

Hydrologic processes related to Kansas ponds and lakes

Presentation to the

Aggregates and Groundwater Resources Task Force

in Salina, KS (August 25, 1997)

by

Marios Sophocleous

August 1997

Kansas Geological Survey
Lawrence, KS
Open-File Report 97-60

OUTLINE

- **Brief overview of components of hydrologic budget for Kansas, and sources of data**
- **Brief overview of some hydrogeologic concepts relevant to ponds and lakes**
- **Outline of estimation methods for recharge and evaporation from water bodies**

A. Hydrologic budget for Kansas and related data

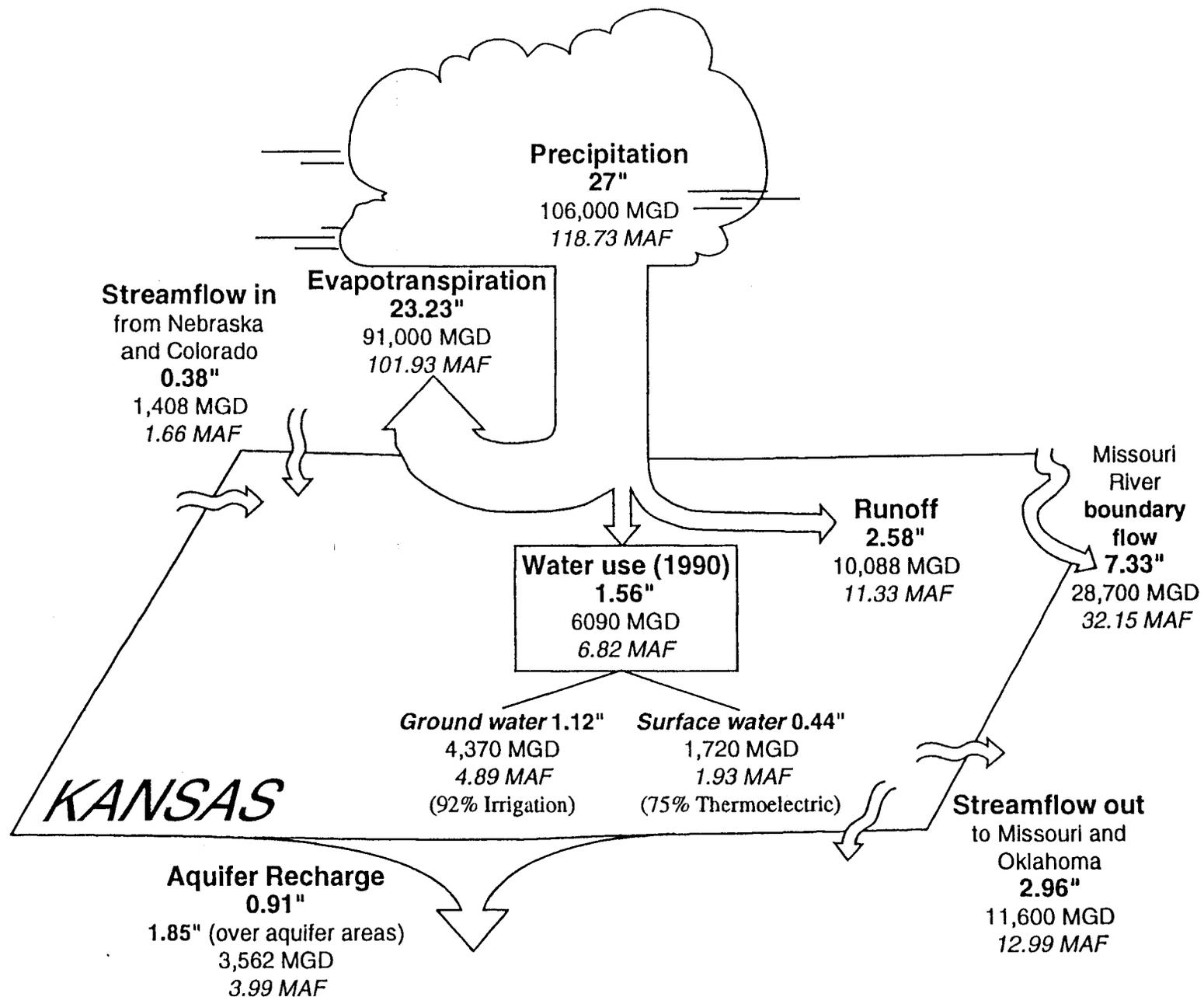
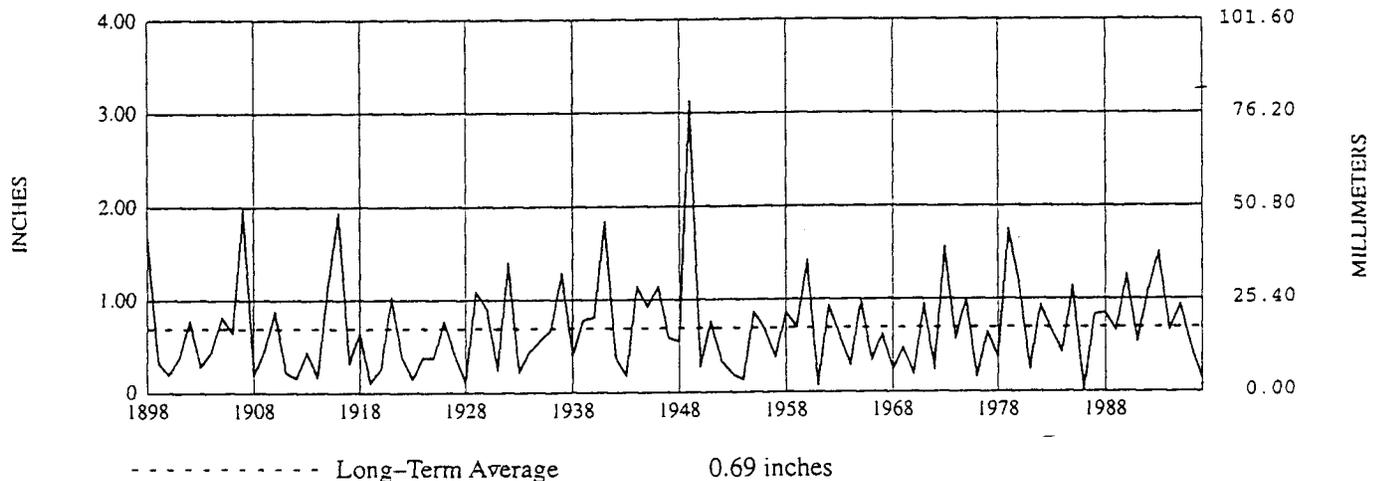


Figure 0. Water budget components for Kansas. Values are in inches per year, million gallons per day (MGD), and million acre-feet per year (MAF).

CLIMATOLOGICAL DATA

KANSAS
JANUARY 1997
VOLUME 111 NUMBER 01
ISSN 0145-0417



KANSAS PRECIPITATION JANUARY, 1898-1997

TEMPERATURE AND PRECIPITATION EXTREMES

HIGHEST TEMPERATURE	82	JANUARY 3	SYRACUSE
LOWEST TEMPERATURE	-18	JANUARY 13	BREWSTER 4 W
GREATEST TOTAL PRECIPITATION	1.71		LA CYGNE
LEAST TOTAL PRECIPITATION	.00		59 STATIONS
GREATEST 1 DAY PRECIPITATION	1.05	JANUARY 8	NORWICH
GREATEST TOTAL SNOWFALL	14.5		STILWELL
GREATEST DEPTH OF SNOW OR ICE	8	JANUARY 10	FORT SCOTT

"I certify that this is an official publication of the National Oceanic and Atmospheric Administration (NOAA). It is compiled using information from weather observing sites supervised by NOAA/National Weather Service and received at the National Climatic Data Center (NCDC), Asheville, North Carolina 28801."

Kenneth D. Haden

DIRECTOR
NATIONAL CLIMATIC DATA CENTER

noaa

National
Oceanic and
Atmospheric Administration

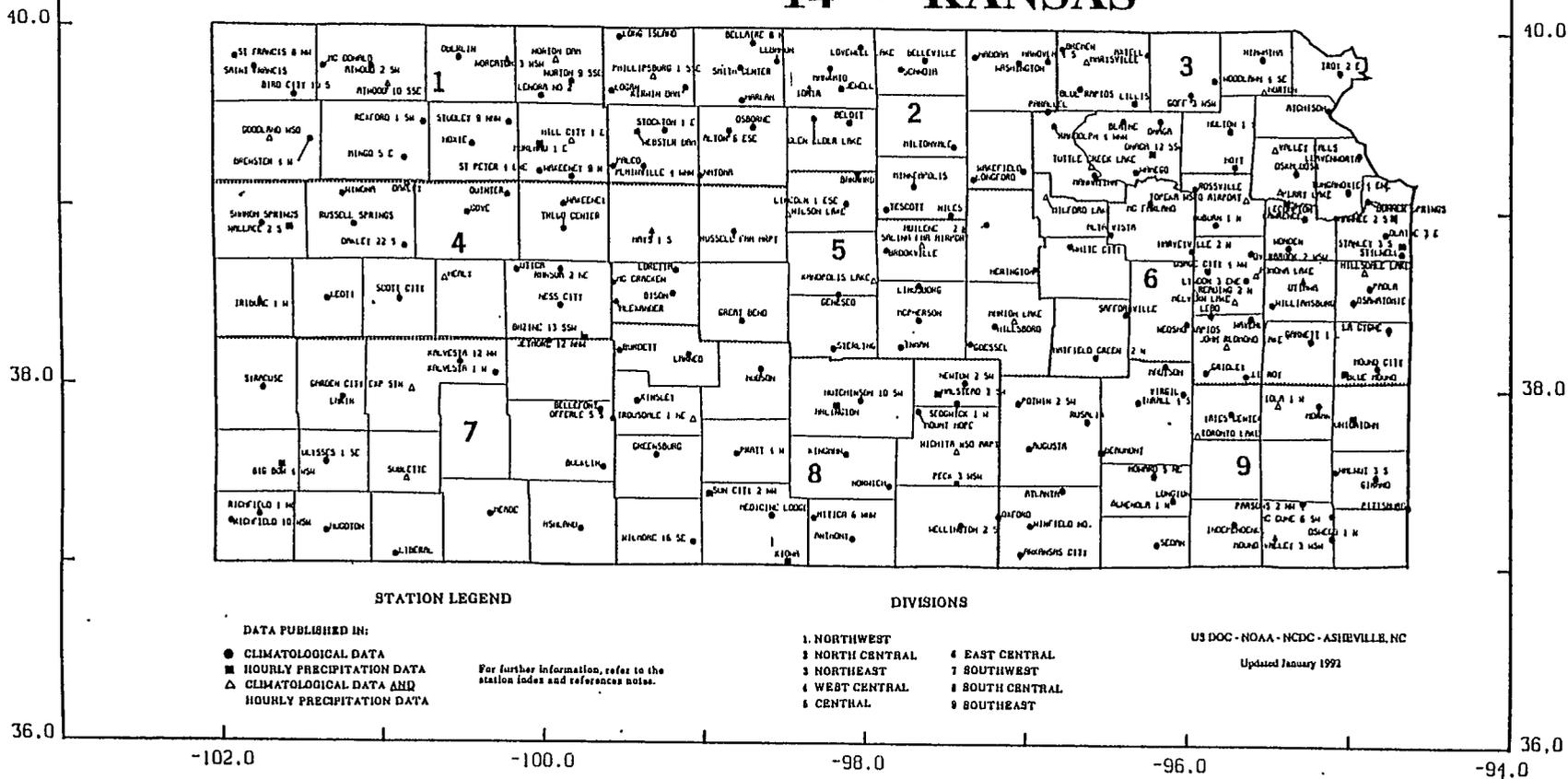
National
Environmental Satellite, Data
and Information Service

National
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Asheville, North Carolina

14 - KANSAS

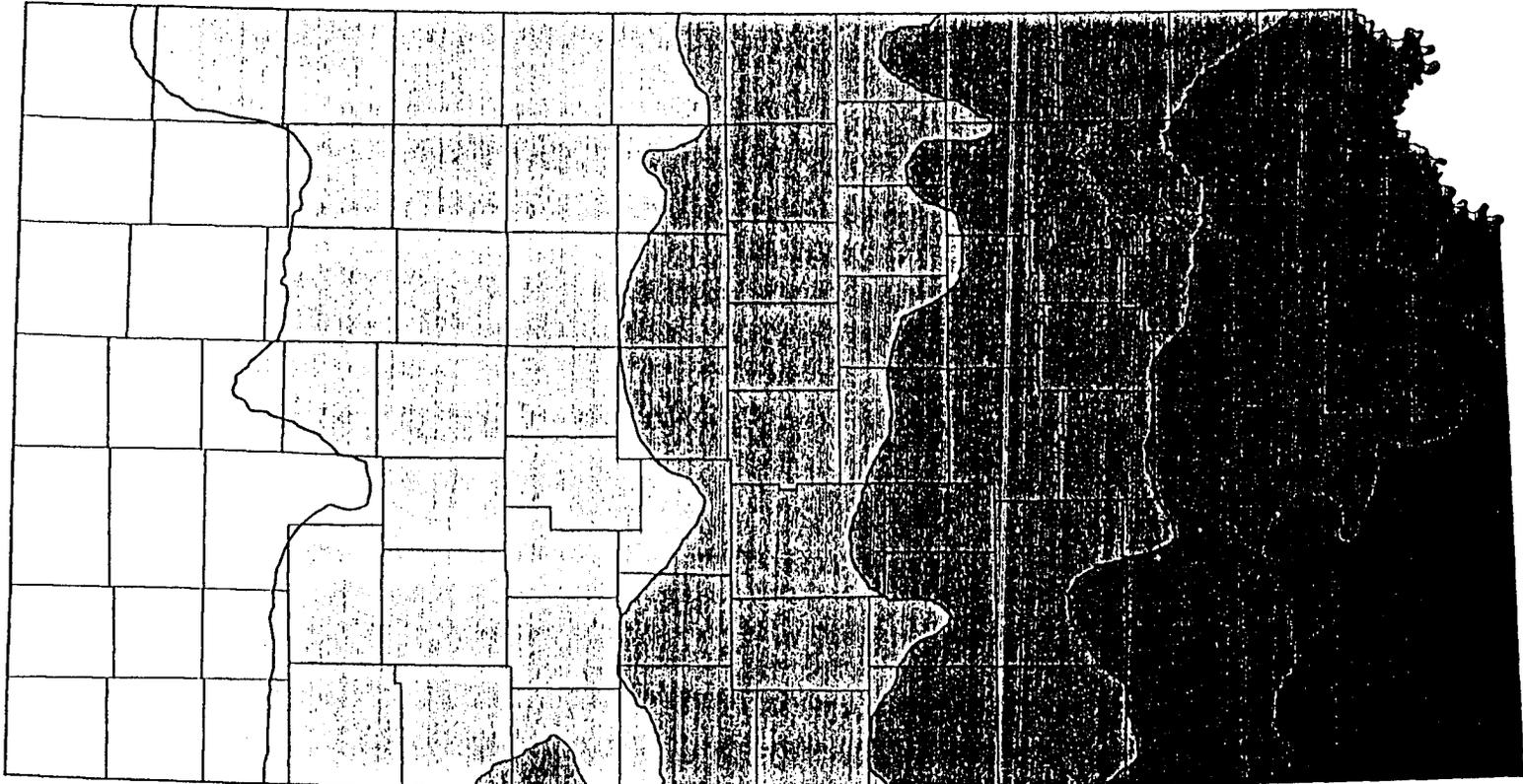
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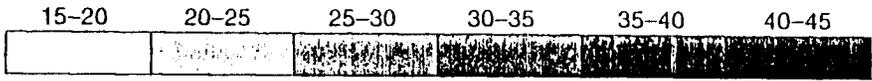


5

ANNUAL NORMAL PRECIPITATION 1961-1990



7



Inches

Normal Annual Precipitation



NOAA Technical Report NWS 33



Evaporation Atlas for the Contiguous 48 United States

Richard K. Farnsworth
Edwin S. Thompson
and
Eugene L. Peck

Office of Hydrology
National Weather Service
Washington, D.C.
June 1982

U. S. DEPARTMENT OF COMMERCE

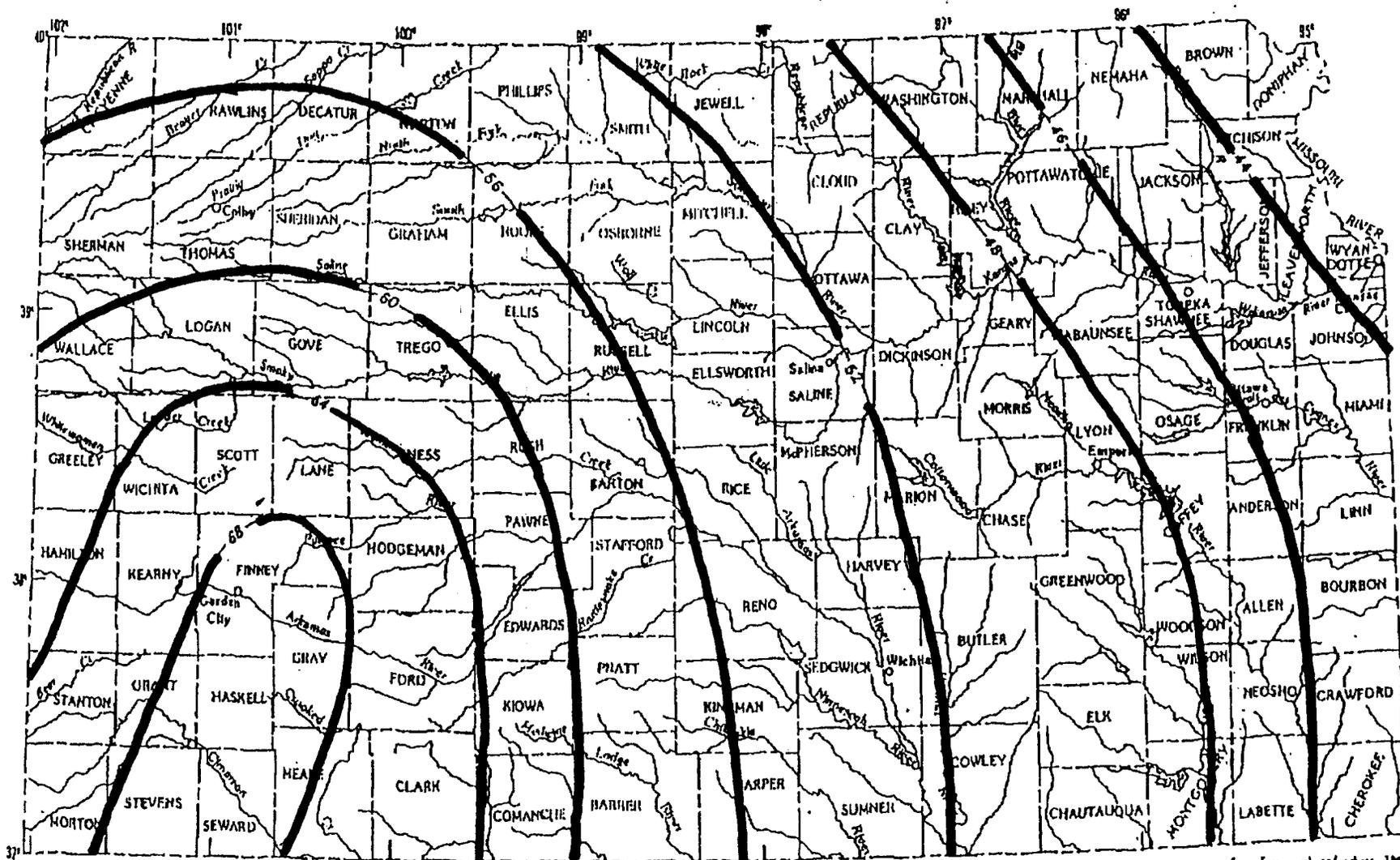
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration

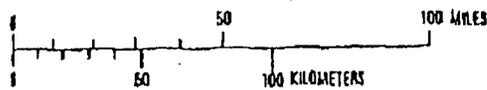
John V. Byrne, Administrator

National Weather Service

Richard E. Hallgren, Director



From Fairweather and others, 1962



EXPLANATION

— 50 — Line of average annual evaporation—
Interval 2 and 4 inches

Figure 4. Average annual free-water-surface evaporation.

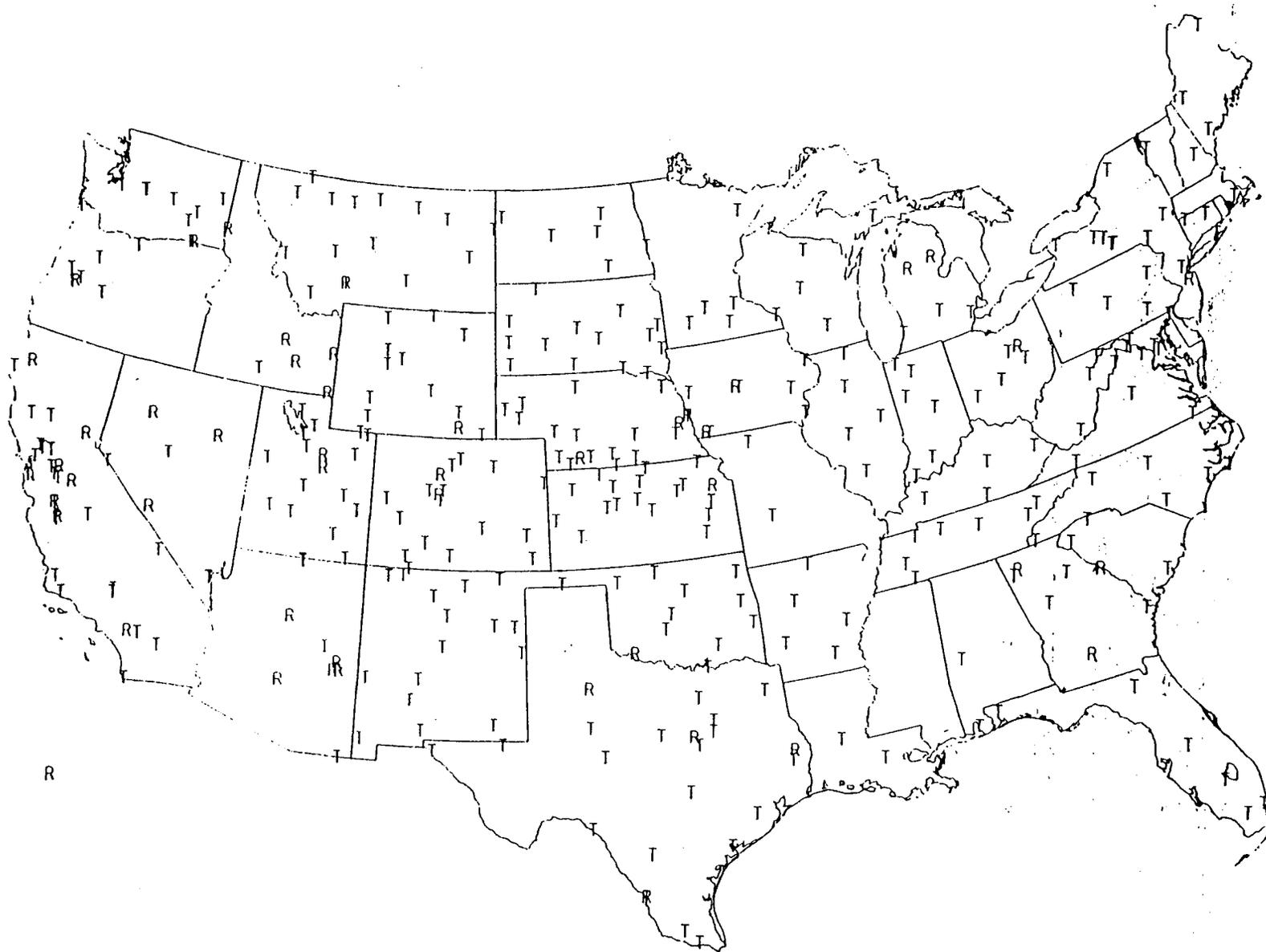
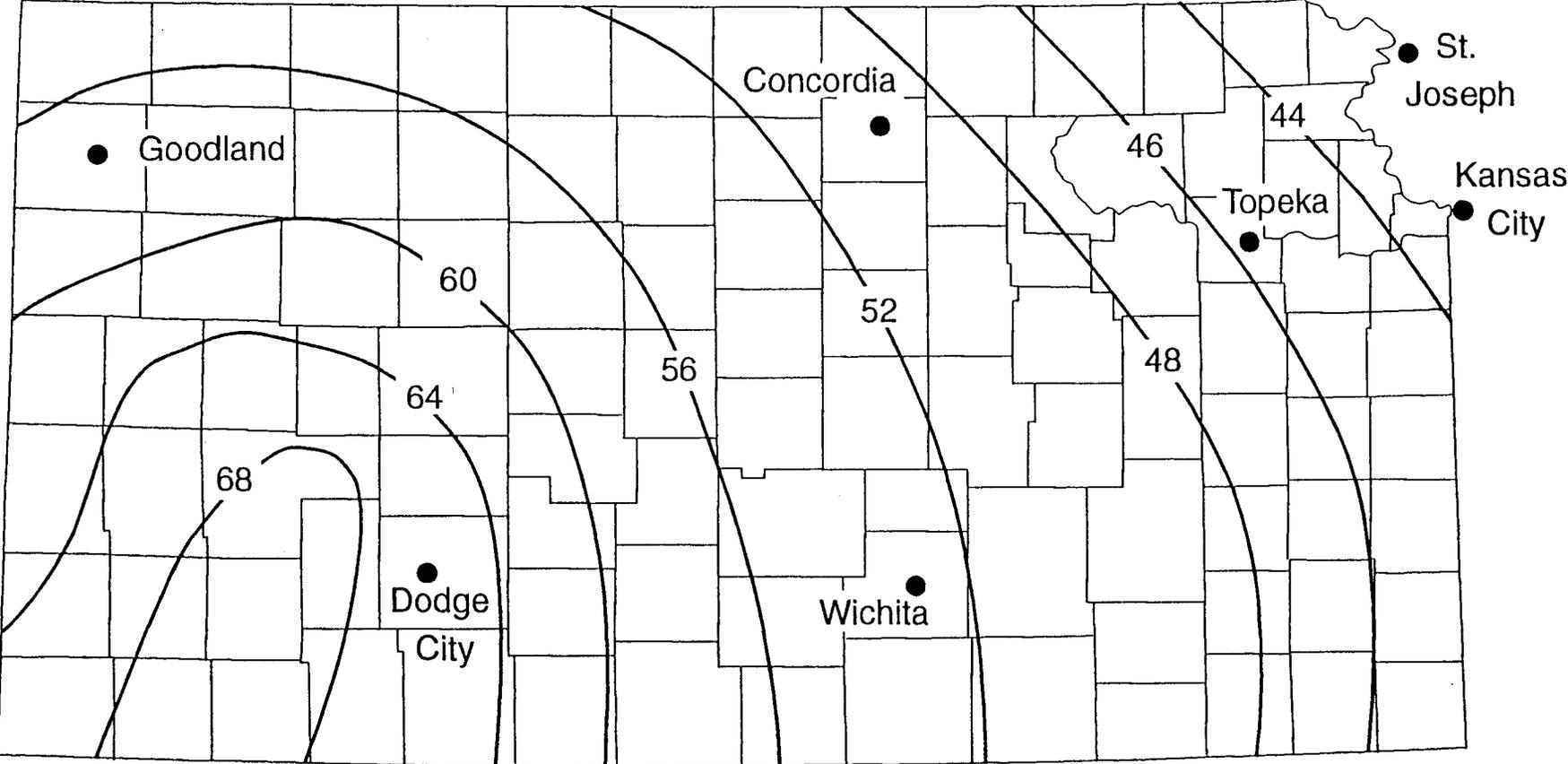
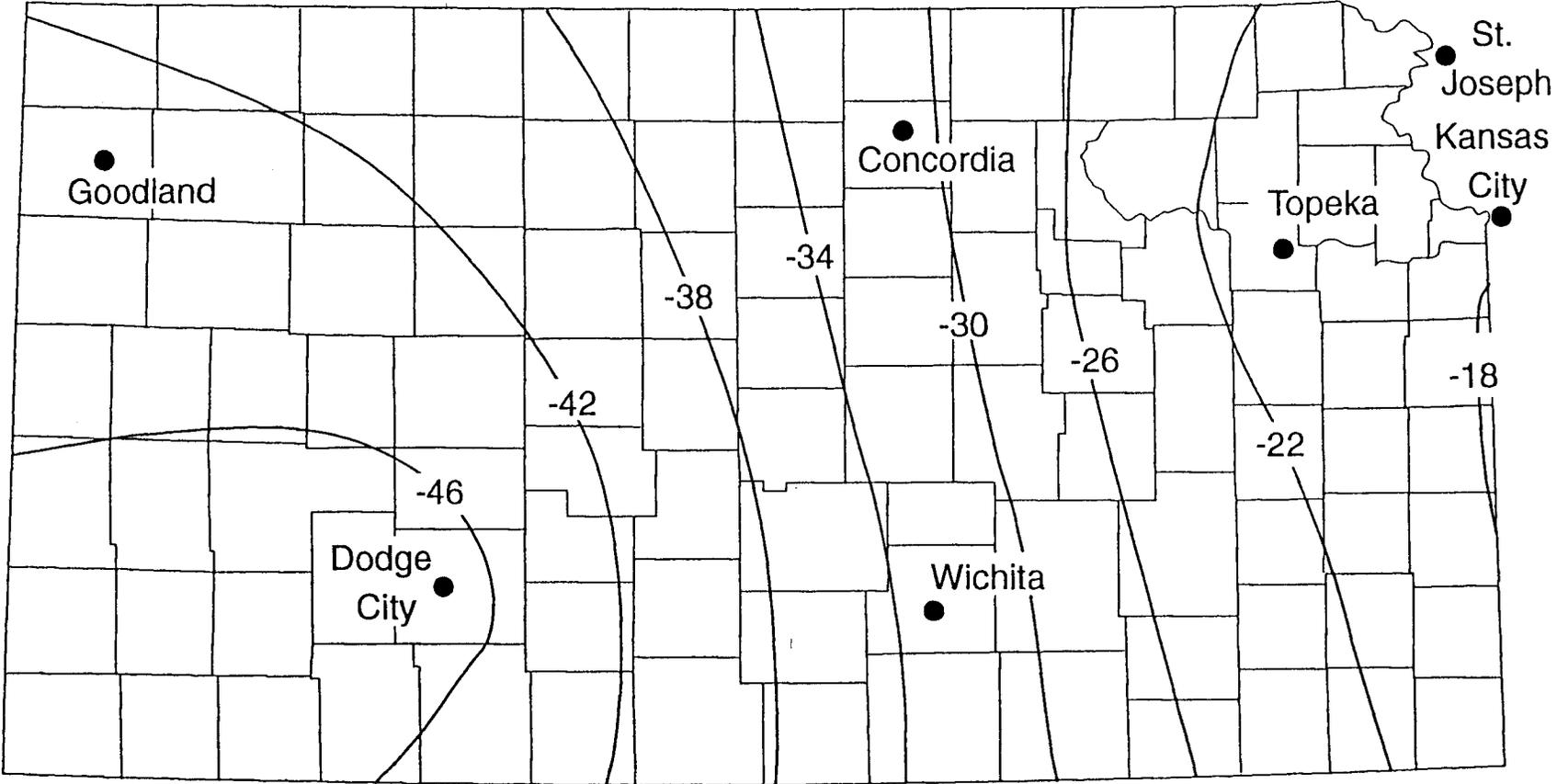


Figure 1--Distribution of Class A pan stations which make concurrent measurements for computing FWS evaporation by equation 3. Stations identified by an R were not equipped with sensors to record additional data until the latter part of the 1956-70 time base.

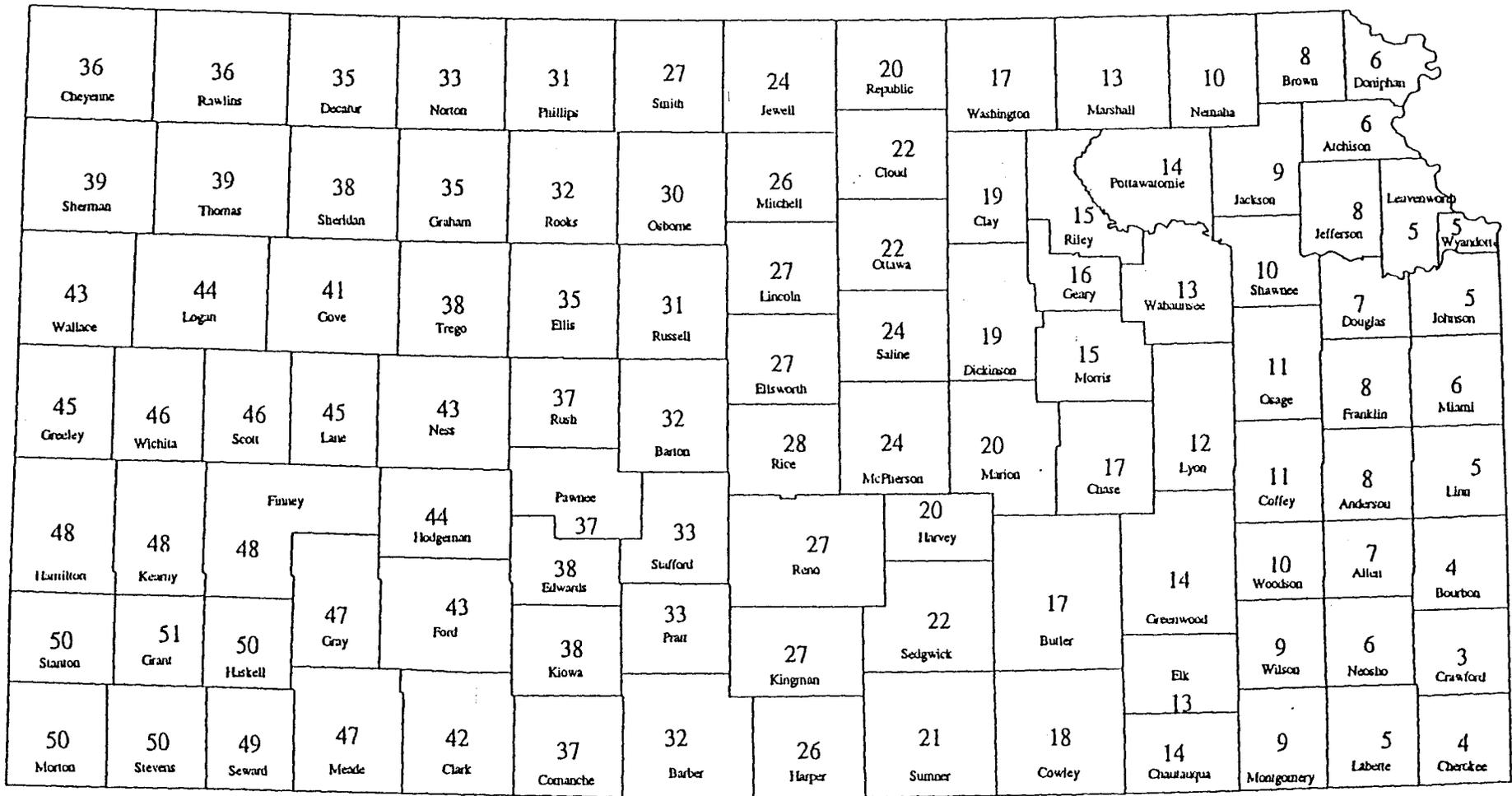
Annual Free Water Surface Evaporation (1956-1970) inches



Annual Precipitation Normal minus Penman ET₀ (inches)



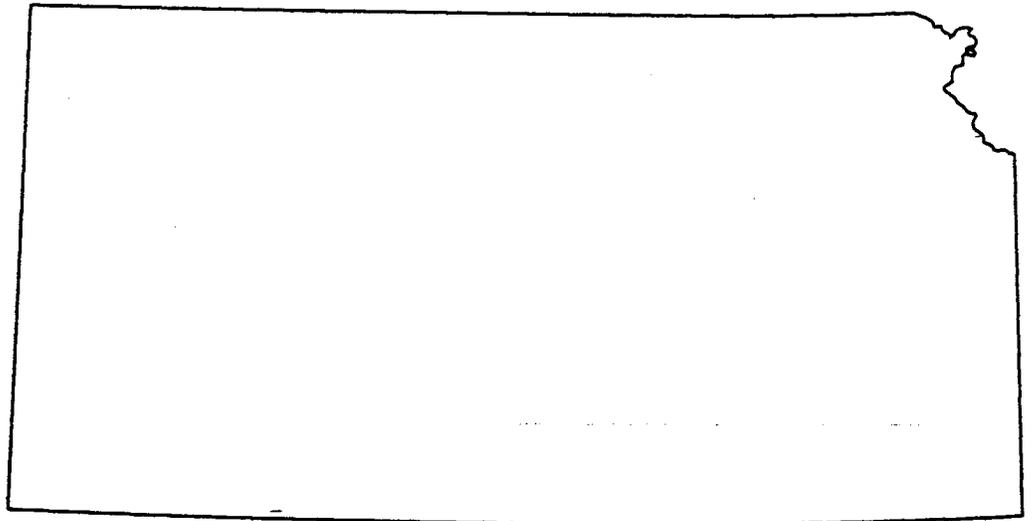
Potential Net Evaporation, in Inches, for Kansas Counties
 (Annual Average Evaporation minus Annual Average Precipitation)



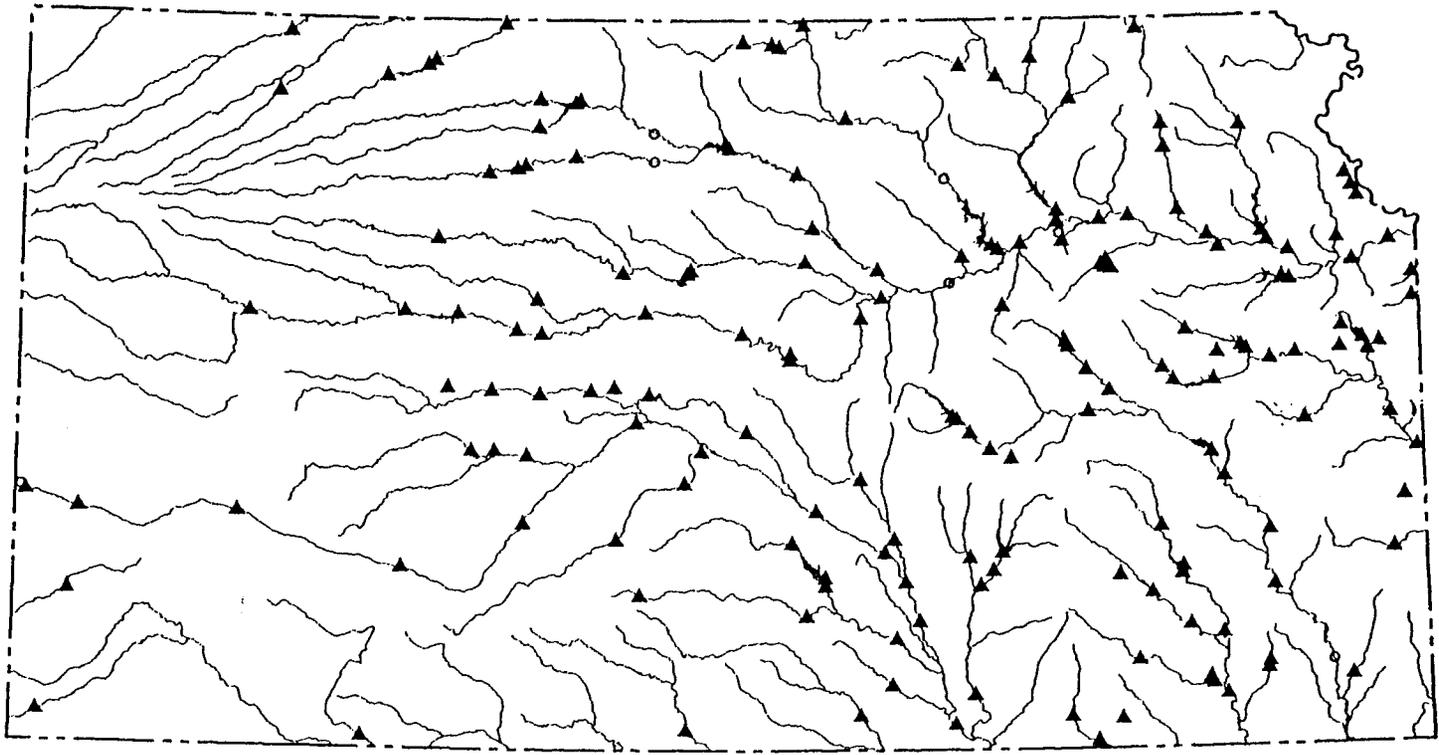
Map Source- NOAA Technical Report NWS 33, 'Evaporation Atlas for the Contiguous 48 United States' and USWEST Optical Publishing, 'CLIMATEDATA- Summary of the Day, 1992'



Water Resources Data Kansas Water Year 1996



U.S. GEOLOGICAL SURVEY WATER-DATA REPORT KS-96-1
Prepared in cooperation with the State of Kansas
and other agencies



EXPLANATION

- ▲ Complete-record streamflow-gaging station
- National Stream-Quality Accounting Network station

Figure 2. Location of streamflow gages and water-quality monitoring sites.

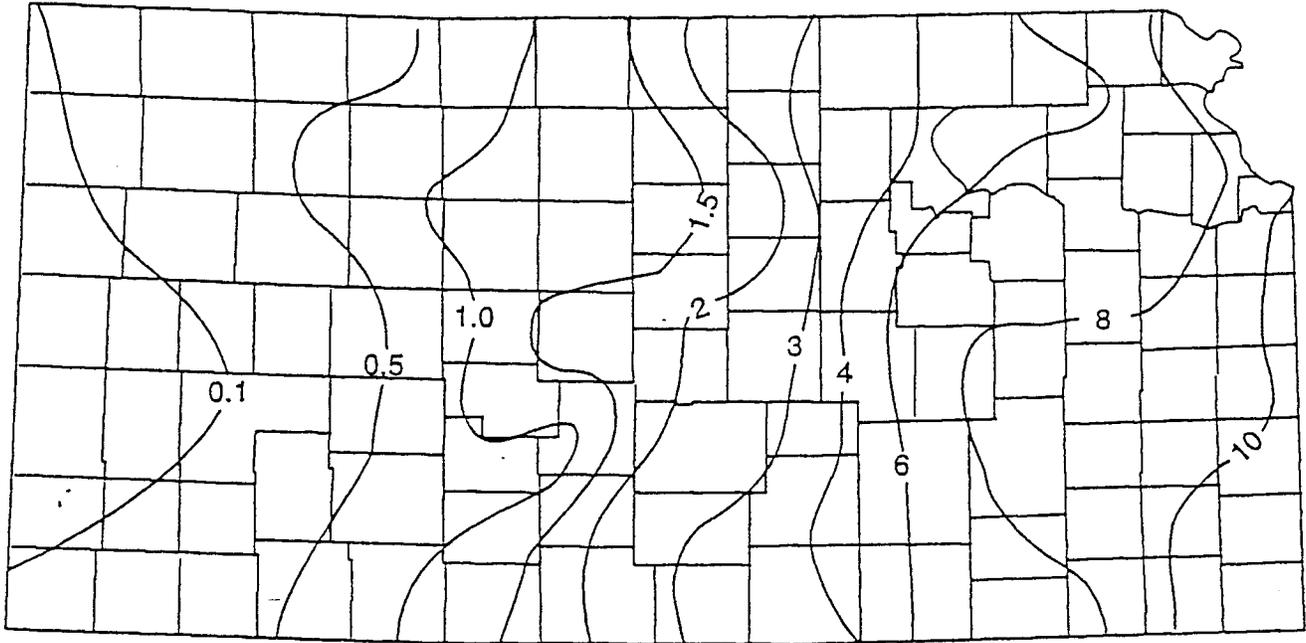
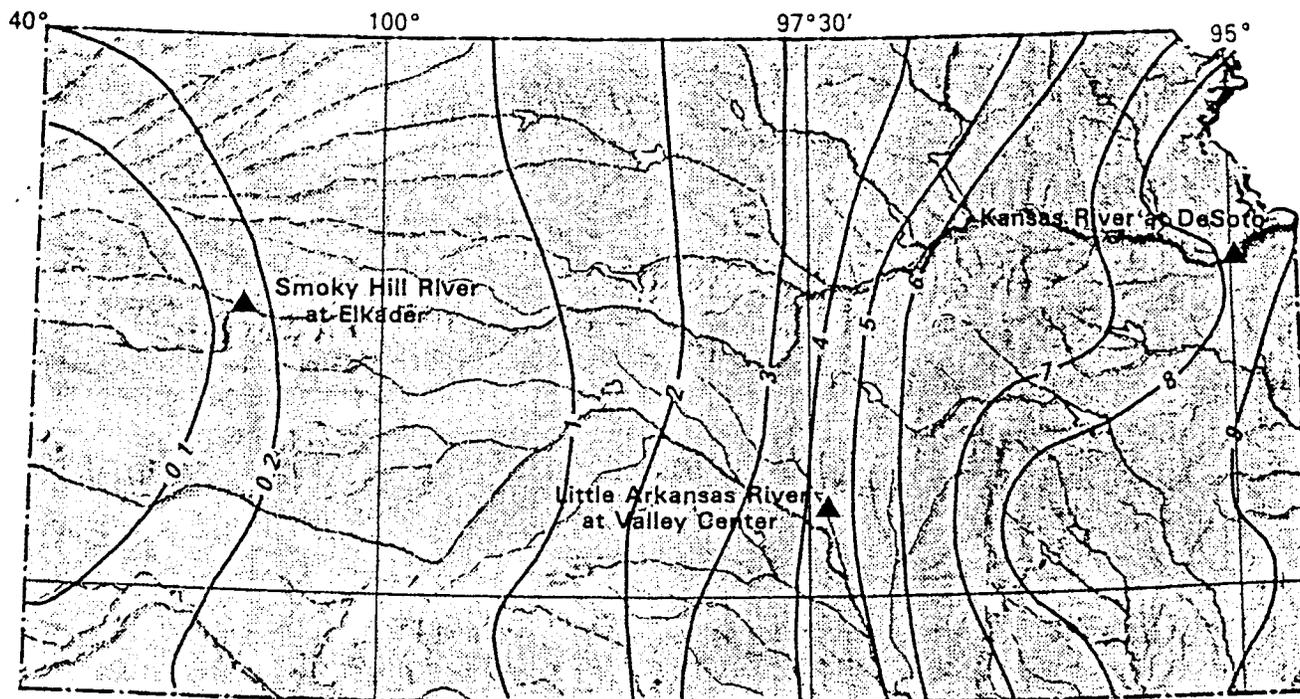


Figure 14. Mean annual runoff in inches. (Adapted from Wetter, 1987).

▲ USGS stream-gaging station—Monthly data shown in bar graphs



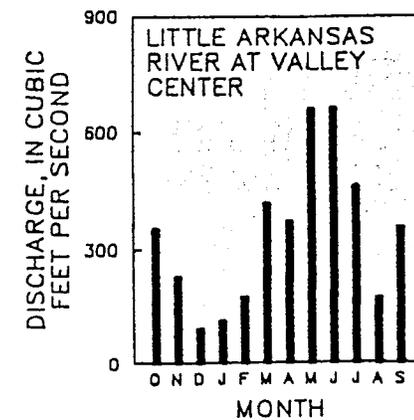
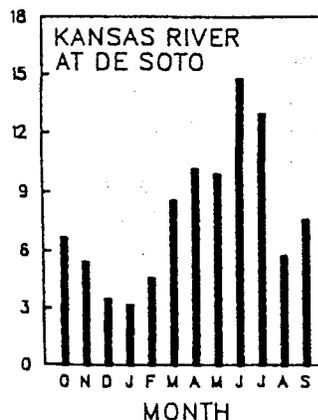
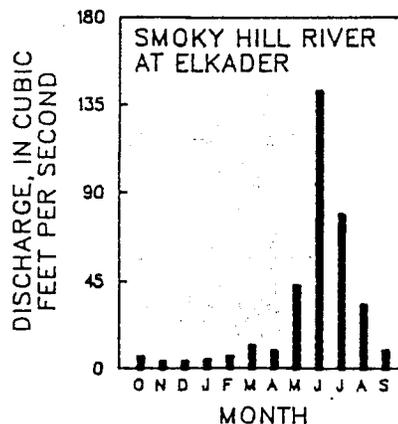
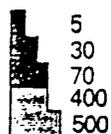
RUNOFF 1951-80.



RELATIVE DISCHARGE

EXPLANATION

Average annual discharge
In hundreds of cubic feet
per second



AVERAGE MONTHLY DISCHARGE

Table 3. Ground-water and surface-water use for Kansas.

(Figures may not add to totals because of independent rounding)

Year		1950	%	1960	%	1970	%	1980	%	1985	%	1990	%
Population x1000		1905		2179		2249		2363		2451		2478	
Ground Water (MGD)		401	68.3	1230	43.8	3170	82.9	5620	85.1	4800	84.7	4370	71.7
Surface Water (MGD)		233	31.7	1580	56.2	630	17.1	980	14.9	866	15.3	1720	28.3
Total Water (MGD)		634		2810		3800		6600		5670		6090	
Per capita use (gpd)		330		1285		1700		2800		2310		2460	
Public Supply (MGD)	GW	75	18.7	120	10.0	130	4.2	140	2.5	158	3.3	176	4.0
	SW	60	25.8	81	5.1	120	18.8	150	15.3	158	18.2	197	11.5
	TL	135	21.3	200	7.1	250	6.6	290	4.4	316	5.6	373	6.1
Domestic and Livestock (MGD)	GW	65	16.2	66	5.5	79	2.5	93	1.7	84	1.8	108	2.5
	SW	15	6.4	28	1.8	51	7.9	50	5.1	26	3.0	31	1.8
	TL	80	12.6	94	3.4	130	3.4	142	2.2	110	1.9	139	2.3
Thermoelectric (MGD)	GW			23	1.9	38	1.2	46	0.8	12	0.3	13	0.3
	SW	N/R		510	31.9	220	34.4	300	30.6	403	46.5	1290	75.0
	TL			530	18.9	260	6.8	346	5.2	415	7.3	1300	21.4
Other (commercial / industrial / mining) (MGD)	GW	100	24.9	120	10.0	120	3.9	140	2.5	75.3	1.6	81	1.9
	SW	95	40.8	60	3.8	37	5.8	41	4.2	19.3	2.2	5	0.3
	TL	195	30.8	180	6.4	160	4.2	181	2.7	95	1.7	86	1.4
Irrigation (MGD)	GW	161	40.1	900	75.0	2800	90.3	5200	92.9	4470	93.1	3990	91.5
	SW	62	26.8	900	56.3	200	31.3	440	44.9	260	3.0	199	11.6
	TL	223	35.2	1800	64.3	3000	78.9	5600	85.5	4730	83.4	4190	68.9
Irrigated land (acres x 1000)		300		1000		1800		3400		2950		3110	

Abbreviations: GW - Ground Water; SW - Surface Water; TL - Total Water (GW+SW); gpd - gallons per day; MGD - million gallons per day; N/R - not reported; % - quantity as a percent of GW, SW, or TL use in particular category over total yearly use of GW, SW, or TL, respectively. To convert MGD to AF/day multiply by 3.0693.

Sources: USGS Circulars 115 (1951), 456 (1961), 676 (1972), 1001 (1983), 1004 (1988), 1081 (1993)

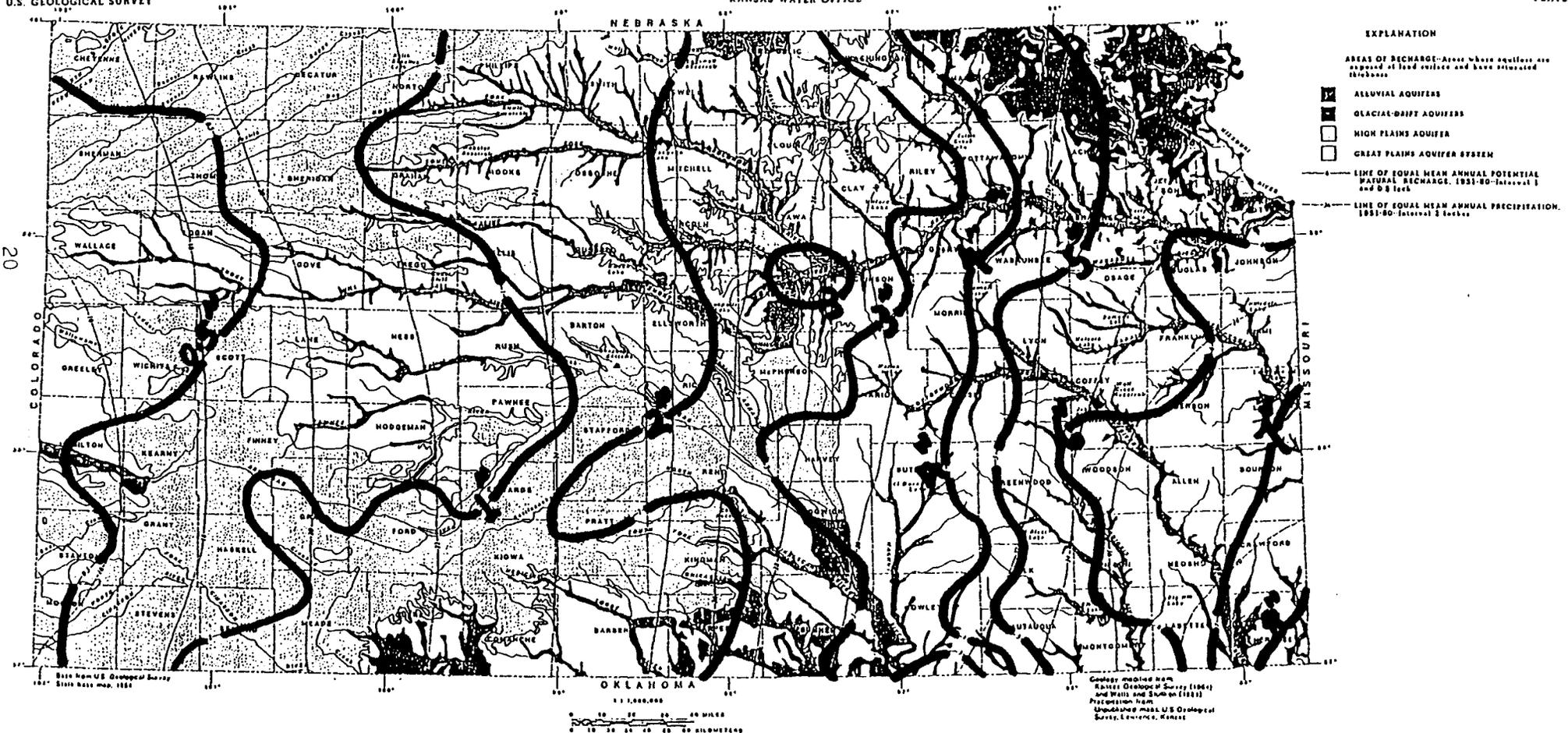
ESTIMATES OF FRESHWATER STORAGE AND
POTENTIAL NATURAL RECHARGE FOR PRINCIPAL
AQUIFERS IN KANSAS

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 87-4230

KGS
01564

Prepared in cooperation with the
KANSAS WATER OFFICE





MAP SHOWING AREAS OF RECHARGE TO PRINCIPAL AQUIFERS, MEAN ANNUAL POTENTIAL NATURAL RECHARGE, AND MEAN ANNUAL PRECIPITATION IN KANSAS

By
Cristell V. Hansen
1987

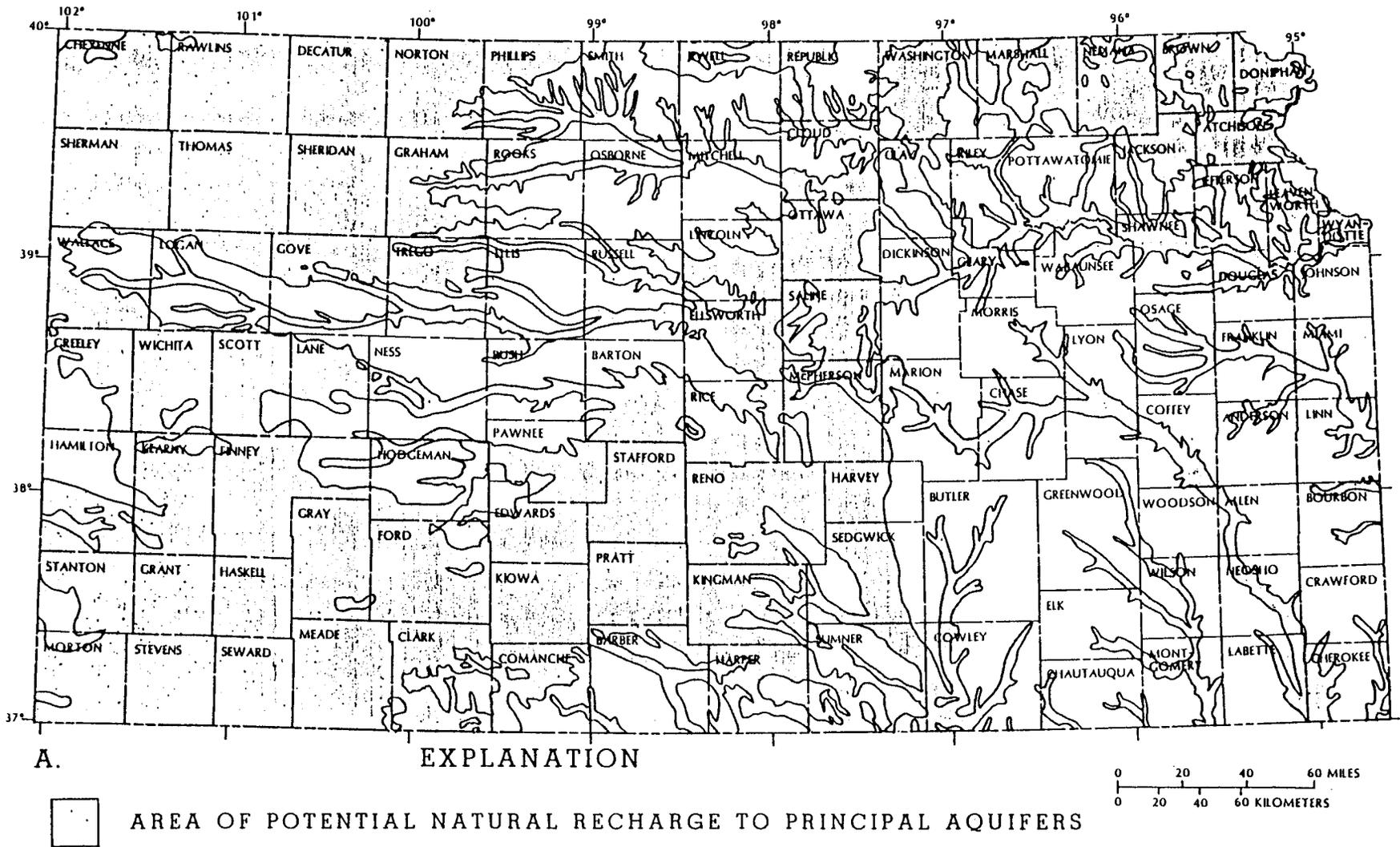


Figure 9. (A) area and (B) volume of potential natural recharge to principal aquifers.

Aquifer	Area of potential natural recharge (acres)	Rate of potential natural recharge (inches per year)	Mean annual potential natural recharge (acre-feet per year)	Percent of potential natural recharge
Alluvial	5,380,000	3.28	1,470,000	37
Glacial-drift	1,640,000	4.85	663,000	17
High Plains	17,300,000	1.06	1,530,000	38
Great Plains	1,560,000	2.48	323,000	8
Ozark	--	--	--	--
Total for State	25,900,000	1.85	3,990,000	100

B. Basic hydrogeologic concepts

SOME IMPORTANT HYDROGEOLOGIC CONCEPTS

***System thinking

***Flow system / flow patterns

--Recharge/Discharge areas

--Flow paths

--Flow system = set of flow paths with common recharge and discharge areas

Local flow systems

Regional flow systems

***Ponds and lakes

--recharge

--discharge

--flow-through

--shallow discharge-deep recharge

--Dynamic (not static) bodies

SYSTEM Concept: Of fundamental importance as a framework for thinking about a G/W problem.

An example of the need for *system thinking* in practical problems is the *site* investigations of G/W contamination from point sources, or the *site* investigation of the hydrologic impact of a gravel pit. Many of these studies suffer irreperably from the investigators' failure to apply *system thinking* by not placing and studying the local "site" in the context of the larger G/W system of which the site is only a small part.

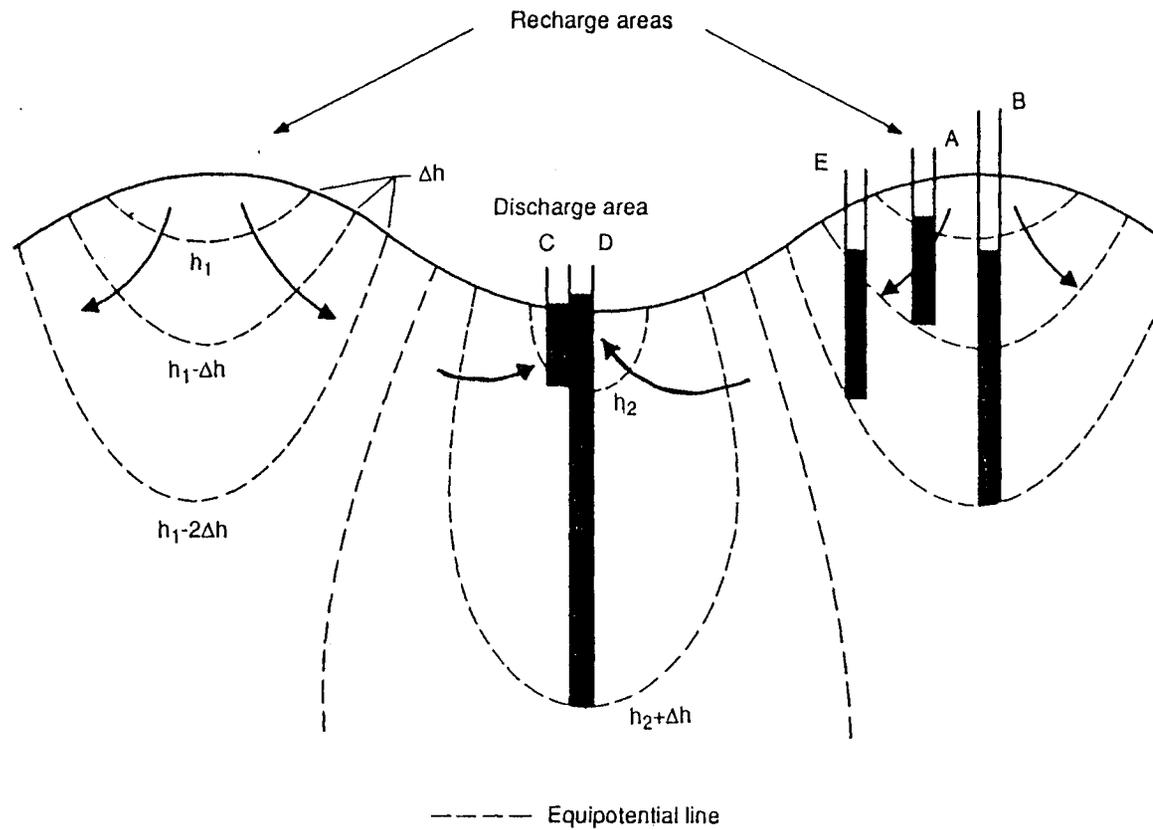


FIGURE 6.3.5 Conceptual model of a groundwater flow system. The dashed lines are lines of constant hydraulic head; head decreases with depth in recharge areas and increases with depth in discharge areas. The piezometers have small screens at the bottom of the borehole.

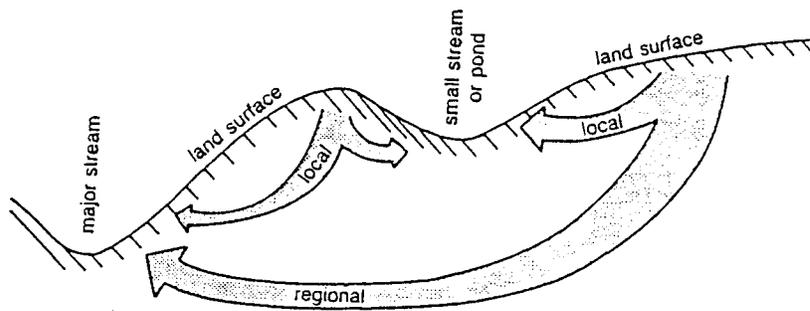


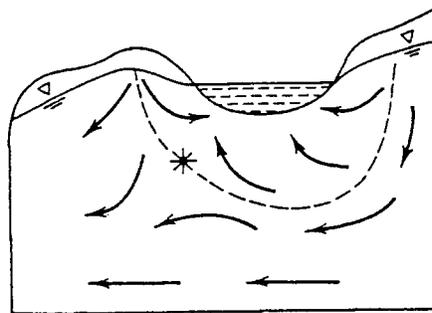
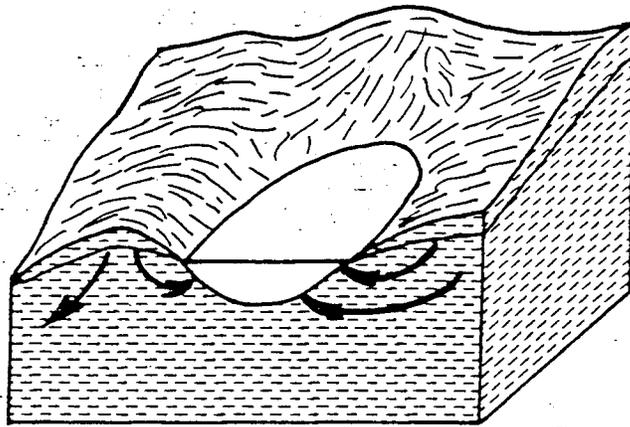
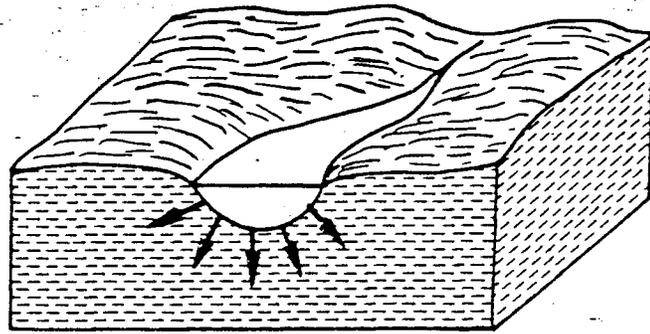
Fig. 4.7 Local and regional flow systems and relationship to recharge and discharge areas

FLOW SYSTEMS

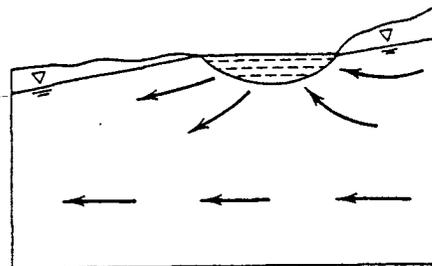
Flow system studies help us understand the interrelations between *recharge* and *discharge* processes. For example, some of the water derived from precipitation that enters the ground in *recharge areas* will be transmitted to distant *discharge areas*, and so cause a relative moisture deficiency in soils overlying recharge areas.

Water that enters the ground in *discharge areas* cannot normally overcome the upward potential gradient, and therefore becomes subject to *evapotranspiration* in the vicinity of its point entry.

Human activities in *discharge areas* may cause waterlogging problems associated with surface water irrigation of lowlands, or due to the distraction of *phreatophytes*.



(a)



(b)

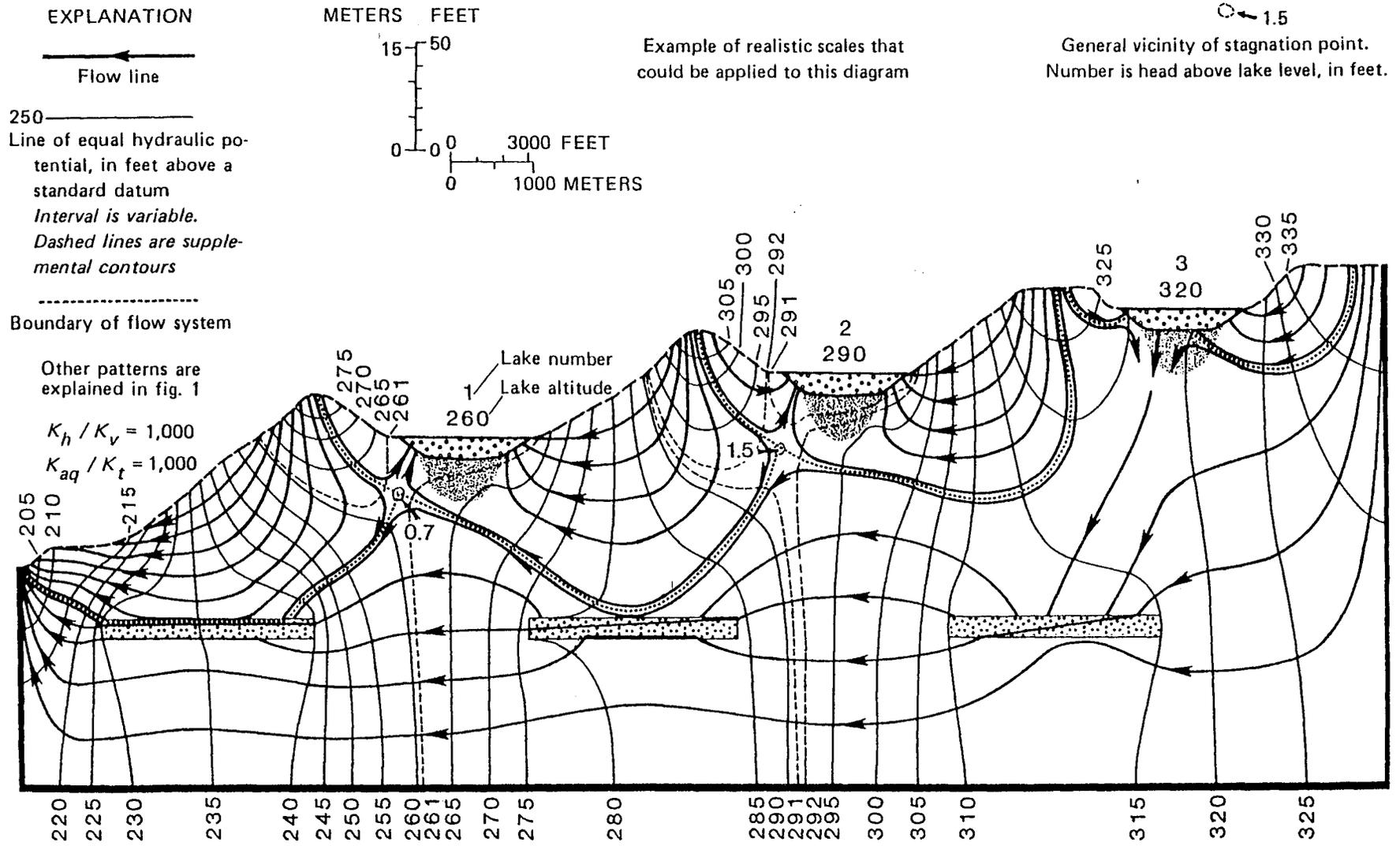


FIGURE 5.—Hydrologic section showing a quasi-quantitative flow net of ground-water flow near lakes in a multiple-lake system that contains aquifers.

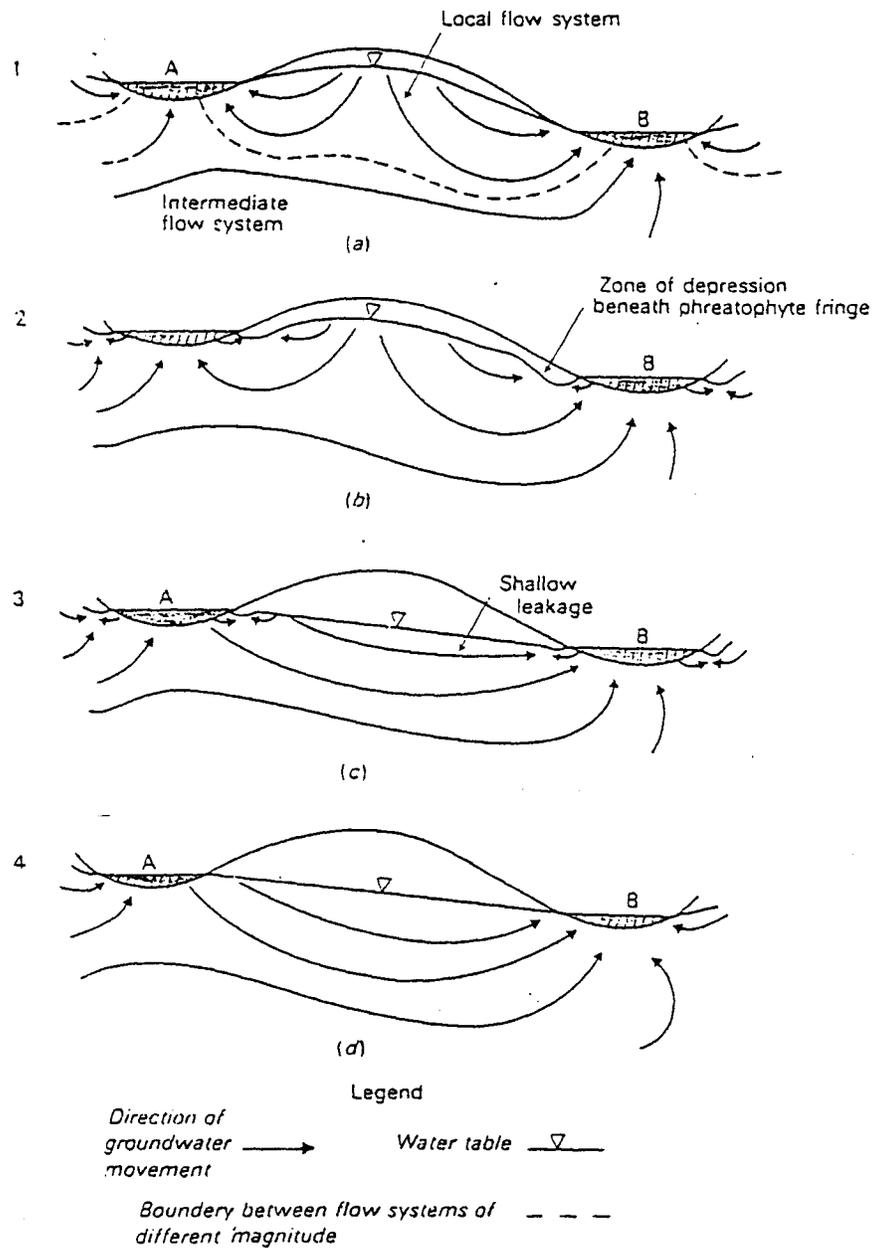


Fig. 2 Diagrams of flow conditions near permanent lakes with (a) a spring condition of discharge from local and intermediate systems, (b) a summer condition of seepage toward the phreatophytic fringe, (c) deterioration of local flow in the absence of recharge, and (d) a fall and winter condition for the deteriorated system, where shallow movement is superimposed on the intermediate system. (After Meyboom, 1967. Used with permission from North Holland Publishing Company, Amsterdam.)

HYDROLOGIC EFFECTS OF GRAVEL PITS

Field observations of G/W level changes seem to confirm the theory that unlined water-filled gravel pits act as areas of high hydraulic conductivity within the aquifer, and modify the G/W flow pattern by lowering water levels upgradient of a pit and raising levels downgradient of a pit

C. Estimation methods for *recharge* and *evaporation*
from ponds and lakes

RECHARGE ESTIMATION METHODS

- 1) Direct measurements
 - Lysimeters (not used in ponds and lakes)
 - Seepage meters

- 2) Water balance methods: $I - O = \Delta S$
 - a. Soil-moisture budget: $R = P - RO - ET - \Delta S$
 - b. River channel water balance
 - c. Water-table rise: $R = S_y \Delta h$

- 3) Darcian approaches: $q_l = -K \Delta h / \Delta l$
 - a. Field methods
 - i) Saturated flow
 - ii) Unsaturated flow
 - b. Numerical methods

- 4) Tracer techniques

- 5) Other---Empirical [$R = f(P)$]

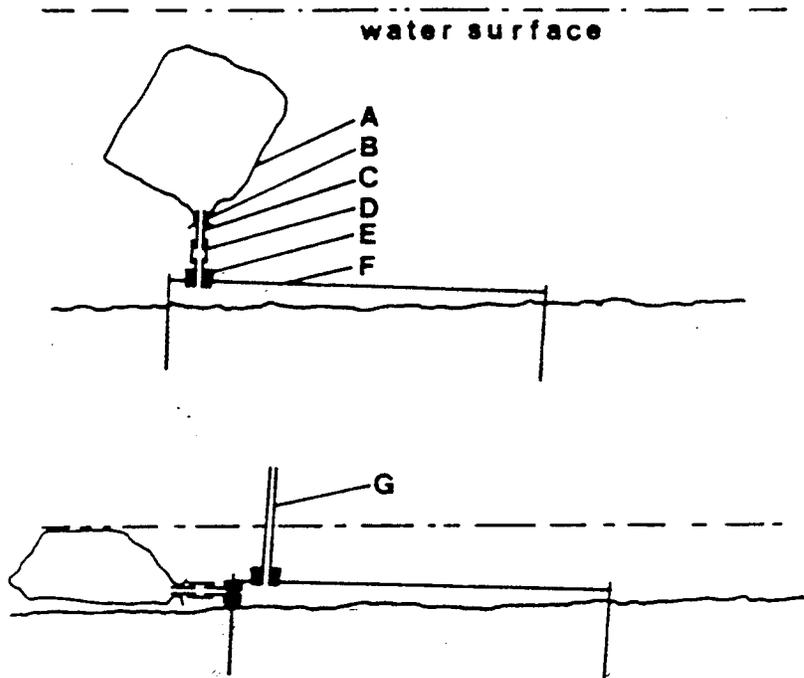
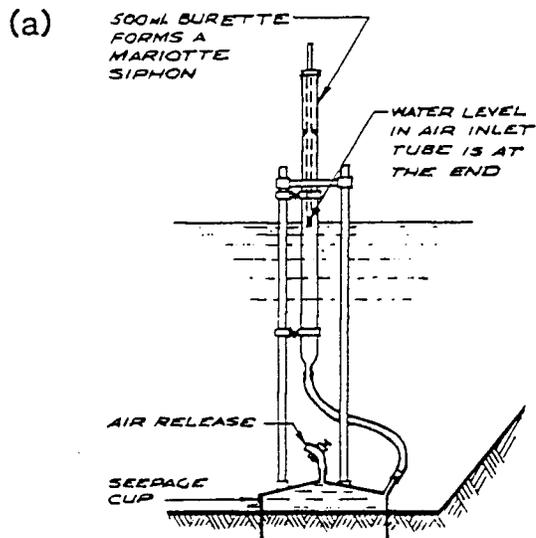


Figure 3.—Cut-off 55-gallon drum seepage meter. From Lee and Cherry, 1978. (Full section view of seepage meter showing proper placement in sediment. A. 4 liter, 0.017 mm membrane plastic Baggies Alligator bag (open end was heat sealed); B. rubber-band wrap; C. 0.64 cm inside diameter, 6 cm long, polyethylene tube; D. 0.79 cm inside diameter, 4.5 cm long, amber-latex tube; F. 15 cm x 57 cm diameter epoxy-coated cylinder (end-section of a steel drum); G. 0.64 cm inside diameter, polyethylene tube long enough to reach above the surface water.)



**WEBER BASIN
SEEPAGE METER**

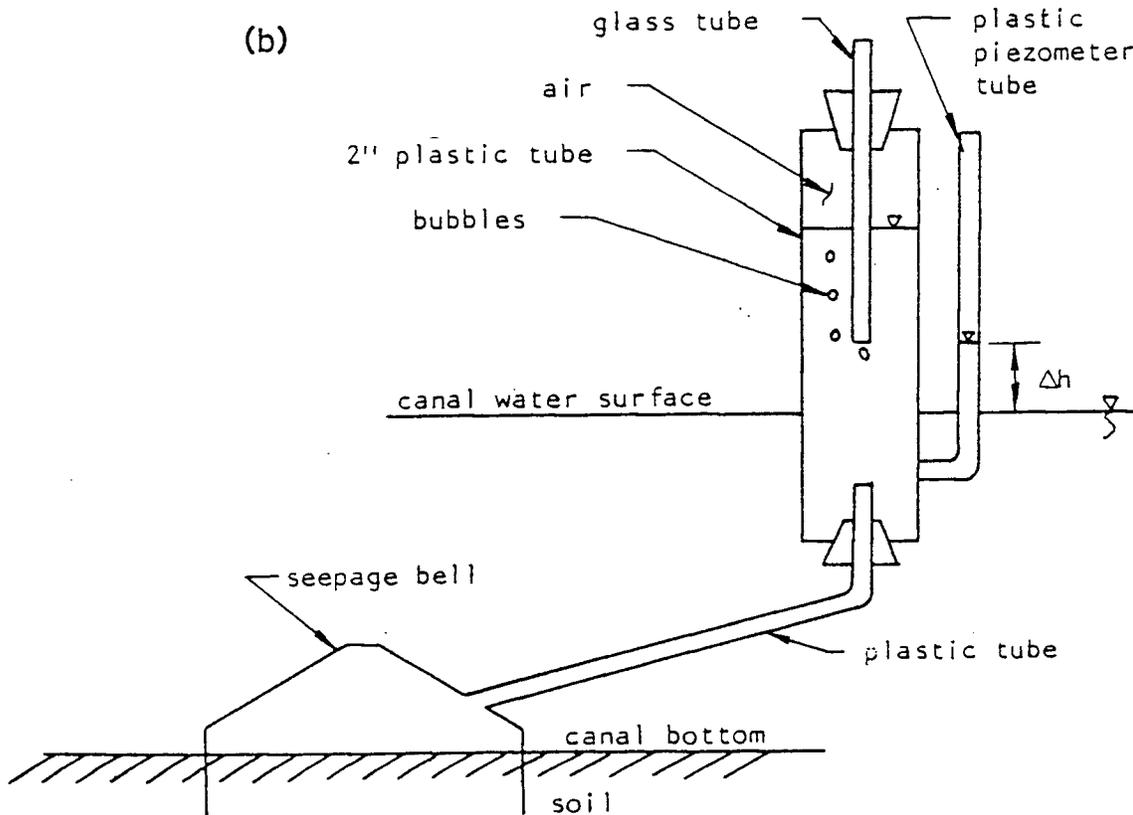


Figure 4. --Weber Basin or Mariotte siphon seepage meter: (a) from Warnick, 1951; (b) from Hendricks and Warnick, 1961.

FREE WATER EVAPORATION ESTIMATION METHODS

1) Empirical mass transfer methods: $E_a = f(W)(e_s - e_a)$

i) Harbeck: $E = k A^{-0.05} W (e_s - e_a)$

ii) Meyer: $E = c (1 + W/16.09) (e_s - e_a)$

2) Evaporation pans --- $E = k E_p$

3) Water balance (budget) techniques:

$$E = I + P - O - O_g - \Delta S / \Delta t$$

4) Energy budget techniques:

$$Q_n - Q_e - Q_h + Q_v = \Delta Q / \Delta t; E = Q_e / \rho L$$

where:

Q_n = net radiation

Q_e = energy used in evaporation

Q_h = energy exchange between water and atmosphere as sensible heat

Q_v = energy advected into or out of lake

ΔQ = change in lake energy

5) Combination methods

Penman equation: Combine methods 4) and 1)

$$E = [(\alpha Q_n / \rho L) + E_a] / (1 + \alpha)$$

where $\alpha = \Delta / \gamma$

Δ = slope of saturation vapor pressure versus temperature curve at air temperature;

γ = psychrometric constant

NOTE: *Lysimeters* not practical for ponds and lakes

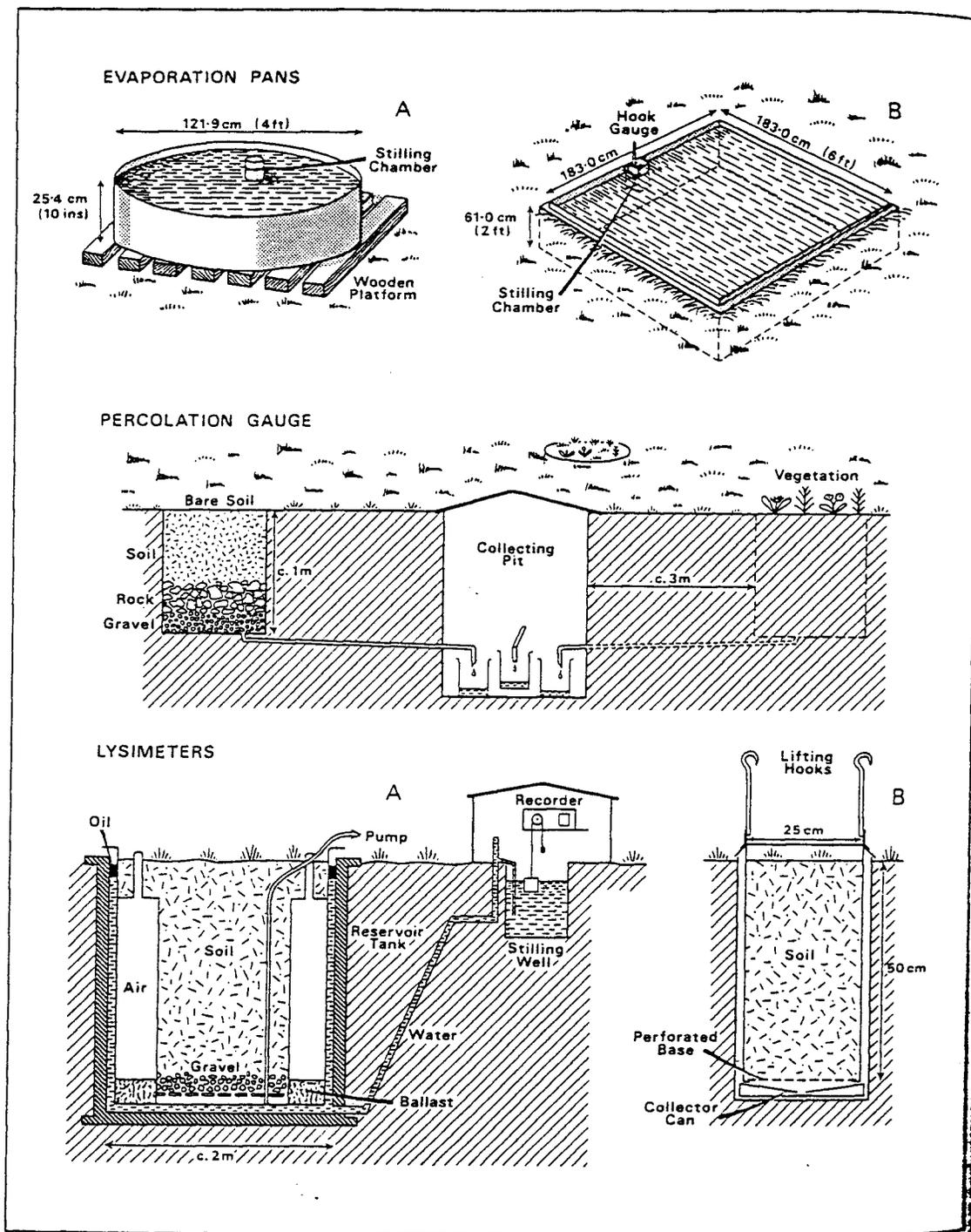


Figure 3.3 Installations for measuring evapotranspiration losses
 This figure shows two types of evaporation pan, the U.S. Weather Bureau Class A Pan (A) and the British Meteorological Office Pan (B); a percolation gauge which could be used to assess evaporation from bare soil and evapotranspiration from vegetated surfaces; and a sophisticated hydraulic lysimeter (A) and a simple weighing lysimeter (B).