounds

OPERATING BUDGET

Cheyenne Bottoms FY 1986*

Salaries and Wages	$103,000
3 full-time staff 1-2 part-time personnel Percentage of law enforcement personnel time Percentage of regional manager time	
Equipment	$ 12,500
Operational Budget	$ 55,584
Supplies, equipment repair, gas, etc	
TOTAL	$171,084

* Per phone conversation from
Darrell Montei to D. Huggins, 14 Nov 86

A Discussion of the Report Titled "Cheyenne Bottoms Use and Management as a Water Fowl Refuge and Public Shooting Area."

By Murray A. Wilson

This document consists of 4 separate sections, two discussing various phases of management of the area, a third is concerned primarily with a discussion of plans, and the fourth is an engineering study discussing things which would be necessary or desirable to carry out the plans for management of the area. Remarks herein will be limited to the engineering features of these reports.

Section I - Management Plan for the Cheyenne Bottoms Water Fowl Refuge.

The plan outlined in this section of the report is predicated on keeping all pools as near as possible at normal water levels until 15 May of each year and then draining the 4 perimeter pools within the month following 15 May. These areas would then be devoted to production of duck food, with systematic re-flooding in the fall, beginning on 15 September. It is stated that the aim would be to bring the pools up to normal water level by the 1st of March. This recital of the outline is given merely to point out the difference between this program and the tentative plan of operation which was used as a guide in designing the entire layout of the structures in the area and the sources of water supply. At the time these features were designed, the aim was to provide sufficient water to keep all pools as near normal elevation as possible for the largest percentage of total time. It was expected that the perimeter pools would be rotated as to use as farming areas, and the basic crop to be grown was whatever type of dwarf sorghum would thrive best in the area.

It might be of interest to assess some cost figures to the auxiliary items suggested in this section. The level ditches suggested on Page 16 would offer no difficulties in the way of construction. The size discussed would cost at present prices approximately $4,000.00 per mile of ditch, though of course on a contract basis a sufficient quantity would need to be contracted at one time in order to obtain a price in this range. Carrying the idea further, if a square mile of land were provided with these ditches, at a spacing of 200 feet center to center, it would result in a total of approximately 27 miles of ditch in one square mile of land, and the estimated cost would therefore be $108,000.00.

In considering the operation of the periphery dikes, it would be well to consider the fact that the water trapped behind these dikes would be quite shallow, and during the interval between the drawdown of the perimeter pools and the time when this water might be needed for irrigation of the balance of the pools, it is probable that most of it would be evaporated in the interval, and that little or no water would be available for irrigation at the time when that seemed most desirable.

The construction of islands would present no difficulties, but of course the work would need to be done with the pool in question drained and kept dry for a sufficient length of time to support excavating equipment. The report calls attention to the desirability of protection from erosion by wave action.

Section II - A Water Fowl Food Management Plan for the Cheyenne Bottoms Water Fowl Refuge.

The author of this section recommends a little later period both for de-watering the perimeter pools and for re-flooding in the fall. One statement about the water in the Bottoms might be worthy of comment. It stated

that the present turbidity is "in marked contrast to the clear waters that covered much of the Cheyenne Bottoms in 1928 and 1951." The writer visited the Cheyenne Bottoms many times during 1927 and 1928 when the area was first brought sharply to the attention of the Commission. On one occasion an extended boat trip was taken over the area. At another time he was part of a hunting party that waited vainly for any ducks to come within range. No clear water was seen at that time. The water that entered the area was heavily laden with silt and the wind action on the area apparently kept enough of it in suspension that it never cleared up. The next appreciable water in the Bottoms began to accumulate in 1950 and was brought to its highest peak by a storm occurring in the late winter of 1950-51. It came when the drainage area was largely covered with a sheet of ice, producing for a part of the time at least, nearly 100 percent runoff. Due to the circumstances surrounding this inflow, the water was relatively low in turbidity. One interesting point was brought out in the suggestion that the water in Pool 1 be held to a depth of not to exceed 3 feet, and preferably only 2 feet. With the unpredictable source of supply, this would essentially eliminate storage as the normal evaporation during the period would deplete this in years when inflow did not happen to be available during this particular period.

The present arrangement of outlet works will theoretically drain the 4 perimeter pools in a period of 20 days if flowing at peak capacity can be maintained. The author is therefore correct in that if this should be accomplished within a 14-day period, a bigger and more dependable method of drainage must be provided. He recommends gated metal pipes for water transfer, which are certainly a standard piece of equipment in this type of construction. It is questionable whether they would show any superiority

over the existing Tainter gates, the principal advantage being that the silt deposited in the pipes would not be visible, but on the other hand, would be harder to dislodge.

Section III - Plan Useful in Resisting Soil Erosion.

It will certainly be worthwhile to try every means possible to find a type of vegetation which will hold the soil on the dikes and prevent erosion. As will be pointed out later, the alternatives are extremely expensive and should be resorted to only if vegetation cannot be found to do the job. No treatment of the slopes of the dikes was included in the original contract because of the expectation that vegetation could be found to accomplish the desired purpose.

Section IV - Report on an Engineering Study on the Control of Water for a Management Plan.

The recommendations of this engineering report are sound if the management plans as outlined are adopted and followed. As was pointed out earlier, the details were designed under all together different criteria, and hence changes are needed to accomplish a new and different purpose.

The question of programming any additional construction or adopting parts of the overall plan appears to be a question of economics and should be viewed from the standpoint of the returns that can be had from each dollar invested. The use of Pool 2 as a storage pool seems warranted to insure enough water in reserve at the start of the hunting season to flood the 3 pools which had been drained for the summer.

The addition of pumping equipment to the plan of water operation appears to be entirely sound and would make it possible to conserve water to the greatest possible extent during the years of deficient rainfall and runoff by pumping water from the perimeter pools into the central pool

instead of draining it direct to waste.

The existing transfer structures were designed to raise or lower the water level in any pool at a rate of not less than one inch per day. The existing outlet canal does not have the capacity to handle such rate of decrease from Pools 3, 4, and 5, simultaneously. In considering the outlet canal as a means of getting rid of excess flood water, it must again be regarded in the light of the damages that might be received during years of excessive runoff. The infrequency of such occurrences, and the fact that the area has excess storage capacity for about double its so-called normal capacity, will need to be studied carefully against the cost of the proposed additional outlet canal.

Erosion of dikes should be brought under control as rapidly as possible, due to the cost involved and certainly the use of stabilizing vegetation should be used wherever it can be done so effectively. The areas and quantities involved here are quite large and the cost of protection by additional construction becomes correspondingly great. As an example, on the inside of the dike surrounding Pool 1, the area which is or may be subject to erosion at different levels, totals 325,000 square yards, while an approximate estimate of all the dikes will run in excess of 700,000 square yards. Thus if it were attempted to protect all these slopes with a facing of reinforced concrete, the cost would be in excess of two million dollars. If gravel surfacing has not been tried, it certainly should be applied to a test section as soon as possible with a range of gradation such that the most economical type could be chosen to accomplish the desired results. It is estimated that 6 inches of select gravel can be placed and spread upon the slopes for an average of 65 cents per square yard, and at the slopes to which these dikes were constructed, it is

reasonable to assume that a gradation can be found which will be satisfactorily stable.

In evaluating the proposed extension of the outlet canal to the Arkansas River, there should be taken into account the other items of expense that would be necessary to get the work completed. These would include the cost of land, including separation damages, and the cost of private crossings for the purpose of transporting farm machinery from one field to the other. It was noted that some of the unit costs used in the estimate were taken from the contract price of the work and it should be remembered that this contract was awarded on 13 December 1950. The construction cost index as of that date, compared to the current one, is in the ratio of 1 to 1.588. We feel therefore that a more realistic figure is as follows:

Construction of Canal - New Portion	$400,000.00
Revision of Existing Canal	150,000.00
Right-of-Way and Separation Damages	75,000.00
Equipment Crossings	75,000.00
Total	$700,000.00

The psychological effects of this addition must also be taken into consideration. The ratio of an outflow of 200 feet to a bankfull capacity of 1,040 second feet on Cow Creek has given rise to much mental anguish among the residents of the Cow Creek area below the mouth of Little Cheyenne Creek. Careful consideration should be given to the effect of introducing 1,000 cfs. into the Arkansas River, a stream having a bankfull capacity of 7,500. The ratio in this case is 50 percent better than the former, but the psychological effect would be somewhat comparable, at least, and so should be given very careful consideration.

It is the opinion of the writer that it would be profitable to investigate more thoroughly the probable results from putting the plan partially

into effect. The establishment of pumping stations or portable pumps for the transfer of water from the perimeter pools into the storage pools would be an important item in adding to the flexibility of operation and in the conservation of water. The stabilization of the slopes of the dikes is essential, regardless of what future plans may be adopted in the way of management and water control. To relieve the situation in Cow Creek and to secure permission to reuse this means of discharge under proper conditions, it is suggested that thought be given to the installation of two automatic water level gages on Cow Creek, one just below the mouth of Little Cheyenne Creek, and the other in the vicinity of Lyons; that these be equipped with telemetering instruments which would indicate simultaneously at a station located within the Bottoms, and preferably adjacent to the control gates at the head of the outlet canal, so that the indicators at this remote station would show at all times the true level of the surface of the stream in Cow Creek at the two points where the gages were installed; then submit to the proper authorities a program, varying with the time of year and designed to eliminate all but the most remote probability of discharge from the Bottoms actually causing an overflow which would not otherwise occur. With this program in operation, Pool No. 1 could be lowered to a predetermined level in the winter time; where records show that in 97 days out of 100, during December, January, and February, the outlet canal could be used to approximately design capacity, during which period a total of 38,000 acre feet could theoretically be discharged. The capacity of the pool can thus be utilized in the spring to receive the pumped discharge from the perimeter pools. At this time of year discharge to Cow Creek would be considerably handicapped by recurring rises of that stream. The stream gages and telemetering equipment would

cost about $7,000.00, with an additional expense for transmission lines for that portion of the route on which existing telephone lines could not be leased.

At various points in the report, reference was made to the turbidity of the water, but no one mentioned the basic cause for such turbidity. It is due primarily to the character of the drainage area, not only of the area that contributes directly to the Bottoms, but also the entire drainage area of Walnut Creek. A program of soil conservation and the establishment of soil saving practices in these areas are essential to receiving cleaner water in the basins, and in fact, are essential to prevent the ultimate silting of the basin to the point where it can no longer be used. This fact was pointed out in the public hearings of the Arkansas-White-Red Basins Interagency Committee and has been discussed unofficially with the officials of the Soil Conservation Service. This is something which should certainly be encouraged and promoted to the fullest extent.

These are made as suggestions as a possible aid to operation while you are deciding what portion of the proposed plans could be economically incorporated into the operation of the area.