

Groundwater Contamination in the State of Kansas:  
Its Extent, Nature, and Socio-economic Impacts

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## ABSTRACT

Environmental degradation has been very much in the public spotlight since at least 1970. In Kansas, air quality problems relating to particulate matter and odors associated with agricultural activities and the typically eutrophic nature of our surface waters are noticed by the most casual visitor. Groundwater, on the other hand, is a resource pretty well out of sight/ out of mind but of enormous economic importance to the state. The purpose of this research project is to define the extent and severity of groundwater contamination in the state of Kansas.

Remediation projects and technology are outlined in the text. Sources of contamination and movement of contaminants through the subsurface are examined. Major recommendations of this project are land management and water use practices, personal concrete actions, as the most cost effective options to prevent groundwater contamination from occurring.

## Introduction

The title of this research paper is, "Groundwater Contamination in the State of Kansas: Its Extent, Nature, and Socio-economic Impact." It was originally undertaken to partially fulfill the requirements of a bachelor of science degree in environmental engineering from Columbia Southern University in Orange Beach, Alabama.

As a long time Kansas resident and water supply/treatment specialist with over ten years experience, I have repeatedly witnessed impacts of groundwater contamination either by monitoring and remediation requirements or by the addition of new treatment processes. With a professional interest in water quality issues, the multitude of articles on this subject in both the general media and trade journals has captured my attention. Every issue of the Kansas Lifeline since 1990, except four, have contained at least one article on groundwater contamination in the state.

Federal water law is a fractured entity. State oversight and administration of water resources is similarly fractured. At least fourteen different regional, state, and federal agencies have varying degrees of oversight of water related issues in the state of Kansas.<sup>1</sup> As I rightly suspected, there is no one source of comprehensive overview of groundwater quality in the state for citizen or professional.

The purpose of this paper is to provide an analysis of and a degree of magnitude for groundwater quality problems in Kansas. I have attempted to provide a snapshot of groundwater use in the state, its occurrence or hydrogeology, a framework of the relevant regulatory community, and the attributes that define a "good" quality water. Conversely, I have attempted to define the primary contaminants of concern, why they are a concern, where they occur, and how remediation is taking place. Above all, I

have attempted to make this paper understandable by providing the background information water quality professionals use to make decisions.

A frequently overlooked consideration is how people react when it is discovered that their water is contaminated in some fashion. Water quality is a very emotional issue. Depending on the point of view, regulatory agencies are often regarded as being overly restrictive or not restrictive enough. Certain anecdotes have been included to illustrate the widely varied attitudes Kansans take regarding their drinking water. It is also apparent that there are concrete actions individuals can take to protect the quality of the groundwater they drink.

Lastly, groundwater use, remediation of contaminated groundwater, and prevention of groundwater contamination represent extensive economic impacts that deserve consideration. Where possible, the dollar costs of these projects have been included for a sense of perspective.

As my research for this paper progressed it became evident that the subject was so complex that I was dealing with a large number of experts in narrow specialities. The scope of the information was so vast, it was difficult to interpret and contradictory at times. As an example, on my inquiry about nitrate occurrence in the state I had been referred to a researcher at Kansas State University. In my conversation with him, he suggested the KDHE 305 b report as an information source. Upon receipt of the report I discovered its primary topic was surface water quality in the state. However, it did contain a scant few pages dedicated to groundwater, probably because of the predominate usage of this resource in the state. I had previously acquired the KDHE identified sites list (ISL) and assumed that I had a pretty good grasp of synthetic chemical contamination in the state. A groundwater contamination summary in the 305 b report listed an additional 456 sites under a federal program. Worse, a second

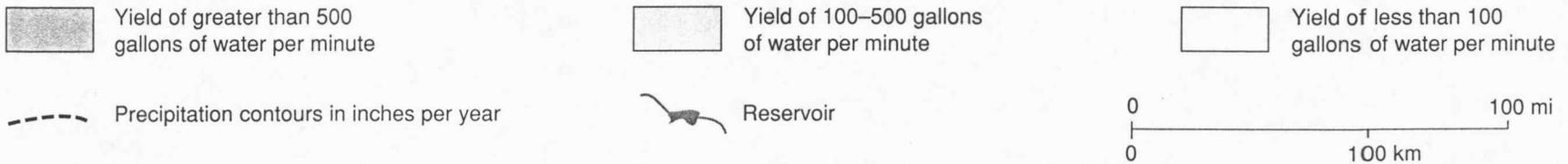
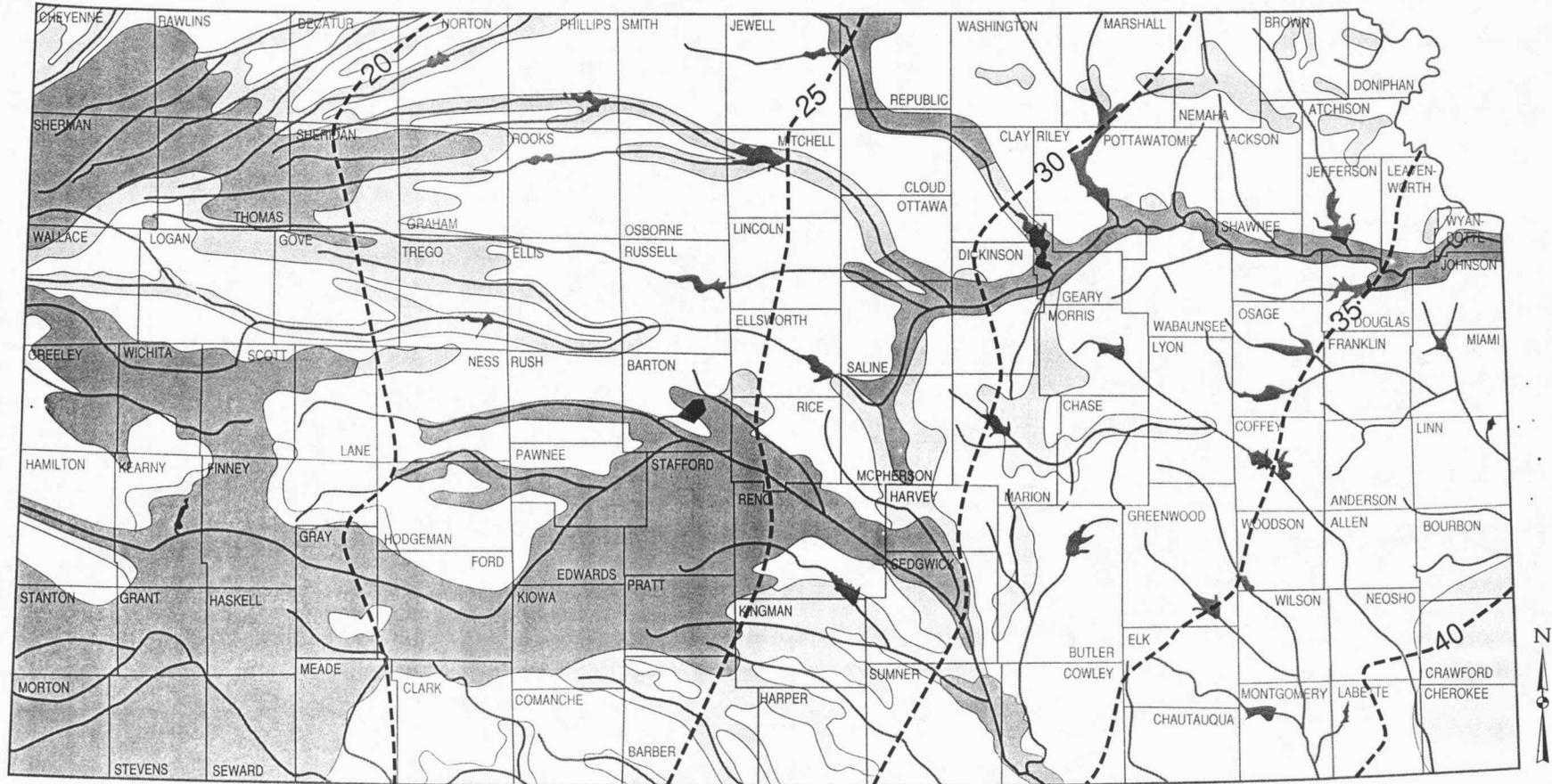
program entitled, "RCRA Corrective Action," was simply noted as under EPA control and posted no data.<sup>2</sup>

Because of the scope of the issue of groundwater contamination, the degree of specialization in addressing it, and the inherent contradictions involved, I have included specific references to various agencies to address specific problems. In the real world of water treatment and supply, a source water typically has relatively stable parameters and treatment trains are specifically built to address those parameters. Water contamination problems have very localized impacts even though the programs regulating them come from afar. Also, no one has to go it alone. There are a fair number of agencies in the state who make it their business to assist people and water supply systems with water quality problems.

It is my intent for this paper to draw upon the widely divergent information sources available to produce a comprehensive overview of this enormous and vital issue affecting virtually all Kansans. Primary sources of my information are various bureaus within the Kansas Department of Health and Environment, Kansas Corporation Commission, Kansas Geological Survey, Cooperative Extension Services, and U.S. Environmental Protection Agency Region VII. The Kansas Lifeline published by the Kansas Rural Water Association and numerous articles by Jean Hays in the Wichita Eagle provided specifics on the local impacts of groundwater contamination. I also had the pleasure of talking to a number of water quality professionals for their insights on this project. My thanks to all.

Actions taken in the past, regarding groundwater, affect us now. Actions taken today will affect us tomorrow. It is my hope that this project proves to have value to all Kansans, citizen and professional alike.

# General Availability of Ground Water and Normal Annual Precipitation in Kansas



## Chapter 1: State Hydrogeology and Usage

Freshwater resources are classified as either surface water (lakes and rivers) or groundwater (any water that can be pumped from a well). In the state of Kansas the majority of surface water resources are available in the eastern half of the state where normal annual precipitation ranges from 25" to over 40" in the extreme southeast corner. As one travels west to the high plains region and the Colorado border annual precipitation drops to 20" or less. Conversely, groundwater resources in eastern Kansas are limited while western Kansas enjoys relatively abundant groundwater. (See map #1 on the preceding page).<sup>3</sup>

Kansas relies on groundwater to supply a higher percentage of its water needs than almost any other state in the US. Statewide, groundwater supplies approximately 4.8 billion gallons a day. About half of all Kansans depend on groundwater for their domestic supplies. 70% of public water supplies use groundwater as their only source of water. An additional 4% use a combination of groundwater and surface water. About 85% of the total water used in the state is groundwater.

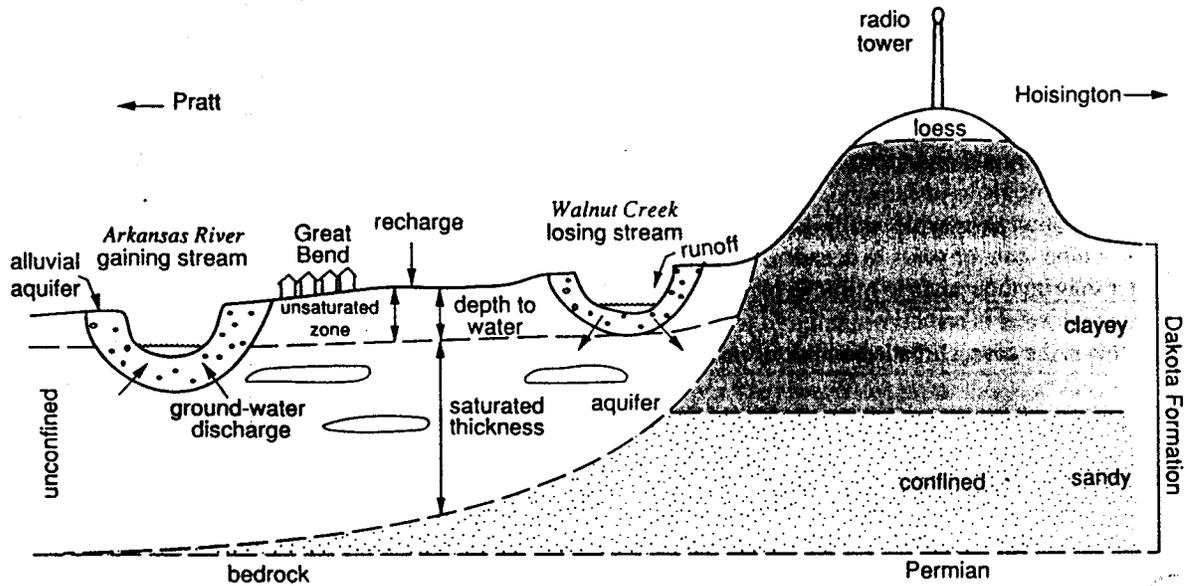
Although per capita domestic use of water averages 160 gallons per day this only accounts for 3.4% of the total groundwater use in Kansas. 94% of the groundwater used in this state goes to the irrigation of crops. An additional .5% is used for watering livestock while industrial usage accounts for the remaining 2%.<sup>4</sup> Although high quality drinking water is essential to life, economic activities consume a lion's share and frequently drive the degradation in quality of groundwater resources.

Kansas contains ten major aquifer formations that supply some degree of freshwater as well as alluvial aquifers associated with all the major rivers and many lesser streams. Although an aquifer may be largely associated with a single geological formation, such

as the Dakota formation or the Jurassic Morrison, aquifers typically include a wide variety of hydraulically interconnected rocks and sediments. A good example is the High Plains aquifer in western Kansas. This aquifer is known by the residents of this area as the Ogallala, after the predominant water bearing formation, but in reality the High Plains aquifer is a hydrologic unit including the Great Bend Prairie aquifer, the Equus Beds, alluvial and sand dune aquifers, as well as having interconnections with the underlying Dakota formation.

Not only are these hydrologic units complex they are also dynamic. Just as a river runs downhill to the sea, groundwater also flows along hydraulic gradients from areas of recharge, where water is entering an aquifer, to areas of discharge, where water is leaving an aquifer such as a spring or river bank. Unlike the river, whose velocity is measured in feet per second, groundwater flow is more sedate, along the lines of approximately one foot per day in western and central Kansas. This foot per day velocity translates to approximately one mile per fifteen years.<sup>5</sup>

Surface water and groundwater are inextricably linked as they frequently discharge into and recharge each other. Alluvial aquifers contribute to a phenomena called baseflow. During times of high stream flow, water typically flows from the stream into the surrounding aquifer and recharges it. As stream flows decline the hydraulic gradient is reversed and the stream becomes a point of aquifer discharge. This baseflow is the water which keeps a stream alive and running as precipitation and runoff decline. Figure 1 shows an interesting relationship between an aquifer and two adjacent rivers at differing elevations while illustrating baseflow into the Arkansas River.<sup>6</sup> Walnut Creek is designated a "losing stream" while the Arkansas River is considered a "gaining stream."



**Figure 1** - A schematic cross section of hydrogeology in the Great Bend area

As one begins to examine the issues of groundwater quality and contamination the complexity of these hydrologic units quickly come into play. Man related activities can influence water quality in surprising ways. For example; not only can heavy pumping of groundwater eliminate the life sustaining baseflow of a stream by lowering the water table but the change in hydraulic gradient can initiate the movement of lower quality water from underlying or connected aquifers into the freshwater aquifer resulting in saltwater intrusion or other contamination. Often, changes in groundwater quality are related to long term changes in land use, such as the effects of urbanization or the conversion of rangeland to irrigated cropland. What has readily become apparent in the study of groundwater issues is that seemingly localized problems have a way of becoming problems affecting us all.

While there are many texts on hydrogeology in general, the best source of information concerning Kansas geology and groundwater is the Kansas Geological

Survey (KGS). This is a research and service division of the University of Kansas and, as such, can be found in Lawrence, Kansas.

Michael Barcelona et al, provides a concise overview of the general principles governing groundwater contamination in the text, Contamination of Groundwater, from which the following paragraphs are derived.

There are at least four ways by which groundwater contamination occurs; infiltration, direct migration, interaquifer exchange, and recharge from surface water. Infiltration refers to water percolating from the surface downward. Moving through a zone of contaminated soil, the water can dissolve contaminants and transport them deeper. Direct migration refers to releases to groundwater directly from below ground sources such as underground storage tanks (UST's) or by leakage through direct conduits such as improperly abandoned wells.

Contaminant releases can occur by design, accident, or neglect. It is frequently overlooked that subsurface percolation systems, such as septic tanks, are intentionally designed to discharge contaminants for the purpose of mitigation in the subsurface environment. Accidental contamination would be exemplified by such incidences as pipeline breaks. Contamination by neglect is illustrated by an uncovered stockpile of material containing leachable, or water soluble, substances. The federal Office of Technology Assessment (OTA), in 1984, grouped 33 types of groundwater contamination sources into six major categories.

Three basic processes govern the migration of contaminants in groundwater; advection, dispersion, and retardation. Advection is simply a term for movement or flow. As can be imagined, the flow of groundwater is governed by complex hydraulic and physical principals beyond the scope of this paper. Dispersion refers to movement caused by the irregular mixing of waters (turbulence and diversion) during advection.

A density difference of as little as one percent, relative to the uncontaminated groundwater, can cause dramatic downward movement of a contaminant plume. Retardation processes slow the movement of chemical constituents in groundwater. Four generally accepted retardation mechanisms are; dilution, filtration, chemical reaction, and transformation.

Dilution is not retardation, *per se*, but becomes an important factor in the function of the latter three mentioned mechanisms. It also serves to lessen the impact, in many cases, of the wave front of a contaminant plume.

Ion exchange processes are important reactions in retarding the movement of many contaminants. These processes operate to bind dissolved substances to the geologic matrix. A measure of this capacity is quantified in the term, "ion exchange capacity." Typically clay materials exhibit greater ion exchange capacities than other minerals. It is important to note that the ion exchange capacity of any geologic material is finite and may eventually be overwhelmed by a continuous source of contamination thereby allowing unretarded transport. Also, changes in environmental conditions (such as pH) or groundwater solution composition can cause the release of constituents formerly bound to the geologic materials.

An interesting aspect of transformation processes is biological activity. It has been noted that the presence of contaminant concentrations great enough to be of environmental concern are often high enough to elicit adaption of the subsurface microbial community. The biotransformation rate of a contaminant in the subsurface environment is not a constant, but increases after exposure to the contaminant in an unpredictable way.

Transformation processes may also increase the mobility of certain substances. Natural organic matter in the soil (such as humic and fulvic materials) can apparently

complex with and enhance the mobility of synthetic organic chemicals such as pesticides. The presence of co-solvents can also cause relatively insoluble chemicals and metals to become mobile.

The philosophy of groundwater programs, as delineated by the EPA in 1984, concluded that the value of a groundwater resource is bounded by the most beneficial present and future uses to which it can be put. Development considerations include the need to protect vulnerable recharge areas and the possibility of conjunctive use with available surface waters.

Barcelona concludes that other factors influencing remediation decisions are the availability of alternate sources of water supply, the political and judicial pressure, and the availability of funds. If alternate water supplies are plentiful and economical, there may be little incentive for more than cosmetic remediation, if any. Conversely, if there is great pressure from the public, press, and/or courts to "do something" there is a tendency to overreact - to install remediation measures that offer more in appearance than substance. In the final analysis, responsible agencies can pursue only those remediation measures for which they have resources.<sup>7</sup>

In summary;

- 1) Groundwater is an invaluable resource to Kansans and is heavily exploited for economic gain.
- 2) The occurrence and movement of groundwater and the interrelated nature of hydrologic formations is complex. A producing well does not operate in isolation from environmental conditions around it.
- 3) The processes affecting the movement of contaminants in groundwater are also complex. The subsurface is not a universal filter as was once widely assumed.

## **Chapter 2: The Regulatory Community**

Mirroring the physical and hydraulic complexity of hydrogeology is the complexity of the political structure designed to use and protect the resource. Law provides the justification and framework from which the regulatory community springs.

Federal laws which impact water quality control include; Federal Water Pollution Control Act (or Clean Water Act, CWA), Safe Drinking Water Act (SDWA), Resource Conservation and Recovery Act (RCRA), Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund), Pollution Prevention Act, Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Toxic Substances Control Act (TSCA), Oil Pollution Act, and Surface Mining Control and Reclamation Act.

As a general rule, federal environmental laws allow states to substitute state programs for federal programs so long as the state programs are at least as stringent. As an example, the KDHE Bureau of Remediation (BER) lists the State Statutes governing BER programs as; The Environmental Response Act, Kansas Storage Tank Act, Kansas Water Plan, Solid Waste Management Act, Kansas Drycleaner Environmental Response Act, and Mined-Land Conservation and Reclamation Act.<sup>8</sup>

This piecemeal approach to legislating "solutions" or oversight of water quality issues as they appear in the public consciousness has engendered a less than comprehensive regulatory framework to address these issues. The number of agencies with some degree of responsibility over groundwater and other entities with more than a casual interest in groundwater issues is simply mind boggling. The Kansas Water Office publishes a complete list of water agencies and responsibilities entitled, "Kansas Water Related Programs Manual," which in 1990 was 60 pages long.

Non-regulatory entities influencing groundwater policy or use include such groups as the; Kansas Water Well Association, Kansas Rural Center, Kansas Rural Water Association (KRWA), and Kansas Natural Resources Council (KNRC). Research organizations include the; Cooperative Extension Services, Kansas Geological Survey, U.S. Geological Survey (USGS), and Kansas Water Resources Research Institute.

All interest in groundwater is driven by use of groundwater. Jan G. Laitos and Joseph P. Tomain provide a very insightful overview of the operation of the resources market and water law in general in the text, "Energy and Natural Resources Law." A useful outline of Kansas water law specifically, is found in the Kansas Rural Center publication, "The Ogallala Aquifer: The Challenge to Sustainability in Western Kansas." Historically, laws governing water use, as with most other natural resources, have been formulated within a development based philosophy. An unused resource is considered a wasted resource.

The Kansas Water Authority was specifically legislated into existence to provide the, "coordinated management, conservation, and development of the water resources of the state."<sup>9</sup> This entity is appointed by the governor of individuals from many diverse fields who have a vested interest in water resources.

The Kansas Water Office operates under the purview of the Kansas Water Authority. This office is responsible for the formulation and revision of the annual State Water Plan. In support of the Water Plan, the Water Office also oversees or funds various programs such as; local environmental protection programs (county sanitation codes), non-point source control, non-point technical assistance, stream/aquifer interaction research, mineral intrusion research, and remediation of "orphaned" water contamination sites. Two key agencies in the operation of these programs are the State Conservation Commission and KDHE.

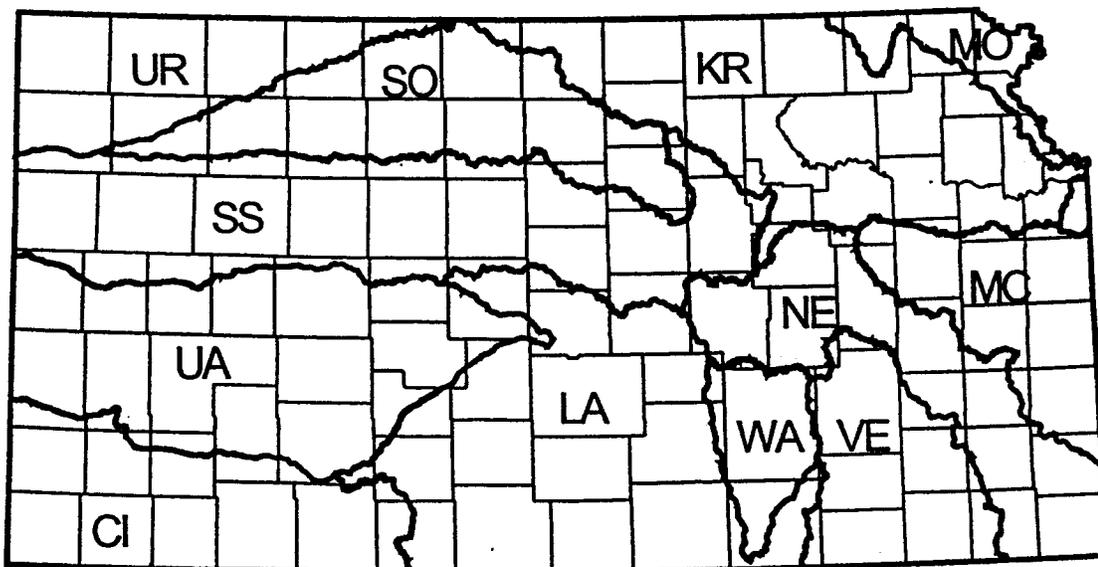
Although first promulgated in 1985, the Kansas Water Plan was not funded until the creation of the State Water Plan Fund in 1989. Revenue sources to the Fund are now the state general fund, economic development fund, water user fees, pesticide and fertilizer fees, and pollution fines or penalties.

The Water Office manages all water resource issues within the framework of individual river basins (Map #2 ) under the assumption that a common drainage area will have common problems and attributes. Each of the twelve river basins has an appointed advisory committee which are assisted by area coordination teams comprised of the top field office staff of various water related agencies. Regular public meetings are held annually within each river basin to delineate public concerns of water issues. Quite obviously, the Water Office is concerned with the quality and management of both surface and groundwater because of the integral nature of the two.

Another significant player in groundwater management is the Division of Water Resources (DWR) in the Kansas State Board of Agriculture. The DWR issues all permits to appropriate water including groundwater withdrawal for the purpose of environmental remediation. Because the use of groundwater has the potential to change the quality of groundwater, permitted use is a vital issue. The DWR also oversees local Groundwater Management Districts (GMD's) and can initiate the formation of Intensive Groundwater Use Control Areas (IGUCA's). One of the triggering conditions for the development of an IGUCA is that deterioration of water quality is occurring or may occur. The role of GMD's is examined in the next chapter.

In examining water supply and quality issues for the state, the annual State Water Plan contains useful summary information. Water use data can be obtained from the DWR. The KDHE also produces a biennial Kansas Water Quality Assessment (305 b Report) for the purpose of reporting surface water quality to the EPA. All this

information is public domain and can easily be acquired directly from the relevant agency. Increasingly, these government documents are also being posted electronically on the Internet.



**Map 2** - Drainage basins in Kansas

CI	Cimmaron	So	Soloman
KR	Kansas-Lower Republican	SS	Smoky Hill-Saine
LA	Lower Arkansas	UA	Upper Arkansas
MC	Marais Des Cygnes	UR	Upper Republican
MO	Missouri	VE	Verdigris
NE	Neosho	WA	Walnut

Non-regulatory entities also play vital roles in maintaining or improving groundwater quality. The Cooperative Extension Services associated with Kansas State University, for example, produce a large number of free educational pamphlets on subjects related to rural health and prevention of environmental degradation. The Kansas Rural Center, as another example, sponsors a Clean Water Farms Project in cooperation with KDHE and funded, in part, by the USEPA. The Kansas Rural Water Association is a unique entity in that not only does it provide education and training opportunities for water suppliers but also pitches in with manpower and technical assistance for those in need.

Although the ubiquitous presence of water quality degradation seems a hopeless situation, the regulatory community widely feels that improvements are occurring. The overall strategy is the elimination and control of point sources with an increasing shift of resources over time for the elimination and control of non-point sources. Continuous research backs these goals in defining the toxicological risks of environmental contaminants, the fate of these contaminants in the environment, and the improvement of technology. The U.S. Environmental Protection Agency and Kansas Department of Health and Environment have numerous and diverse responsibilities in the protection of groundwater quality . Their roles are discussed in the next chapter and throughout the following text.

The degradation of groundwater quality is, to a large extent, related to historical federal policies encouraging the consumption of natural resources. Conversely, the recent proliferation of federal environmental protection laws has generated a profusion of agencies responsible for their execution. Many private sector organizations also take an active role in the protection or remediation of groundwater quality because of the widespread usage and importance of the resource.

### Chapter 3: Defining Water Quality

In examining groundwater contamination it first becomes necessary to define water quality. Quality to a large extent is defined by its intended use. Large industrial boilers, such as those found at electric generation stations, must have water low in calcium carbonate hardness to protect their process heat transfer efficiencies while for public drinking water supplies calcium carbonate hardness is a nonregulated concern related to aesthetics. Table 1 shows a range of chloride concentration from 70 to 3000 mg/L with attendant suitability for domestic or agricultural use.<sup>10</sup> Even the cold, clear water of a high mountain stream is likely to contain the pathogen *Giardia* making it unfit for human consumption without disinfection.

The water quality issues which typically generate the most emotion are those regarding drinking water quality. Public water supplies are regulated by federal law under the Safe Drinking Water Act (SDWA) which sets national standards for allowable levels of contaminants in drinking water. Not only are substances which are harmful when consumed regulated but also those which may pose a health risk when outgassing from running water, such as occurs in taking a shower. Radon is an example of the latter as are some Volatile Organic Compounds (VOC's).

Levels of substances dissolved in water are typically expressed in the weight to volume ratio of milligram per liter (mg/L) or the volume to volume ratio of parts per million (ppm). Both are roughly equivalent. For perspective, a concentration of 1.0 mg/L of a substance is equivalent to 8.34 pounds the substance dissolved in one million gallons of water.

A related term of measurement, seen in the MCL's for many VOC's, is micrograms

per liter (ug/L) or parts per billion (ppb). For perspective, a concentration of 1.0 ug/L is equivalent to 8.34 pounds of a substance dissolved in one billion gallons of water.

Federal drinking water standards regulating the amounts of dissolved substances allowed in potable water are divided into two groups. Primary regulations establish maximum permissible contaminant levels (MCL's) which are enforced. Secondary regulations are recommended levels, not enforced, and typically reflect aesthetic concerns such as palatability or staining of fixtures.

The United States Environmental Protection Agency (USEPA) develops MCL's by a process called risk assessment. For there to be risk there must be exposure. Degree of risk is dependent on concentration and length of exposure (time). For the purpose of setting drinking water standards, the EPA assumes an average adult drinks two liters (1.89 quarts) of water per day throughout a seventy year lifespan.<sup>11</sup>

Risk is divided into two types, acute and chronic. Acute effects are those which immediately threaten health or life upon a single exposure above certain limits. Chronic effects are those which occur upon continual exposure over time.

MCL's for acute hazards are set at levels below which no adverse effects are expected to occur. For chronic hazards, MCL's are generally set at levels that limit the risk of physiological damage from that contaminant to between a chance of 1 in 10,000 and 1 in 1,000,000 over a lifetime.<sup>12</sup> Because MCL's for drinking water are based on exposure over a lifetime, short term exceedances of chronic hazard contaminants pose a limited health risk.

Additional considerations of the EPA in setting MCL's is the ability of various technologies to remove the contaminant in question, their effectiveness, and cost of treatment. All MCL's are set at levels intended to protect public health. Table 2 shows the current drinking water standards.<sup>13</sup>

**Table #1**

<b>TDS mg/L</b>	<b>Cl mg/L</b>	<b>Water Use Limits</b>
5700	> 3000	Unsuitable for most domestic/agricultural purposes
3900	> 2200	Poor water for livestock
2100	> 1500	Poor water for poultry
1200	> 500	Generally unsuitable for irrigation
	> 350	May adversely affect many crops
	140 - 350	Moderately tolerant plants usually show slight to substantial damage
700	250	Drinking water standard
	70 -140	Sensitive plants usually show slight to moderate injury
	< 70	Generally safe for most purposes

**Table #2**

**DRINKING WATER QUALITY STANDARDS**

**Inorganic Compounds (IOC) MCL's**

<b>Contaminant</b>	<b>mg/l</b>	<b>Contaminant</b>	<b>mg/L</b>
Antimony	0.006	Fluoride	4.0
Arsenic	0.05	Lead	Treatment Technique
Asbestos	7 MFL*	Mercury	0.002
Barium	2.0	Nickel	0.1
Beryllium	0.004	Nitrate	10

*\*million fibers per liter*

Cadmium	0.005	Nitrite	1.0
Chromium	0.1	Nitrate/Nitrite (total)	10
Copper	Treatment Technique	Selenium	0.05
Cyanide	0.2	Thallium	0.002

#### **Volatile Organic Compounds (VOC) MCL's**

<u>Contaminant</u>	<u>mg/L</u>	<u>Contaminant</u>	<u>mg/L</u>
Benzene	0.005	Hexachlorobenzene	0.001
Carbon Tetrachloride	0.005	Monochlorobenzene	0.1
p-Dichlorobenzene	0.075	Styrene	0.1
o-Dichlorobenzene	0.6	Tetrachloroethylene	0.005
1,2 Dichloroethane	0.005	Toluene	1.0
1,1 Dichloroethylene	0.007	1,2,4 Trichlorobenzene	0.07
cis-1,2 dichloroethylene	0.07	1,1,1 Trichloroethane	0.2
trans-1,2 dichloroethylene	0.1	1,1,2 Trichloroethane	0.005
Dichloromethane	0.005	Trichloroethylene	0.005
1,2 Dichloromethane	0.005	Vinyl Chloride	0.002
Ethylbenzene	0.7	Xylenes (total)	10

#### **Synthetic Organic Compounds (SOC) MCL's**

<u>Contaminant</u>	<u>mg/L</u>	<u>Contaminant</u>	<u>mg/L</u>
Acrylamide	Treatment Technique	Ethylene Dibromide	0.00005
Adipates	0.4	Glyphosate	0.7
Alachlor (Lasso)	0.002	Heptachlor	0.0004
Aldicarb (Temik)	0.003	Heptachlor epoxide	0.0002

Aldicarb sulfone	0.003	Hexachlorobenzene	0.001
Aldicarb sulfoxide	0.003	Hexachlorocyclopentadiene	0.05
Atrazine	0.003	Lindane	0.0002
Carbofuran	0.04	Methoxychlor (DMDT)	0.04
Chlordane	0.002	Benzo(a)pyrene (PAHs)	0.0002
Dalapon	0.2	Pentachlorophenol	0.001
Dibromochloropropane (DBCP)	0.0002	Phthalates	0.006
2,4-D	0.07	Picloram	0.5
2,4,5-TP (Silvex)	0.05	PCB's (Polychlorinated Biphenyls)	0.0005
Dinoseb	0.007	Simazine	0.004
Diquat	0.02	2,3,7,8 TCDD (Dioxin)	0.00000003
Endothal	0.1	Toxaphene	0.003
Endrin	0.002	Vydate (Oxamyl)	0.2
Epichlorohydrin	Treatment Technique		

In examining this table of MCL's note that "treatment technique" signifies water treatment methods that are required to be performed in place of an MCL.

To translate mg/L to ppb multiple by 1000. Note that in the enormously low tolerance for Dioxin this still yields the unwieldy number 0.00003 ug/L. This is further abbreviated as 3E-5 ug/L (or 3E-8 mg/L) on this KDHE listing.

The Trihalomethanes (THM's) chloroform, bromoform, bromodichloromethane, and dibromochloromethane are regulated at a MCL of 0.1 mg/L as a sum total of all. These

compounds are disinfection byproducts resulting from the reaction of chlorine with organic acids in the treated water.

In addition to these regulated compounds there are a number of synthetic compounds for which no MCL's are set but require monitoring as a "watch list".

### Unregulated Compounds

Bromobenzene	2,2 Dichloropropane
Bromomethane	1,3 Dichloropropane
Chlorobenzene	1,1 Dichloropropene
Chloroethane	1,3 Dichloropropene
Chloromethane	1,1,1,2-Tetrachloroethane
o-Chlorotoluene	1,1,2,2-Tetrachloroethane
p-Chlorotoluene	1,2,3-Trichloropropane
Dibromomethane	m-Xylene
m-Dichlorobenzene	o-Xylene
1,1-Dichloroethane	p-Xylene

Other regulated concerns are radionuclides, turbidity - which is a measure of finely divided or colloidal suspended particles, and microbiological contaminants such as bacteria and viruses.

Non-mandatory limits for various compounds and attributes are recommended as;

### Secondary Standards

Aluminum	0.2 mg/L	Manganese	0.05 mg/L
Chloride	250 mg/L	Odor	3 TON*

\* *threshold odor number*

Color	15 color units	pH	6.5-8.5
Corrosivity	non-corrosive	Silver	0.1 mg/L
Foaming agents	0.5 mg/L	Sulfate	250 mg/L
Iron	0.03	Zinc	5 mg/l
TDS	500mg/L		

MCL's do not reflect a total absence of risk but rather reflect an acceptable level of probability regarding health effects balanced against economic considerations and technological limitations. This is a fact that generates endless public debate and even hysteria regarding drinking water quality. For perspective it should be noted that only a small fraction of domestic water supplies are actually consumed. Fire protection, sanitation, and domestic irrigation are primary end users of treated drinking water.

It should be noted that these MCL's, as any chemical exposure health effects standards, tend to change over time in response to continuing research efforts. The EPA uses a concept called the Maximum Contaminant Level Goal (MCLG) in its risk assessments. This may be a preferred concentration level but unattainable because of detection and monitoring difficulties or treatment costs. The MCL will consequently be set at a higher value. Improvements in detection or treatment technology would logically result in a lowering of the MCL.

Other non-binding EPA standards or guidelines are Health Advisories (HA), Health Advisory Levels (HAL), and Unreasonable Risk To Health (URTH). These terms become relevant in the review of research or toxicological studies. Health Advisories are calculated based on animal studies and other exposure data. They provide initial information on health effects, analytical methods, and treatment technology for the chemical under study.

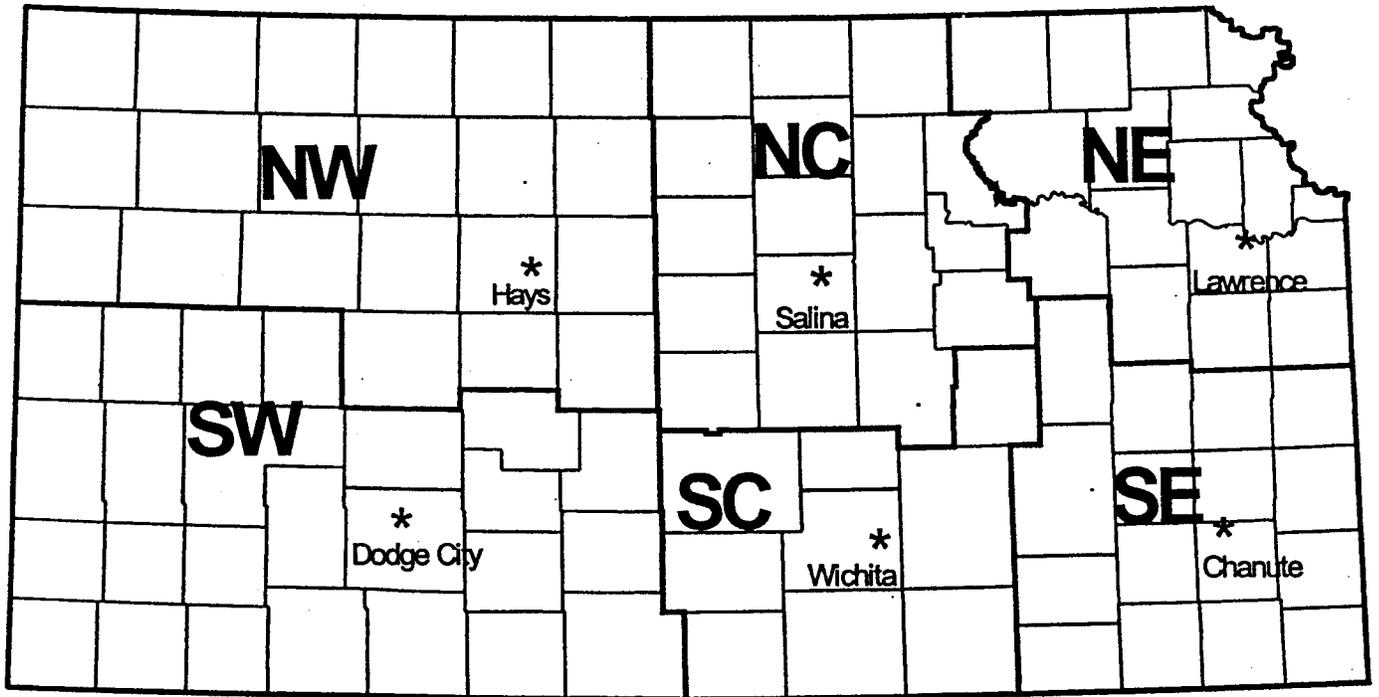
As a final consideration in understanding drinking water regulations it must be noted that the SDWA encourages the states to assume responsibility for enforcing federal drinking water standards. This is referred to as primacy. For a state to be granted enforcement primacy it must adopt the federal standards as minimum allowed standards. More stringent state requirements are possible.

In the state of Kansas the Kansas Department of Health and Environment (KDHE) has primacy for drinking water programs. This department also has regulatory responsibility over related programs which have a high probability of impacting water quality such as coal mining, nonpoint source pollution, waste treatment facilities of all types, and remediation of environmentally contaminated sites. The department shares concurrent authority with the Kansas Corporation Commission (KCC) with regard to the regulation of oil and gas wells, saltwater injection wells, and underground storage reservoirs.

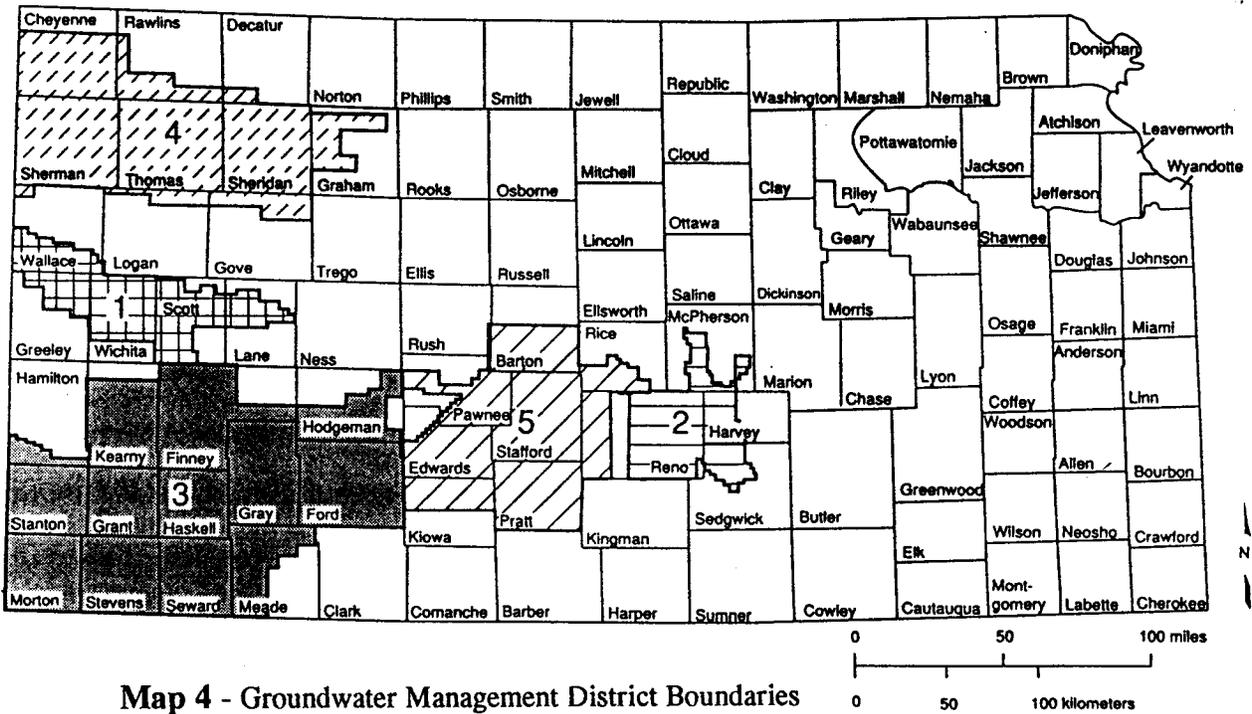
The local regulatory framework for Kansas drinking water begins with the EPA Region VII office in Kansas City, Kansas. Region VII encompasses Kansas, Missouri, Nebraska, and Iowa.

KDHE has divided the state into six administrative districts. KDHE's central office is in Topeka but each district maintains a local office. See Map #3 for the boundaries of each district and location of the district office.

Also of importance are five groundwater management districts (GMD's) created in the 1970's to provide local levels of management for groundwater use and planning. Map #4 outlines the boundaries of these GMD's. The districts have been instrumental in identifying local problems and taking action to protect groundwater quality. GMD 4, for example, undertook a vigorous program in the early 1990's to plug abandoned wells in its jurisdiction.



Map 3 - KDHE Administrative Districts and District Offices



Map 4 - Groundwater Management District Boundaries

Under natural conditions groundwater quality depends primarily on the nature of the materials the water has been in contact with and on the length of time it has been in contact. It must be pointed out that there are a large number of naturally occurring substances such as heavy metals, arsenic, salts, and flouride which may be dissolved in groundwater at levels making it unfit for human consumption without sophisticated and expensive treatment technology. Not all groundwater quality problems are caused by man.

In the state of Kansas the primary groundwater contaminants associated with the activities of man are salt, nitrates, and synthetic chemicals such as fuels, solvents, and pesticides. Heavy metals, such as lead and mercury, are serious contaminants but outside of the mining district in southeast Kansas their occurrence is fairly isolated and will only be examined briefly in relation to the discussion of Kansas NPL sites in chapter 6, "Synthetic Chemicals."

In summary;

- 1) Water quality is a condition related to its intended use.
- 2) Groundwater in its natural state may be unsuitable for many purposes.
- 3) The determination of drinking water quality standards is based on acceptable risk and achievability, not absence of risk.
- 4) Drinking water quality standards can reasonably be expected to change as research and technological development continue.
- 5) KDHE, under authority of the USEPA, has responsibility for enforcing federal drinking water quality standards required of all public water supply systems.

## Chapter 4: Saltwater Contamination

Freshwater is defined as having less than 500 mg/l of chloride (designated Cl) and less than 1,000 mg/L of total dissolved solids (TDS).<sup>14</sup> Secondary drinking water regulations are half these amounts. Chloride concentration is the primary indicator for salinity while TDS is an approximation because it is measuring all dissolved substances and minerals.

Aside from its use for human consumption, Table 1 on page 18 illustrates the limitations various chloride levels have on agricultural uses. From another perspective, the KCC defines 10,000 mg/L TDS as the absolute upper limit of water usable for any purpose. Water above 10,000 mg/L is considered mineralized and unusable.<sup>15</sup>

Saltwater, while corrosive, is not especially toxic to organisms in and of itself. Excessive salt intake exerts a physiological effect of disrupting the osmotic pressure balance at the cellular level. This osmotic pressure is what drives the uptake of free water by cells. As salt intake rises it causes water retention with its attendant cellular disruption and high blood pressure in humans. Taken to an extreme, salt intake will reverse the osmotic pressure and cause dehydration. Although the kidneys are very good at excreting salt, elevated levels of salt consumption increase the probability of kidney failure.

Naturally occurring salt contamination is a significant problem in Kansas where thick deposits of salt, deposited during the Permian Period of geologic history, underlie much of central Kansas. These deposits result in the presence of saltwater aquifers underlying freshwater aquifers often in poorly confined or nonconfined zones. Additional sources of saltwater contamination are anthropogenic and include improper disposal of oilfield brine or salt mine waste and recharge by irrigation water. Chloride, because of its ionic nature, moves almost uninhibited with the flow of water.

Point source salt contamination is now rare but still occurs as a result of pipeline breaks, accidental spills, and the like. However, in the early days of oil and gas production in central Kansas the brine associated with the extraction of these resources was pumped into evaporative ponds. Frequently the saltwater migrated underground and contaminated freshwater aquifers. Although these evaporation ponds have long since been banned their contamination problems remain with us.

As an example of the magnitude represented by some of these old point sources, consider that in 1989 the KDHE agreed to spend about \$250,000 for a five year demonstration project in the Hollow-Nikkel oilfield north of Burrton. Salt contaminated water was pumped out of the Equus Bed aquifer and disposed of in brinewater injection wells. The project removed 72 billion gallons of water and 400 tons of salt before the money ran out and the project terminated. In 1994 it was estimated that over 1.5 million tons of salt remains at this site alone.<sup>16</sup>

An important point regarding these oilfield point sources is that the KDHE and KCC are jointly responsible for remediating the associated pollution and protecting the usable waters of the state. The KCC currently levies a tax on oil production in the state to clean up these sites and plug abandoned wells. Salt mining activities leading to contamination of groundwater remains under the authority of KDHE.

The KCC Conservation Division publishes an annual Remediation Site Status Report of abandoned oilfield sites for use by the office of the Governor and certain legislative committees. As of January 12, 1998 there were eighty active sites listed of known saltwater contamination of groundwater in twentyeight counties, five of which were under active remediation. Public water supplies are impacted at seven sites. Domestic supplies are shown impacted at 35 sites. The report notes that some sites have impacts to

multiple resources.<sup>17</sup> A breakdown of these sites by number per county is shown in the following **Table #3**;

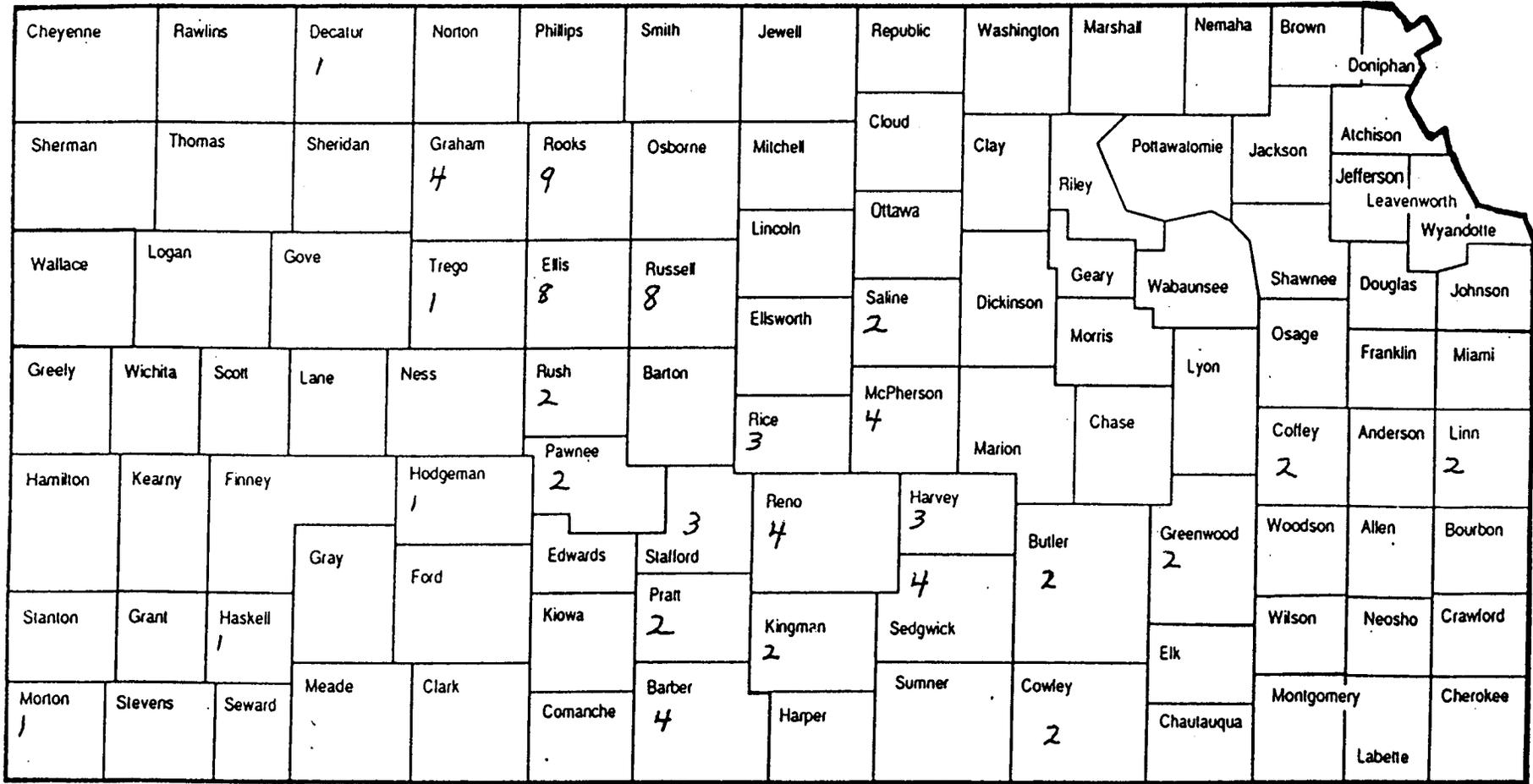
Barber	4	McPherson	4
Butler	2	Morton	1
Coffey	2	Pawnee	2
Cowley	2	Pratt	2
Decatur	1	Reno	4
Ellis	8	Rice	3
Franklin	1	Rooks	9
Graham	4	Rush	2
Greenwood	2	Russell	8
Harvey	3	Saline	2
Haskell	1	Sedgewick	4
Hodgeman	1	Stafford	3
Kingman	2	Trego	1
Linn	2	Wilson	1

Map #5 provides a spatial orientation for these sites.

Also included on the list were six sites not directly related to groundwater, one site in Marion county relating to natural gas in the aquifer, one site in Reno county with apparent oil pollution of an aquifer, and nine sites resolved from the time of the last report.

It should be noted that the part of this listing I was allowed to access did not provide any estimation of areal extent or severity of contamination. One can only infer that information from the estimated cost of remediation or, in the case of the Hollow -

Map 5 - KCC listed sites of saltwater contamination



Nikkel field, a presence in more than one county. Most of the listed sites appear to be minor in environmental impact.

Because resources for remediation are limited the report ranks each site according to an immediacy of action requirement. Also of interest is that target levels for remediation range from 250 to 1000 mg/L (Cl or TDS is not specified) with the majority set at 500 mg/L. The report concludes a total estimated cost of remediation as \$6.62 million although the operation of some projects is stated as an annual cost.

In addition to the KCC's list of sites, the KDHE lists an additional twelve sites in its Summary of Environmental Sites in Kansas for 1997 broken down by number per county as;

Ellsworth	1	Reno	2
Mcpherson	5	Rice	4

Only three of these sites are related to salt mining activities, two in Rice county and one in Reno county. The rest are associated with salt production by oil and gas refining operations.<sup>18</sup>

Some of these sites appear to be fairly extensive. All five sites listed in McPherson county center around refining activities in the town of Conway. One site in Reno county is simply listed as South Hutchinson.

The KDHE list is a summary form of all contaminants of all environmental media with a broad breakdown of source. As such, salt contamination is somewhat difficult to pick out of the list except where the source is specifically designated as "salt production." The broad source category designated "other" encompasses certain point sources of salt such as leaking saltwater injection wells and mining operations but also includes dry cleaning operations, termite extermination, portable fuel tanks, et cetera. Salt itself is a contaminant designated as, "inorganic."

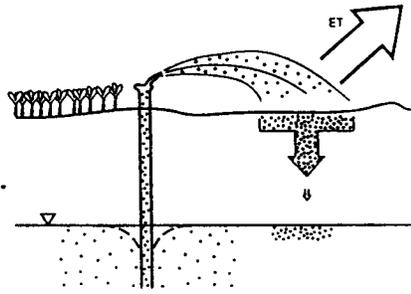
As an example of the difficulty in specifically identifying saltwater contamination from this list consider that the former owner of American Salt in Rice county was reported in the March 1998 issue of the Kansas Lifeline<sup>19</sup> as being the defendant in a fifth lawsuit by farm families seeking compensation for crop damages. The first lawsuit in 1977 alleged that company brine wells and storage caverns had fouled the aquifer, making it unusable for irrigation. Attempted remediation was reported as having been underway since 1985. The responsible party, General Host Corporation, was reported as having paid over \$20 million in damages to plaintiffs to date. This problematic site has as contamination sources on the KDHE list; "spill, pipeline, lagoon, landfill, factory operations." The contaminant itself is listed as "inorganic."

In summary, the KCC and KDHE together report 92 known sites of point source saltwater contamination of groundwater in 29 counties of the state with cleanup currently underway at seven sites.

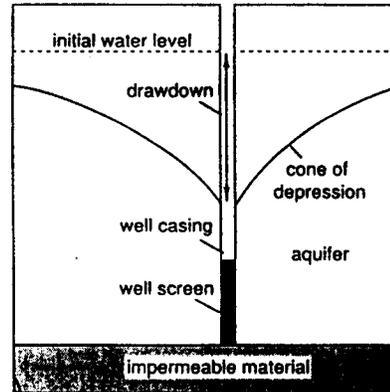
Nonpoint source salt contamination is most common and largely addressed by land and water use management. Concentration of salt and TDS by irrigation, improperly constructed wells, and overpumping can all lead to salt contamination.

Figure #2 illustrates the principle by which irrigation increases soil and groundwater salinity. The exposure of groundwater to atmosphere allows the evaporation of the water but leaves the mineral solids and salts behind as a distillation process would. The mineral solids accumulate until they are dissolved by excess soil moisture and removed by runoff or percolate back through the soil.

Improperly constructed wells can connect different aquifers by penetrating intervening confining layers, or can provide a direct pathway from the surface to the groundwater. This can allow the mixing of waters of differing qualities.



**Figure 2 - Concentration of salts by irrigation**



**Figure 3 - Cone of depression**

Overpumping can result in salt contamination by altering the hydraulic gradient in an aquifer. When a well is pumped, the groundwater near the well forms a cone of depression in the static water level (see Figure #3). What is not so obvious is that in a case where an underlying saltwater aquifer is unconfined or partially confined the flow of groundwater to a pumping well can create an upconing of the heavier saltwater. While domestic or stock wells are unlikely to impact water quality in such a manner, high capacity irrigation or municipal supply wells may have zones of influence that extend more than a mile from the well. Extended drought can serve to exacerbate the situation.

Some Kansas aquifers also contain highly variable water qualities within their systems. The Dakota, for instance, contains waters with TDS ranging from less than 1000 mg/L to over 10,000 mg/L.<sup>20</sup> Overpumping would create lateral saltwater movement in these cases. Study of the Dakota is now underway to determine appropriate water use management.

Recommended groundwater management practises where saltwater contamination might be anticipated because of the local hydrogeology or other reasons include; 1) irrigate conservatively, 2) install the well carefully, 3) properly plug abandoned wells, 4) screen wells as shallow as practical and pump slowly (see Figure #4), and

5) test water quality and keep records. If water quality begins to deteriorate, early detection allows time to modify operating or crop patterns and minimize loss.

For assistance or information on local saltwater problems contact the Kansas Geological Survey, KDHE, your local Groundwater Management District if one is in place, or the Kansas Groundwater Association.



**Figure 4** - Dispersed pumping reduces the risk of upconing

Remediation of saltwater contamination is difficult and costly, if not impossible. In some severe cases an isolated water well with high chlorides may simply be redesignated by the KDHE as a class II disposal well for brine. For a contaminated domestic well, point of use (POU) treatment of drinking water by reverse osmosis (RO) or distillation may be the only viable option. For a municipality, like Burrton, the easiest solution may be to drill new supply wells.

Interestingly, Jonelle Rains, supervisor of environmental protection and remediation for the KCC, states that she is more concerned about salt contamination than oil pollution. Oil tends to stay in place and can be bioremediated successfully. Salt, once it is in place, cannot be cheaply contained. The removal of salt contaminated freshwater for injection into brine disposal wells effectively removes that water from the hydrologic cycle and its use by man. She goes on to say that salt contaminated soil must be disposed

of in a lined landfill because the salt will leach out of it. Even the use of gypsum to remediate salt contaminated soil *in situ*, while effective, still has a high probability of allowing the salt contamination of unconfined groundwater.<sup>21</sup>

As an example of proactive water use management to avoid saltwater intrusion, the City of Wichita has undertaken an innovative project. Raw water supplies for Wichita come from Cheney Reservoir and a wellfield sixteen miles northwest of the city drilled into the Equus Beds aquifer. Heavy pumping by irrigators and a number of municipalities has resulted in a water level decline of 20 to 40 feet in that aquifer since the 1950's. This negative gradient has initiated the movement of saline groundwater plumes from former oilfield brine disposal ponds northwest of the wellfield and from the Arkansas River along the southern boundary of the wellfield.

To avoid the loss of their wellfield, the city has initiated a project to capture above baseflow water from the Little Arkansas River on the north side of the wellfield and subsequently recharge the aquifer via injection wells and percolation basins to near 1950's water levels. Not only will restoration of the hydraulic gradient stop or slow the advancing salinity, the captured surface water will be in effect stored in the aquifer for use by the city to meet dry weather demands.

The project is expected to be fully operational in the year 2005 for an estimated cost of \$49.6 million.<sup>22</sup>

Saltwater contamination of fresh groundwater is a very serious matter, frequently resulting in loss of all use of the affected resource by man. The geologic existence of extensive salt beds in Kansas requires careful and intelligent exploitation of groundwater in many parts of the state. While contamination from past mineral exploitation has created some catastrophic sites, the concentration of salts by irrigation results in widespread and continuing environmental degradation.

## Chapter 5: Nitrates

Nitrate contamination is widespread in the state. Designated as  $\text{NO}_3$ , this is an inorganic compound occurring naturally at levels rarely over 3 mg/L. Elevated levels appear to come from leaking or improperly maintained septic systems, animal wastes, and fertilizer use.

Regulated at an MCL of 10 mg/L nitrate is considered an acute hazard by the EPA because of its toxicity to infants. Pregnant women and the infirm are advised to avoid high nitrate consumption. An EPA guideline indicates 20 mg/L nitrate as an unreasonable risk to health for everyone else. Nitrate levels over 40 mg/L are considered hazardous to livestock. The related compound nitrite ( $\text{NO}_2$ ) is regulated at an MCL of 1.0 mg/L. Although it is a more serious health threat, nitrite is quite unstable and rarely found in significant concentrations in water or food.

A known health effect of nitrate consumption is methemoglobinemia in infants which is an interference with the blood's ability to carry oxygen and can be fatal. Suspected health effects include stomach cancer, birth defects of the Central Nervous System (CNS), and hypertension. The mechanism of methemoglobinemia is the conversion of nitrate to nitrite in the stomach. Nitrite is readily absorbed by the blood and reacts with hemoglobin. Infants are especially susceptible to nitrate poisoning because of the abundance of bacteria in their digestive systems capable of converting nitrate to nitrite. Infants have little acid in the digestive tract and depend on these bacteria to aid digestion. Typically around six months of age, hydrochloric acid increases in the stomach to a level where these bacteria no longer thrive. When older children and adults consume nitrate it is readily absorbed from the digestive tract and excreted in urine.

Livestock react to nitrate poisoning in ways similar to people. Symptoms of severe methemoglobinemia are lack of coordination, labored breathing, blue discoloration of mucous membranes, vomiting, and death. Chronic, low level methemoglobinemia can induce stresses resulting in reduced rate of gain, generally poor performance, reduced conception rates, and abortions. Dairy cattle may have reduced milk production without showing other symptoms.

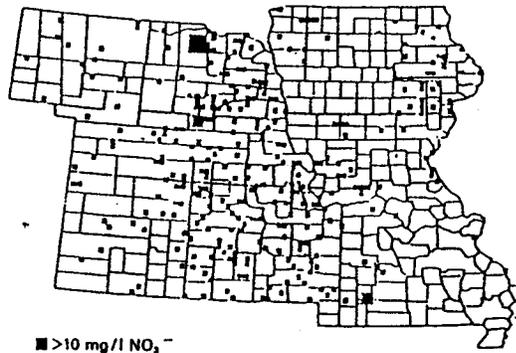
High nitrate water is generally a poisoning hazard to animals only when it adds to high nitrate concentrations already present in some feeds. Ruminant animals, such as cattle and sheep, are most susceptible to nitrate poisoning because of the presence of bacteria in the rumen which convert nitrate to nitrite even in adult animals. Young monogastric animals also have a high level of susceptibility to nitrate poisoning. Interestingly, although horses are monogastric they have a large cecum where bacteria which convert nitrate to nitrite thrive. Thus, adult horses are highly susceptible to nitrate poisoning.

As early as 1980, the EPA Region VII became aware of a large number of wells in its jurisdiction containing excessive concentrations of nitrate and initiated a regional study. Although northeastern Kansas had the greatest number of wells exceeding 10 mg/L of nitrate, it appears that nearly every county in the eastern two thirds of the state was impacted at the time. (See Map #6).

Some of the major conclusions of the study were;<sup>23</sup>

- 1) High levels of nitrate in groundwater appear to be randomly distributed through the region.
- 2) The most common cause of high nitrate concentration in well water appears to be related to inadequate well construction, maintenance, and siting.

- 3) In areas of extensive irrigation where excess water and fertilizer are applied to coarse textured soils, the nitrate concentration in groundwater appears to be increasing.
- 4) In the western part of the region, changes in land use, particularly the cultivation or irrigation of grasslands, has resulted in leaching of substantial amounts of naturally occurring nitrate from the unsaturated zone.



**Map 6** - Nitrate occurrence in groundwater, EPA Region VII, 1980

An extensive article entitled, "Nitrate removal from municipal water supplies," in the November 1990 Kansas Lifeline stated that approximately 7% of the 600 Kansas water supply systems exceeded the nitrate MCL at the time.<sup>24</sup> Prior to 1993, the Kansas Rural Water Association (KRWA) reported about 35 communities as having had nitrate problems with their water supplies.

In 1994 the KDHE reported seven community water systems with nitrate levels above the MCL. By February of 1996, seventeen water suppliers were listed in violation of federal nitrate standards including two from the 1994 list. An additional 65 communities exceeded 5 mg/L and were ordered to increase their sampling frequency for nitrate to quarterly. They have been listed as potential problem sites.

Also in 1996, an environmental advocacy organization called the Environmental Working Group released a report stating that since 1993 sixty one Kansas communities and schools had reported at least once having nitrates in their water supply over the MCL. Although probably not a significant health risk, this transient "spiking" appears to mirror some of the observations of the aforementioned EPA Region VII study sixteen years earlier. Its possibility is confirmed by current research on the movement of nitrate in groundwater.

The EPA acknowledges that elevated nitrate levels are common to farm states. Ralph Flournoy, a drinking water expert with the EPA, was quoted in 1996 as saying that the amount of nitrates in groundwater appears to be increasing and the number of towns that have had to correct nitrate problems is rising. He also cited a change in testing requirements that makes it more difficult for small towns to avoid reporting contaminated wells as a possible contributing factor in the rising numbers.<sup>25</sup>

To further expand the problem, 11% of Kansans do not have access to public water supplies but instead rely on private domestic wells. A 1988 survey by Kansas State University found that 28% of the private wells in the state exceeded the MCL for nitrate. In 1995, a study by the Centers for Disease Control (CDC) found 30% of the private wells in Kansas so contaminated with nitrates or bacteria that they were deemed an immediate health threat. An additional 30% of the private wells in the state were deemed chronic health hazards by this same study due to contamination by metals, chlorides, SOC's, or VOC's.<sup>26</sup>

These observations raise several issues. Point sources would appear to be the large confined animal feeding operations (feedlots) common to the state and the rapid development of rural areas outside of metro areas with the attendant increase in the number and density of septic systems. The mechanism by which nitrate migrates to

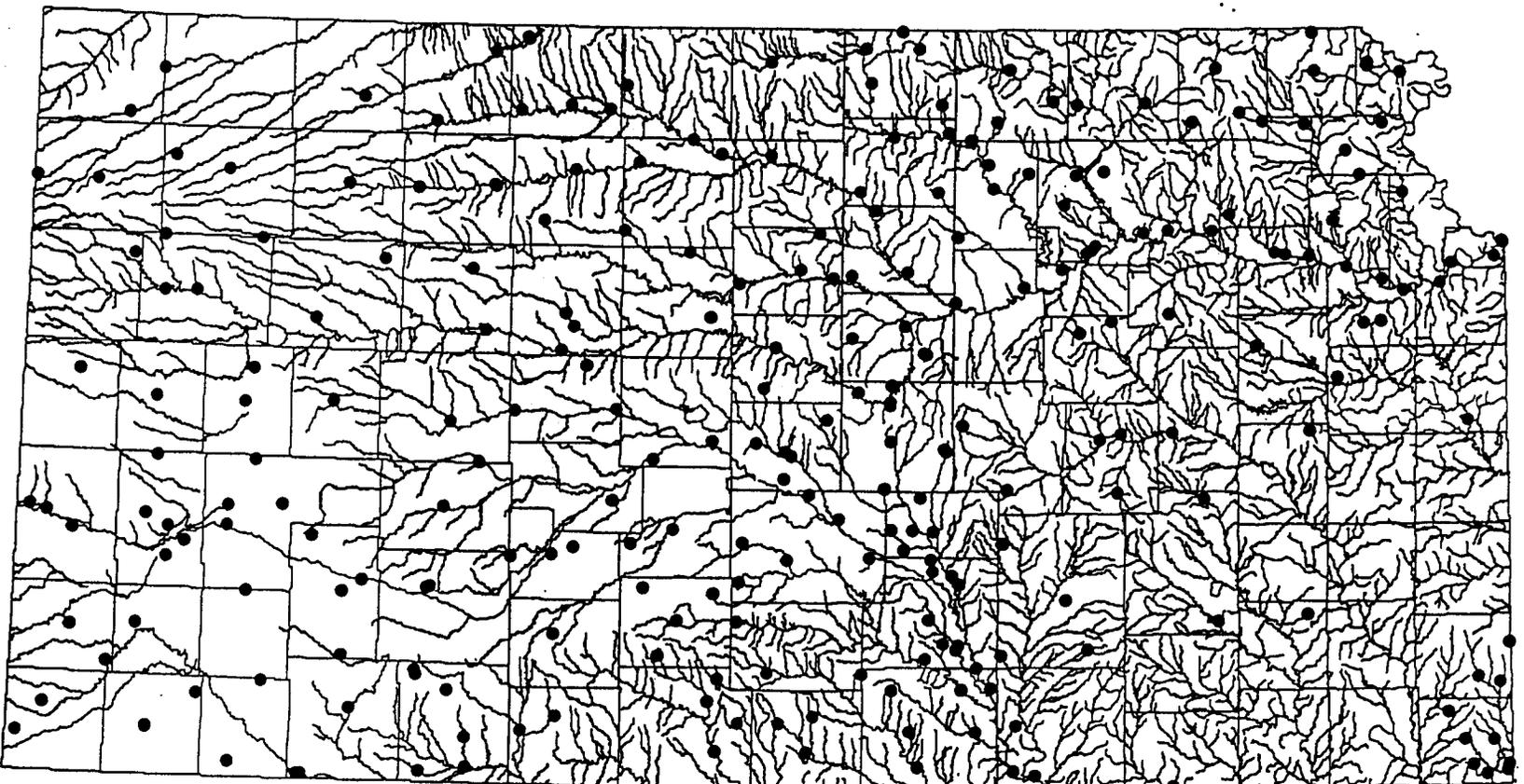
groundwater has been illuminated to the point that there is general consensus that nitrate is also a byproduct of fertilizer application which would make the nonpoint source enormous.

A second issue is that the entity least likely to be aware of nitrate contamination and least likely to have the resources to alleviate the problem is the owner of a private domestic well.

The most current data on nitrate occurrence in Kansas public water supplies is the KDHE 1998 305 b report for the 1996 - 1997 reporting cycle. 94% of the public water supplies using groundwater had no MCL exceedences. Of the 6% that did, 4% of the exceedences were for nitrate. The majority of the samples with excessive levels of nitrate were obtained from wells less than 100 feet in depth or in wells located in areas of sandy soil and high water tables.

The 305 b report goes on to tabulate data from the ambient groundwater quality monitoring network and finished water quality from public supply wells. The monitoring network is comprised of 242 wells used for public or domestic water supply, irrigation, livestock watering, or industrial purposes (see Map #7). Established in 1976, its purpose is to provide data for identifying trends in groundwater quality associated with alterations in land use, the implementation of best management practises, changes in groundwater availability or withdrawal rates, and shifts in climate conditions.

Of 267 well samples taken from this monitoring network 27 exceeded the nitrate MCL. An additional 78 had nitrate concentrations above 5 mg/L. The finished water quality data from public water supply wells showed that of 3,057 well samples taken, 284 exceeded the nitrate MCL. An additional 864 had nitrate concentrations above 5 mg/L. Of the total samples from both programs 9.4% exceeded the nitrate MCL while



Map 7 - KDHE Groundwater Monitoring Network stations

the additional 28.3% of the samples above 5 mg/L would indicate a potential problem.

What does all this mean? Unfortunately, I was unable to find data correlating locations to occurrence. It should be noted that for the finished water quality data from public water supply wells that an MCL exceedence in one sample does not necessarily mean the water supply in its entirety was out of compliance. For the groundwater monitoring network data, a nitrate MCL exceedence would be largely irrelevant to a strictly dedicated use such as irrigation, livestock watering, or industrial process water. My best postulation is that nitrate contamination problems are a widespread and shifting occurrence. Current research does show a correlation between fertilizer application, rainfall amount, and penetration of nitrate through the soil. Putting aside any debate as to whether nitrate is indeed the public health threat the EPA thinks it is, the potential for nitrate contamination is the number one quality concern for public water suppliers in Kansas.

Understanding the occurrence of nitrate in groundwater begins with understanding the physiochemical nitrogen cycle. Nitrogen is a basic part of the environment. The atmosphere is 78% nitrogen gas ( $N_2$ ). Nitrogen accumulates in the soil, bound in organic matter (humis) and fixed by bacterial action. Worldwide, nitrogen is the plant nutrient most limiting for vegetative production. A natural ecosystem typically reaches equilibrium between vegetative growth, with uptake of soil nitrogen, and the production of humis from decaying organic material returning nitrogen to the soil. In most natural ecosystems, nitrogen cycling is efficient with low losses. Aside from plant and bacteria driven fixation, nitrogen losses from the soil system occur from leaching, denitrification, and volatilization.

Human activities have increased rates of nitrate movement and altered the balance of the nitrogen cycle. As organic matter is oxidized in the soil, it releases nitrogen in the

primary form of nitrate. If not used by a growing groundcover it becomes susceptible to leaching. With greater nitrogen inputs for higher crop yields, efficiencies of nitrogen uptake may be lower. Nitrogen not removed from the field in crop harvest can reach groundwater as nitrate.

The implications are immediately obvious. To avoid cropland becoming a source of groundwater contaminating nitrate, fertilizer use must be optimal. The Cooperative Extension Service has several things to say on the subject. A profile nitrogen test is recommended to determine the amount of nitrate in the soil. All potential nitrogen sources need to be considered including previous legume cropping, applied or residual organic material, and nitrate in irrigation water. Fertilizer use should be reduced in accordance to the presence of these other nitrogen sources.

Furthermore, growers need to have realistic yield goals. The crop, productive capacity of the soil, and moisture availability must all be considered. On highly permeable soils, split or sidedress applications of fertilizer generally result in increased nitrogen uptake efficiencies. Research indicates injection or deep incorporation of fertilizer allows greater nitrogen uptake by crops. Any management practise that improves the amount of crop uptake of applied nitrogen reduces the potential for nitrate contamination of groundwater.

Proper fertilizer handling practises are emphasised. Any spill near a wellhead should be immediately cleaned up. Equipment used for fertilizing should be cleaned in fields where fertilizer is applied.

A research paper published in 1995 by the KGS contains some interesting insights on the movement of nitrate in groundwater.<sup>27</sup> The study was performed on the Great Bend Praire aquifer under Stafford County in the jurisdiction of GMD #5. Depth to water is generally less than 30 feet. The median depth of domestic and stock wells was 60 feet

while irrigation wells were found to be deeper with a median depth of 85.5 feet. 60 feet was chosen as a convenient dividing point between shallow versus deep wells for this study. Some conclusions include;

- 1) The shallow portion of the aquifer was contaminated by nitrate to a greater degree than the deep portion.
- 2) Nitrate concentrations were not significantly different under any classification or grouping of soils.
- 3) The occurrence and thickness of clay lenses above the well screen proportionally reduced the occurrence of nitrate in the well water. It was postulated these clay lenses were a retarding factor, redirected nitrate movement, or facilitated denitrification processes.
- 4) Irrigation well density showed a positive correlation with nitrate concentrations in shallow wells. Several reasons were presented for this phenomena.
- 5) Nitrate concentrations in flood irrigation wells tended to be higher than those in center pivot irrigation wells. The authors remark that compared to nitrate levels of two flood irrigation wells sampled previously in 1978, their data implied that similiar land use practises in the study area over time may result in a near constant recharge of nitrate to groundwater.

The correlation between irrigation well density and nitrate occurrence was attributed to;

- 1) an increase in the area of irrigated cropland generally results in greater applications of fertilizer over time.
- 2) The additional input of water can be the driving force for nitrate movement.

3) Increased density of irrigation wells result in more vertical mixing of groundwater.

Figure 5 attempts to illustrate some of the effects of two wells pumping in close proximity to each other.

4) Backsiphonage from fertigation equipment or leaking equipment near the well can result in the direct entry of nitrate to groundwater.

5) Improper or deteriorated well construction can permit contaminated surface or subsurface flow into the aquifer.

For further consideration, note that prior to 1975 wells were not required to be grouted in along the upper section of casing. The gravel pack instead was brought to very near the surface to induce the greatest yield possible.

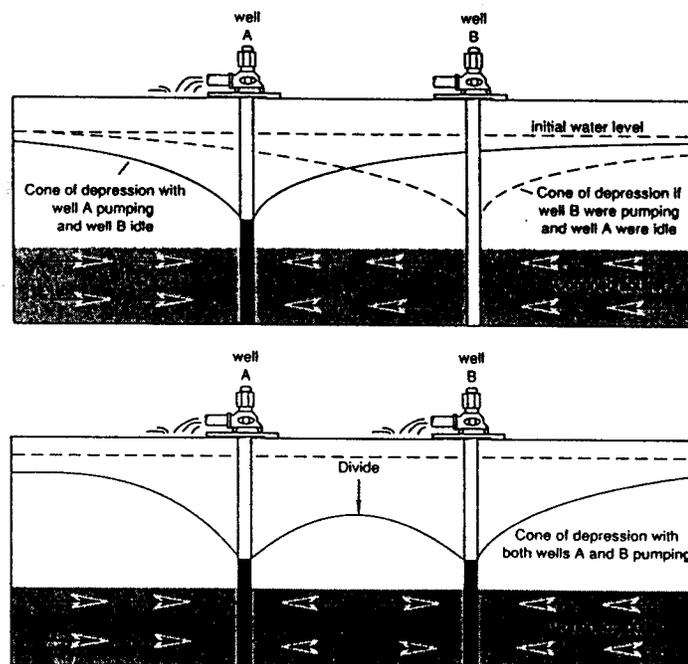


Figure 5 - Two wells pumping in close proximity create complicated groundwater flows

Nitrate is highly mobile in groundwater with no transformation and little or no retardation as a result of its anionic state. As nitrate moves deeper into the soil system it may undergo denitrification if it reaches an anoxic or anaerobic zone and there is an organic fuel source for the denitrifying bacteria. Denitrification results in the reduction of nitrate to nitrite and ultimately to nitrous oxide, nitrogen gas, or ammonium. This process most frequently occurs in the unsaturated zone above the water table. Although it is conceivable that denitrification could occur below the water table, the presence of an organic fuel source, such as humic and fulvic acids, would raise other water quality concerns. There has been little research done on denitrification in groundwater itself.

As with salt contamination, the remediation of nitrate contaminated water is difficult if not impossible. The only treatment processes that effectively remove nitrate are membrane filtration (such as RO) or ion exchange. Land use and water management practices are preferred to avoid the occurrence of nitrate problems.

In such a heavily agricultural state such as Kansas, the modification of current land and water management practices may be difficult outside of economic forces. Irrigation currently consumes 94% of the groundwater used in the state. Fertilizer use amounted to 500,000 tons in 1987. The average cattle population of the state amounts to several hundred thousand head. The impact of this activity on the state economy is enormous.

A current public debate among Kansans is whether to allow corporate hog farming in the state and to what degree they should be regulated. One recurring theme is the public's fear of more groundwater contamination from these proposed large-scale hog confinements. This may be a sign of the increasing awareness of the widespread nature of nitrate contamination and the generally poor record of cattle feedlots or the regulation thereof. Considering that livestock produce more waste per individual than

their human counterparts, these feedlots are an important issue. It has been estimated that 1000 head of cattle produce wastes equivalent to a town of 6000 people.<sup>28</sup>

Management of livestock wastes to prevent nitrate contamination is a critical issue. Livestock facilities should be 400 feet or more from wellheads and downslope to minimize nitrate contamination potential. Lots must be cleaned regularly and wastes applied to cropland at controlled rates.

Interestingly, when lots are in continuous use by livestock the soil develops a surface seal (hardpan) that limits downward percolation of water. Abandoned or intermittently used lots may pose the most serious risk of nitrate contamination as the hardpan quickly deteriorates. Removal of accumulated wastes and the planting and harvesting of crops in these lots is a recommended practise.

One participant in the Kansas Rural Center's Clean Water Farms project gained considerable attention from the farm community by pasture finishing hogs and partially converting to pasture farrowing as well for his 100 head operation. The finishing system is established on an alfalfa acreage divided in half with water hydrants down the center and a road adjacent to the hydrants. Every two years the finishing lots and road are changed to the other side of the water hydrants. The previously used lots are planted to a grain crop.

The real question for Kansas is management of feedlots where wastes are typically diverted to anaerobic lagoons. Should any rate of percolation be prohibited? Maybe the use of facultative ponds in series discharging to constructed wetlands would be more appropriate treatment of these wastes. Mechanical treatment works are possible but nutrient removal processes are specialized and costly in comparison to pond treatment.

The rapid development of rural areas outside of metro areas presents a number of problems regarding water quality issues. In Sedgewick County, surrounding Wichita,

the biggest growth in the past decade has been suburban and rural on five acre lots with private sewer systems and water wells, says Marvin Krout, director of the Sedgewick County Metropolitan Planning Department. He goes on to say, "There are likely to be future problems with sewers, private sewer systems that don't work, groundwater that becomes contaminated..."<sup>29</sup> In addition to the proliferation of septic systems as point sources of water contamination is a large number of sites surrounding Wichita where early oilfield activity has damaged water quality and limited freshwater supply.

KDHE does not regulate private wells. It only has oversight of public water supplies. Concerning private wells, KDHE can only make general public recommendations on water testing and well service, issue warnings of problems detected in an area, and assist groups in hooking up to a regulated water supply such as a RWD or municipality.

The 1995 CDC study indicating 60% of the private wells in Kansas as unsafe for consumption points to a widespread ignorance of water quality protection. Ron Hammerschmidt, KDHE's environmental director says quite bluntly, "If you have a well house, don't keep pesticides in it. Don't keep fertilizer in it. Don't let the dog sleep in it. Don't change the oil [in your car] next to the well."<sup>30</sup>

Shallow wells (less than 100 feet) are a risk because they are likely to be contaminated with human or animal waste, according to KDHE. The EPA also recommends periodic maintenance of wells such as inspection for cracked or damaged casing, settling and cracking of surface seals, maintaining a slope around the well to drain surface runoff away from the well, disinfection of the well annually, and annual testing for bacteria, nitrates, and other constituents of concern.

In a related fashion the EPA reminds homeowners not to dispose of wastes in dry wells or abandoned wells (these wells should be plugged according to Kansas law), not to dispose of hazardous materials in septic systems, and to pump and inspect septic

systems as often as recommended by the local health department. The March 1983 Farm Journal also reminds its readers not to dispose of wastes in sinkholes or dry ravines as these may be groundwater recharge points.<sup>31</sup>

The Cooperative Extension Service analyzed the data of the 1988 farmstead well study. They identified nitrogen sources as septic systems, livestock facilities, silos, and fertilizer storage, handling, and cleanup. It is recommended that wells be located a minimum of 400 feet from these sources and upslope.

Septic systems have the potential to contribute nitrate year round. A good perennial grass cover of the leaching field is recommended. Also, it is pointed out that nitrogen fertilizer should not be applied in the area.

Lastly, it is pointed out that fertilizer applications on large lawn and garden areas surrounding the home must be properly controlled. Excessive watering should be avoided. The mechanisms that cause nitrate leaching from cropland are the same for home and garden.

This is a lot of responsibility for homeowners. The near identical results of the KSU and CDC surveys seven years apart would also indicate a lack of resources to deal with water quality problems such as by finding a new water source. The additional findings by the CDC of wells contaminated by metals, chlorides, SOC's, and VOC's is not surprising considering the expense of the screening tests (around \$800) for priority pollutants.

POU devices can treat many poor water supplies but each type of treatment device is frequently selective in the types of contaminants it removes so a user must know what he is trying to remove. The devices must also be maintained or they may make the water quality at the point of use worse. Lastly, the membrane filtration devices, such as

RO, and also ion exchange devices produce a wastestream of concentrated brine, the disposal of which may cause problems.

Bottled water must also be scrutinized by the consumer. It is interesting to note that the bottled Conway Springs spring water is actually blended with distilled water because of the elevated levels of nitrate in the spring water itself.

By far, it is highly recommended that rural households hook up to public water supplies which are heavily regulated and monitored by law. Even this is an expensive option. The KRWA estimated in 1998 that it would cost about \$900 million to provide a public water supply to everyone in the state. Individual hook up fees may typically range into thousands of dollars.<sup>32</sup>

For rural households, the Cooperative Extension Service prints a series of free pamphlets covering a large number of water quality subjects. Topics include; testing your drinking water and understanding the test report, discussions of different POU treatment devices, the occurrence of nitrates and pesticides in drinking water, best management practises to minimize groundwater contamination, well plugging standards, and managing septic systems, to name a few. The Extension Service maintains offices in every county of the state. For self education and "how to" information these pamphlets are highly recommended.

In Kansas, public water suppliers faced with a nitrate problem typically seek to drill new supply wells with acceptable nitrate concentrations as a solution. While this is not remediation of the problem area in any sense, it does keep the water supplier within regulatory limits. Typically a water supplier will also seek to blend the high nitrate and low nitrate waters to achieve an acceptable nitrate concentration in the water served to customers while preserving some use of the offending wells.

As a recent example of this type of project, the City of Kingman (population 9,500) drilled three new wells, laid five miles of pipeline, and built a new filtration/ blending plant in 1996 for this purpose. Total cost was \$2.8 million. It should be noted that the filtration capabilities were added to comply with provisions of the Surface Water Treatment Rule (SWTR). The city owns a spring which gravity flows 280 gallons per minute (gpm). Because the spring has been a water source for Kingman since 1882 the city council found it unacceptable to abandon it as a water supply.<sup>33</sup>

As a point of special interest, there are only two plants in the state built for nitrate removal, one each in Downs and Abilene.

The City of Downs (population 1,100) opted to build an ion exchange plant after extensive test drilling searching for a new water supply. City council members remained concerned that any new wells would later develop elevated nitrate levels.

The plant, built in 1994, is a continuous absorption ion exchange system built by Advanced Separation Technologies Incorporated of Lakeland, Florida. The system is a series of thirty fixed-bed columns that rotate continuously on a support structure called a carousel. This allows the continuous production of finished water from a four phase cycle of separation, media wash, media recovery, and media rinse. Life of the zeolite media is expected to be 8-10 years. The plant was shipped to Downs completely assembled for installation into the water supply system. Incredibly, the operational target level for nitrates in the blended system water is 9.5 mg/L.<sup>34</sup>

Total cost of the project was \$455,000. The city received CDBG monies of \$452,000 in 1992 to offset most of the cost.<sup>35</sup>

The City of Abilene (population 7,000) undertook construction of a reverse osmosis plant for several reasons. The KDHE had conducted a study in 1995 of thirty square miles called the Sand Springs Area which stretches from the eastern edge of Soloman,

Kansas to the west side of Abilene. The sandy soil transmits nitrogen sources quickly before the compounds can break down. Numerous point sources, as well as fertilizer spills and normal fertilizer use contributed to nitrate contamination of the area.

In addition to widespread nitrate occurrence, the city's supply wells are drilled into solution cavities under the Sand Springs Area which show evidence of being under the influence of surface water. Under the SWTR, this requires filtration. RO was chosen as a means of ultrafiltration as well as for nitrate removal.

The four million gallon a day (MGD) plant was built in 1998 for a cost of \$5.3 million. The plant was oversized in anticipation of providing finished water to surrounding entities such as rural water districts (RWD's) and smaller communities.<sup>36</sup>

On a final note, Scott Roberson, water protection tech for KRWA, recommends keeping a buffer zone between irrigated cropland and municipal supply wells. He feels planting as much of the area over the well's zone of influence as possible to grass would have an appreciable affect on nitrate occurrence in the well water. Although the landowner would require compensation for removing cropland from production, it is suggested that the CRP program may be a source of at least partial funding.<sup>37</sup>

In summary;

- 1) Nitrogen and nitrogen compounds comprise a large part of the natural world. We are physiologically adept at excreting excess nitrate from our bodies.
- 2) Consumption of elevated levels of nitrate are a proven health threat to a specific target population. Suspected health impacts on the general population remain inconclusive. Livestock can also be adversely affected by high nitrate concentrations in feed and water.
- 3) The occurrence of elevated levels in groundwater has been documented for at least the past two decades. Currently, nitrate MCL exceedences are predominantly in wells

less than 100 feet in depth or in wells located in areas of sandy soil and high water tables.

4) Elevated levels of nitrate in groundwater are directly linked to point sources such as septic tanks, animal confinement compounds, and silos. Use of nitrogen fertilizer is the predominant nonpoint source. In general, alterations in land use are responsible for the spread of nitrate contamination. The activities of man have altered the natural nitrogen cycle and unbalanced it.

5) Best land use and water management practises are critical in preventing and remediating nitrate contamination. There are many concrete steps the agricultural community can take to reduce the occurrence of nitrates in groundwater. In a similar fashion, control of rural expansion outside of urban areas is necessary as is the regulation of confined animal feeding operations.

6) The occurrence of excessive nitrate in private domestic wells is directly related to the ability of the well owner to monitor, maintain, and manage the well and the area surrounding the wellhead. Current research indicates a widespread failure of these requirements.

7) Although numerous public supply wells have been impacted by nitrate contamination only two entities in the state have chosen to build mechanical plants for nitrate removal. The preferred option is to find a new supply.

## Chapter 6: Synthetic Chemicals

By far, the water contaminants that make the most spectacular news and generate the most fear in people are man-made chemicals. These are typically lumped together as Volatile Organic Compounds (VOC's), which are primarily solvents, or Synthetic Organic Compounds (SOC's) which are primarily pesticides. The typical range of health concerns generated by these compounds is cancer, liver damage, and central nervous system (CNS) damage but specific compounds may have toxicological impacts on virtually any human physiological system. The Extension Service pamphlet MF-1142, "Organic and Radiological Chemicals in Drinking Water," and the USEPA booklet, "Water on Tap," both have excellent summary tables of the toxicological impacts of all organic contaminants regulated by drinking water standards.

Every two to three years the KDHE releases a document entitled, Summary of Bureau of Environmental Remediation Sites in Kansas, which is quite useful in the examination of the subject at hand. Not only does it provide a comprehensive listing of sites by name, county, contaminant type, contaminated media, source, and site status, it explains the function of the KDHE Bureau of Remediation (BER), how the bureau is organized by section, lists State Statutes governing BER programs, and provides a wealth of historical and current summary information of such things as remediation action types, underground storage tank (UST) program activity, material spills, Kansas National Priority List (NPL) sites, et cetera.

The current BER list released in July 1998 identified 551 active sites state wide. Not including a small handful of listed sites involving solely salt or nitrates, groundwater is contaminated at 397 sites in 67 counties. Seventy-two contaminated sites involve a public water supply. Private wells are contaminated at 68 sites. VOC's are the

predominant contaminant type.<sup>38</sup> A breakdown of these sites by number per county is shown in the following Table #4. Map #8 provides a spatial orientation for these sites.

**Table 4 - KDHE listed sites of groundwater contamination by synthetic chemicals;**

Atchinson	2	Montgomery	9
Barber	1	Morris	5
Barton	12	Morton	2
Brown	4	Nemaha	1
Butler	15	Neosho	5
Cherokee	8	Ness	2
Clay	3	Norton	2
Cloud	6	Osage	1
Cowley	5	Osborne	2
Dickinson	8	Ottawa	5
Doniphan	1	Phillips	3
Douglas	2	Pratt	3
Edwards	5	Reno	24
Ellis	9	Republic	3
Ellsworth	4	Rice	2
Finney	5	Riley	5
Ford	3	Rooks	1
Geary	9	Russell	3
Gove	1	Saline	15
Graham	1	Scott	3
Grant	2	Sedgewick	73

Harvey	10	Seward	4
Jackson	1	Shawnee	10
Jewell	2	Stafford	1
Johnson	11	Stanton	1
Kearny	1	Stevens	1
Kingman	2	Sumner	5
Labette	2	Thomas	2
Leavenworth	7	Trego	1
Lincoln	3	Washington	3
Lyon	4	Wichita	1
Marion	3	Wilson	3
Marshall	4	Wyandotte	29
McPherson	11		

A second, but far less extensive than the BER list, summary of groundwater contamination in the state by synthetic chemicals is found in the KDHE 1998 Kansas Water Quality Assessment 305 b Report. This report is generated biennially for the purpose of reporting the condition of the state's surface water quality to the EPA. The 305 b report groundwater contamination summary is a simple block chart reproduced here as figure # 5.<sup>39</sup> While it is useful in its own right, it is also confusing in listing data under the CERCLIS program.

The CERCLIS listing is redundant in that it contains sites under both state lead, or authority, and federal lead. It is not indicating an additional 456 sites of groundwater contamination in the state. The NPL sites are included in the BER listing of state sites. Adding the data of the state sites and DOD/DOE listing produces a direct correlation

Map 7 - KDHE listed sites excluding nitrates and salt

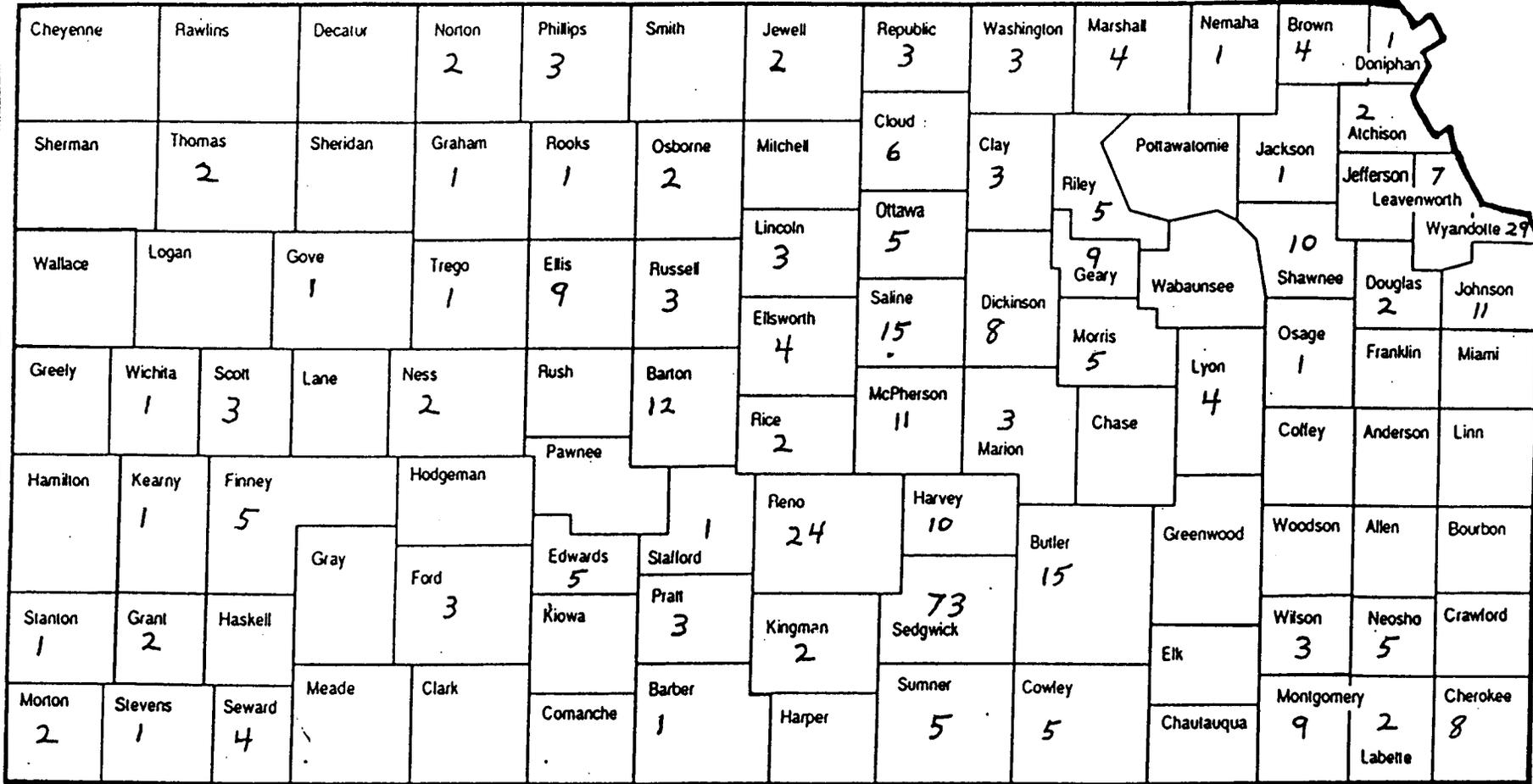


Table 5 - 1998, 305 b Report groundwater contamination summary

Source Type	# of Kansas Sites	# of Sites with Confirmed Releases	# with Confirmed Groundwater Contamination	Primary Contaminants	# of Site Assessments	# of Sites with Source Removed	# of Sites with CAPs	# of Sites with Active Remediation	# of Sites with Cleanup Resolved
NPL	15	15	13	VOCs, metals	15	unavailable	1	5	3
CERCLIS (non-NPL)	700	700	456	VOCs, metals & pesticides	700	unavailable	26	154	159
DOD/DOE	50	50	22	VOCs, metals	50	unavailable	2	6	2
LUST	8,000	3,900	unavailable	petroleum	8,000	3,500	unavailable	1,700	1,900
RCRA Corrective Action	under EPA control								
Underground Injection *	40	0	0	none	0	0	0	0	0
State Sites **	650	650	434	VOCs, metals	650	unavailable	24	148	157
NPS	unknown								

CAPs - Corrective Action Plans

CERCLIS - Comprehensive Environmental Response, Compensation, and Liability Information System

DOD/DOE - Department of Defense/Department of Energy

LUST - Leaking Underground Storage Tanks

NPL - National Priority List

NPS - Non Point Source

RCRA - Resource Conservation and Recovery Act

\* Represents Class I and III injection wells and hydrocarbon storage sites, but does not include Class II brine injection wells.

\*\* Numbers do not include sites under KCC jurisdiction or LUST sites.

with the CERCLIS data.

CERCLIS is the national data base of environmental degradation by regulated pollutants. The heading, RCRA Corrective Action, in figure #5, concerns only those facilities managing hazardous waste. This information is found in the federal RCRIS data base.

Broad characterization of the activities creating this pollution is difficult. Pipeline breaks and leaks, normal manufacturing operations, grain fumigation practises, spills, and past disposal methods are all contributing factors. While improper disposal is often cited it must be noted that Congress did not pass the first law governing hazardous waste disposal until 1976. As an example; McConnell Air Force Base, in Wichita, (legally) disposed of solvents in the base's twenty acre landfill until 1970. Vern Imes, environmental engineer, remarks, "The material placed in that landfill could have been disposed of for \$300 to \$400 at the time. Now it will cost \$2 million to clean up"<sup>40</sup> Much contamination would seem to stem from an earlier lack of understanding of the fate of contaminants in the environment.

The first KDHE list of contaminated sites in 1988 listed 327 occurrences. Although the listing has nearly doubled, Larry Knoche, BER director for KDHE, remarks that the sites being discovered are getting smaller. He adds that for the first time the list holds few surprises.<sup>41</sup>

Note also the amorphous nature of the data of the BER list and 305 b summary. Events in the real world seem to move faster than the paperwork sometimes. Rick Dean, BER, stated to me in a conversation that an additional fifty sites would probably be on the next state ISL because of actions by industry under a voluntary cleanup program.<sup>42</sup>

Sedgewick County holds the distinction of having, by far, the most listed sites in the state. Its problems stem from a heavy manufacturing base and shallow groundwater. The 73 sites here include some of the most spectacular in the state including the Furley hazardous waste landfill opened in 1977 and closed by order of the governor in 1982, the Gilbert and Mosley site south of downtown Wichita which is one mile wide and four miles long, and the Northern Industrial Corridor site which borders the Gilbert/Mosley site on the north and is nearly as large.

In addition to the identified sites list, the BER Storage Tank Section represents a significant volume of contamination sites. Summary data of the underground storage tank (UST) program and trust fund shows various levels of activity at 2300 sites across the state with remediation underway at 427 sites.<sup>43</sup> The 305 b summary, however, shows a statewide total of 6,100 leaking UST sites with 1,700 under active remediation. The discrepancy is probably related to jurisdiction, funding source, or reporting format.

Leaking UST's represent differing degrees of hazard for groundwater contamination. The average UST leak only covers 200 square feet.<sup>44</sup> Viscous petroleum products, oils, tend to agglomerate to soil particles and stay relatively confined. All petroleum products will tend to float on the surface of a water table if they reach it. In the case of highly volatile products, like gasoline, and shallow groundwater this can create problems such as the accumulation of explosive vapors in sewer lines or basements. Fuel additives such as methyl tertiary butyl ether (MTBE), however, may leach into the underlying water and prove highly mobile. Chlorinated solvents are also highly mobile, as one might deduce from examining the drinking water standards in Table #2. As an interesting note, products with a specific gravity greater than water will actually sink through an aquifer until they reach an impermeable or equally dense confining layer and then migrate along the physical slope of the barrier.

In examining the management and remediation of environmental hazards what becomes apparent is that the issue is so complex it has, by necessity, been greatly subdivided. Funding sources for programs vary. Responsibility for program operation varies. The degree of impact of environmental contamination varies greatly. When I asked Kyle Parker, KDHE environmental geologist, if there was a comprehensive data base of groundwater contamination sites for the state, he replied that there was around 1000 sites in the seven counties of the south central district alone. Oversight of these areas is provided by various programs each with their own files.

Even in the face of these staggering numbers, the KDHE feels it is making progress in addressing these sites. Larry Knoche, KDHE, said in December 1996, about half of the sites in the state are being cleaned up, primarily by companies that caused the pollution or bought polluted land. He also says businesses are being more careful in preventing pollution.<sup>45</sup>

It should be pointed out that the vast majority of groundwater contamination occurs in very shallow aquifers. Nationwide, most groundwater monitoring wells are completed at less than 75 feet. The maximum penetration of an auger type drilling rig, most commonly used in groundwater contamination assessment, is 150 feet. It could easily be argued that a drinking water supply well should never be placed in such a shallow zone. Quite probably, the real concern of this shallow zone contamination is discharge to surface waters or seeps, where it becomes an exposure hazard, or transport to deeper aquifers through areas of recharge. In this light, containment of contamination, removal of the source, and discontinuing use of the affected waters makes economic sense.

By economic necessity, the remediation of groundwater contamination by synthetic chemicals can only take place on a "worst case first" basis. The KDHE's primary goal is to protect the public health and welfare. Its first actions will typically be to assure a

safe drinking water supply for affected residents. The department owns a portable air stripping unit for loan to public water supplies in emergencies. It has been used at the cities of Agenda in 1994 and LaCrosse in 1998. In the cases of the NPL sites at Wright, Kansas and 57th Street/North Broadway in Wichita where private wells were affected, the EPA provided bottled drinking water to residents until a new water supply system was in place.

While the objective of the KDHE is to remediate all contaminated sites, funding is limited. To focus resources appropriately, the department uses a hazard ranking system (HRS) to expedite activity at sites where public health or water supplies are at greatest risk. In cases where remediation is not immediately undertaken, the preliminary investigation and monitoring serve an important function in delineating the location and areal spread of contamination and noting any degree of natural attenuation or degradation.

The BER reports that the removal of contaminated groundwater and subsequent treatment is the most common remediation technique for the state. Unlike the removal of brine and its disposal by injection wells, groundwater contaminated with VOC's can frequently be salvaged for use.

Although pump and treat systems are generally effective in containment of a contaminant plume and effective in reducing the mass of the contaminant in the aquifer, they typically exhibit a tailing effect in which contaminant levels plateau above MCL's.

Causes of this effect are generally attributed to;

- 1) slow diffusion of contaminants from low permeability zones,
- 2) slow desorption kinetics,
- 3) zones of immobile contaminated water, and
- 4) continuous release of contaminants from non-aqueous phase liquids (NAPL's).

The operation of pump and treat systems are frequently long term projects. Once plume containment has been achieved and the tailing effect has become evident it is not uncommon in the state for the system to be shut down and the project advances to long term monitoring of natural attenuation by soil microorganisms. At this point, certain actions designed to enhance the degradation of contaminants by biological activity, such as the addition of oxygen or nutrient substrates, may also take place.

Other possible remediation techniques, aside from air stripping, include soil vapor extraction, air sparging, chemical enhancements such as surfactants or co-solvents, monitored natural attenuation, reactive barrier walls, and bioremediation. It should be noted that one of the first goals in a remediation project is frequently containment. Cutoff walls serve this purpose without actually affecting the degree of contamination.

Of particular interest in examining groundwater contamination are the ten NPL sites in Kansas. These sites are characterized by extensive soil and water pollution, some over a large land area. They are located by county and city with date of listing in the following Table #6;<sup>46</sup>

Butler County	El Dorado	1989
Cherokee County	25 square miles	September 1983
Cowley County	Hackney/Strother Field	June 1986
Ford County	Wright	June 1996
Geary County	Fort Riley	August 1990
Johnson County	Kansas City	September 1983
Johnson County	Olathe	May 1994
Reno County	Hutchinson	July 1987
Sedgewick County	Wichita	October 1992
Thomas County	Colby	September 1995

These sites are included in the BER identified sites list and granted individual activity summaries.

The primary contaminants involving groundwater at these sites are VOC's and SOC's but two, Colby and Cherokee County, involve metals, and one, El Dorado, involves oil, refined petroleum products, and heavy metals as well. The sites range in size from 25 square miles (Cherokee County) to 1.5 acres (Olathe). Although many of the sites are associated with the normal practises of industrial operations at the time, some stand out as glaring examples of neglect and lack of concern.

The Cherokee County site in southeast Kansas stands out from its sheer size. It is also unusual in having extensive heavy metal contamination of its ground and surface waters. The problems stem from lead and zinc mining and processing activities. Water percolating through the abandoned mines and tailing piles become acidic by association with weathering sulfide materials, such as pyrite. This lowering of pH allowed heavy metals, notably lead, to become mobile and cause widespread contamination of a shallow aquifer which had been in wide use as a drinking water supply. Deeper wells were drilled and a distribution system built to provide an alternate drinking water supply. The only remedial action implemented is that which is necessary to prevent the mixing and cross contamination of the shallow and deep aquifers.

Heavy metals are dangerous in that they tend to be bioaccumulative, building up in an organism's tissues during exposure. The toxicological impacts of lead poisoning are kidney and CNS damage. Metals typically only become water soluble because of environmental conditions, such as low pH, or the presence of a co-solvent, such as might occur in an industrial process.

The story of Wright, Kansas is interesting in that the only major industrial facility in an unincorporated town of 200 people managed to pollute over half of the wells in town

with metals, nitrates, pesticides, and VOC's. The problem was discovered in 1988 when a private well was tested to fulfill property loan requirements. In 1997, Wright was connected to the Dodge City public water system by 3.5 miles of transmission main and a distribution system including fire hydrants installed to provide fire protection and safe drinking water for the town.

The occurrence of pesticides in groundwater is more unusual than one might think. They are far more likely to impact surface water supplies. Like metals, however, they have been shown to become more mobile under favourable environmental conditions or in the presence of a co-solvent.

Key factors limiting pesticide penetration into aquifers is chemical half life and ion exchange capacity of the soil. Chemical half life refers to the amount of time required for degradation processes to reduce a given concentration of a compound by one half. Atrazine, for example, has a half life of roughly sixty days. Environmental persistence is the reason some pesticides, such as chlordane, are no longer available on the market. Ion exchange capacity refers to the ability of the soil structure to adsorb a pesticide and hold it immobile. Soils high in clay and organic material generally have high ion exchange capacity.

I strongly suspect that the occurrence of pesticides in groundwater is usually linked to poor management practises. Not cleaning up spills may allow the ion exchange capacity of the soil to be overwhelmed and allow pesticide breakthrough. Direct entry to an aquifer by backsiphonage, poor storage and handling practises, or cleaning spray equipment near a wellhead seem very real contamination possibilities.

For more information on pesticide movement in the soil subsurface, the KGS has published a research paper by R. A. Evenson et al in 1990. The study was undertaken of the Great Bend Praire aquifer under GMD #5 specifically to examine the aquifer

contamination potential of atrazine. The executive summary concludes, "the probability that atrazine will leach through the soils to the underlying aquifer in the Great Bend Praire under present conditions seems remote."<sup>47</sup>

In Wichita, the report is a good-news/bad-news story. The July 18, 1994 Wichita Eagle reported four Superfund sites, including what is known as the Northern Industrial Corridor. In this latest BER report only one site remained listed on the NPL, the 57th Street and North Broadway location. The bad news is that the remaining site was larger than previously thought and was impacting private wells in an adjacent neighborhood.

The City of Wichita has proven to be quite proactive and innovative in its approach to the Northern Industrial Corridor and Gilbert/Mosley sites. When notified by KDHE that the Gilbert/Mosley Site was in danger of federal intervention through Superfund, the city government signed a Settlement Agreement with the state accepting responsibility for environmental cleanup at this site. They later signed a similiar agreement concerning the Northern Industrial Corridor which allowed this site to be delisted. Their reasoning, as had been proven out by events concerning the Northern Corridor, was that typical intervention through Superfund substantially elevated cleanup costs and led to a legal quagmire in the inability of affected landowners to allocate financial responsibility for cleanup costs resulting ultimately in economic stagnation. Total remediation costs for these two sites are currently estimated at \$20 to \$30 million dollars. A number of businesses have already shouldered responsibility for portions of the cleanup. In October 1998, the City initiated a lawsuit against a number of other PRP's to bring them to the table also.<sup>48</sup>

The City has also undertaken considerable research of the Gilbert/Mosley site and successfully negotiated a Corrective Action Decision with the KDHE, in 1994, which reduced the area requiring treatment by almost 50% and established Alternate Cleanup

Levels (ACL's) for selected compounds it was deemed unlikely to be remediated to levels below MCL's. The current focus is on containment of the contaminant plumes. Some rather innovative treatment methods are also being pilot tested including *in situ* bioremediation trenches (IBT's) coupled with a reductive iron wall and air stripper unit.

For a public water supply, the solution to contamination by synthetics is frequently a new supply well with the contaminated well given over to pump and treat remediation. For the City of McPherson a new supply well was not feasible. VOC contaminated groundwater is air stripped and finished as a public drinking water supply. These entities have the resources to detect problems and treat or relocate their water supply sources.

The occurrence of synthetic chemicals in groundwater is a troubling issue as it impacts private well owners who frequently don't have the resources or expertise to detect contamination of their water supply. Even if a contaminated well is only used to water the grass it may still represent a health hazard from outgassing fumes. Because most groundwater contamination occurs in a relatively shallow zone, owners of these wells must operate prudently especially when located close to a possible source of contamination.

The overall impact of synthetic chemicals on the environment is debatable. It can be argued that because we know so little of the interrelated functions of the biosphere as a whole, any amount could be considered environmental degradation. On the other hand, we know that microorganisms can adapt quickly to use synthetic compounds found in their environment as a food source. As with saltwater and nitrate contamination problems, the use of best land management and water use practises is recommended to avoid groundwater contamination by synthetic chemicals.

## Chapter 7: Some Notable Social Reactions

The experience of the town of Pretty Prairie, Kansas (population 601) provides an interesting example of the interplay between water quality, regulation, human emotion, and money.

On October 24, 1993 the Wichita Eagle<sup>49</sup> reported that Pretty Prairie had been violating drinking water laws since 1975. Pretty Prairie also appeared on a published list of water supply systems in violation of the nitrate MCL in 1994 and again in 1996.

The KDHE, which has primacy as the regulatory authority over drinking water suppliers in Kansas, fined the town \$12,675 in 1990 but backed down when it discovered the town only took in \$16,000 per year in property taxes. The town agreed to build a water treatment plant to resolve their nitrate problem by October 1992.

During this time, the March 1991 Kansas Lifeline<sup>50</sup> reports on the KDHE fine of Pretty Prairie. It also notes that the city had hired a consulting firm which concluded the current water rates were not even covering the cost of operation and should be raised. They also factored in the additional revenues necessary to build the proposed treatment plant and recommended a new base rate and charge per 100 cubic feet. The city failed to implement this recommendation in its entirety until the following year. This article also reports the city as being unsuccessful in two attempts to acquire Community Block Development Grant (CBDG) monies.

The 1993 Eagle article states that the town discovered the proposed treatment train would produce a brine wastestream and apparently only considered an evaporative lagoon for disposal rather than underground injection. At this point the town reneged on its promise to build a treatment plant.

In early 1993 the USEPA stepped in to directly enforce federal drinking water standards. On October 8, 1993 the EPA ordered the town to provide free bottled drinking water to its residents at an estimated cost of \$2,388 a month. The town was also ordered to build a treatment plant for nitrate removal at a then estimated cost of nearly \$600,000. The town promptly hired a lawyer to request that the EPA acting regional administrator waive the drinking water standards.

The article goes on to say that the EPA had never granted such a waiver for nitrates. The agency was reported as preparing a legal order to tell the town to straighten out its problems in six months. Failure to comply with such an order could result in fines of \$10,000 per day.

The March 1993 Kansas Lifeline<sup>51</sup> also reported on Pretty Praire's request for variance. Interestingly, they also report the city had been awarded a \$200,000 grant by the Kansas Department of Commerce (KDOC) specifically for improvements to their water system. As of press time, the city had been notified that KDOC intended to cancel the grant because of inaction. The notice also requested that the \$22,869 already spent be returned to KDOC.

The townspeople were portrayed in the Eagle article as wanting proof that consuming water high in nitrates was indeed a health threat. They also were angry that the state had done little to find the cause of nitrate problems and eliminate it. Tim Stucky, editor of the local paper, was quoted as saying, "This is not a town that doesn't care about its children. This is a town which has studied the facts."<sup>52</sup>

Individual reactions varied. One hundred fifty adults and children sent a petition to the EPA saying that they didn't believe anything was wrong with the town's water. City Council members talked about sending the surrounding farmers a bill for the proposed, new water treatment plant or filing a class-action lawsuit against the fertilizer

and pesticide industry. City Council member, Bob Seefeldt, commented that a \$10,000 per day fine for noncompliance would quickly bankrupt the city and said, "Then it would be the government's problem."<sup>53</sup> The town also threatened to stop supplying municipal water and drill private wells for its residents and businesses. City resident, Eugene Jones, simply said, "I don't have a water problem. I drilled my own well."<sup>54</sup>

In the end (?), Pretty Praire drilled a replacement well for its municipal supply in 1995. Nitrate levels are currently rising in that well also. To its credit, this town was reported in the November 1997 Kansas Lifeline as having implemented a wellhead or source water protection program.<sup>55</sup>

This story appears to be a collision between understanding and intent. Obviously, personal opinion about or simply ignoring a problem is not enough to make it go away. What is most clear is that, although the improper management of this town's public water supply system was actively endorsed by the majority of its citizens, the EPA was forced to act on a moral imperative to safeguard the health and welfare of all US citizens.

The November 1991 Kansas Lifeline<sup>56</sup> provides an interesting contrast to the saga of Pretty Praire in an article entitled, "Public fears add to the threat of more regulations." The article relates an incident where the Kansas Rural Water Association (KRWA) had been requested by KDHE to assist a small north-central Kansas community with a history of water quality problems.

After repeated complaints of poor quality water to city officials went unaddressed, one of the community residents acquired a chlorine test kit (available at any pool supply store) and began checking for chlorine residual in the distribution system. There was no chlorine residual in the majority of the system. A 0.2 mg/L free chlorine or 1.0 mg/L combined chlorine (chloramine) residual is required up to the last free flowing tap.

After inspection of the system, KRWA found; 1) bird feathers floating in the water tank, 2) another tank not fluctuating in level to change over water because of the way the system was designed, approved, and built, and 3) no chlorine residual in most of the system. The article goes on to outline corrective actions taken.

In contrast to the previous story, residents of this community forced their elected officials and system operators to comply with accepted industry practise and state drinking water standards because of drinking water quality concerns.

Also of note is the method by which KDHE went through a third party, one with wide-standing credibility in the rural community, to resolve an obvious problem. Although some people tend to paint KDHE personnel with black hats, it has been my experience that they are there to help a water supplier to maintain compliance, not just to force the issuance of embarassing public notices or to levy fines.

It is difficult to understand the social or economic decisions that would cause a person to use a water supply of questionable quality. Are the risks overstated or simply misunderstood? Consider the following examples.

A neighborhood near 57th Street and North Broadway in Wichita, which had been plagued with bad water since 1985, was placed on Superfund's NPL in 1992. Residents mostly abandoned their private wells and hooked up to a nearby municipal supply for up to \$800 a home. However, the August 1, 1994 Wichita Eagle<sup>57</sup> reported that about 25 homes, where water is contaminated, had still not hooked up. Every time they flush a toilet or wash dishes, they were exposed to toxic fumes, according to the EPA.

By February 1998, contaminants from this NPL site had migrated to an adjacent neighborhood at 50th Street and North Arkansas which was still using private wells. Incredibly, some residents remarked on suspecting problems as early as 1992 but neglect-

ed to test their own water. Hookups to city water are currently estimated at \$10,000 per home.<sup>58</sup>

A Wichita Eagle article on August 24, 1997<sup>59</sup> regarding a health study in the area of the closed Furley hazardous waste landfill in northeast Wichita reported that some people in the area still use private wells despite widespread general health concerns of many people in the area.

Even the discovery in spring of 1996 of a groundwater plume containing VOC's from Brooks landfill very nearly reaching the Wichita subdivision called Meridian Gardens raised the question of unwitting homeowners using the contaminated water for irrigation. The Eagle duly noted that, "The main health risk would come from drinking, showering, or playing in it."<sup>60</sup> Precisely the activities one expects from children when the lawn sprinklers are on. Unsurprisingly, part of the Gilbert/Mosley site remediation plan includes, "strict institutional controls and public education to prevent future groundwater usage (mainly irrigation) in all areas with contaminant levels above MCL's."<sup>61</sup>

Mark Bradbury, KDHE administrator for the south central district in 1994, has made some relevant comments. He said, "I still believe that government cannot be the solution to all environmental problems. We have to have businesses, local governments, and local citizenry taking care of our environment." He further states that the agency (KDHE) hasn't done enough to explain basic environmental science to people, so they can improve the environment through their own actions and help influence policy decisions made by local and state governments.<sup>62</sup> These thoughts indicate a call for personal responsibility and understanding.

Just as the Farm Journal in March 1983<sup>63</sup> noted that some people develop an immunity to the coliform bacteria levels in their wells, merely exhibiting flu-like

symptoms or a tendency towards infections, it stated that the health of all family members must be considered when drinking or using contaminated water. The same could be said of the health of visitors to your home.

Equally troubling is what frequently seems a public lack of understanding of basic science concepts. When the neighborhood at 50th Street and North Arkansas in Wichita was notified of the contamination of its wells by VOC's, one family's reaction, as recorded by the Wichita Eagle, was described thusly, "...the EPA enclosed a chart meant to answer health questions. But the chart, filled with acronyms like ug/L's and MCL's and strange chemical names like Cis-1,2-Dichloroethane, might as well have been in a foreign language. They stared at the information for a long time, as if hoping it would explain itself."<sup>64</sup> I would expect a more knowledgeable reaction from someone living next door to an NPL site.

As I have frequently pointed out in this paper, there are countless sources of information regarding water quality issues. Any one operating a well must understand basic industry principles to safeguard the integrity of their water supply. A well located near a potential source of contamination must be prudently monitored to insure the delivery of a safe water supply.

Admittedly, water quality, supply, and treatment are a specialized issue. Although the number of sources of information on these subjects is staggering, they do not always cite their professional colleagues or other agencies as additional sources. Sometimes the causes of effects are not apparent without further investigation. Sometimes an information source contains a biased agenda or viewpoint. Sometimes there is no answer but only a best guess. Regardless, proper use and management of a resource requires that an operator understand that resource to the best of his ability.

## Chapter 8: Concluding Remarks

In reviewing the subject of this paper, several concluding remarks and observations can be made. Foremost is that expansion of the public infrastructure by regional water and sewer systems in rural areas seems the only moral choice to safeguard the health of all citizens and to protect groundwater quality by preventing the proliferation of septic systems and other point sources.

While it is true that water and wastewater system operators all vary in their individual levels of technical proficiency, it is also true that these people are professionals in a highly specialized field. Rigorous state certification exams establish levels of competency among them. Continuing education requirements to maintain certification ensure that they receive regular refresher training whether they like it or not.

Water supply systems typically spend considerable effort in locating and safeguarding the best quality water supplies available because the higher the quality of raw water to begin with, the less expensive it is to treat to drinking water quality. They also are political entities frequently able to influence land use practices causing nonpoint sources of pollution such as nitrates or saltwater intrusion. Finally, they represent greater capital and technical resources when water quality deteriorates and a new water supply well is needed or a new treatment process is required.

While the case for public water and sewerage suppliers is strong, their greatest drawback is a high level of public distrust of government operations in general. Whether this distrust is well founded or not, it must be remembered that, in the case of an incompetently run public water supply system, oversight is provided by the state and federal government and problems will indeed be corrected to certain minimum standards.

Secondly, proper well siting, construction, and maintenance are critical. Time and again through my research these factors have been indicated as direct causes of groundwater contamination. Past and current land management practices are also important contributors. All of these factors are addressed by what is variously known as a sanitary survey, source water protection program, or wellhead protection program.

The sanitary survey should include the location of all potential and existing health hazards and the determination of their present and future importance. Items that should be assessed and recorded include;

- 1) Local geology of the wellfield, from the topography of the surface to the nature of the underlying strata.
- 2) Local hydrology of the wellfield including depth of the water table, slope of the water table, pump drawdown and recovery, and the extent of the drainage area likely to contribute water to the supply.
- 3) Nature, distance, and direction of local sources of pollution.
- 4) Land use characterization of the wellfield and recharge area.
- 5) Well construction materials and methods.
- 6) Protection of the wellhead at the top and sides from surface water intrusion or seepage.
- 7) Pumping station construction.
- 8) Cross connection identification and abatement.
- 9) Adequate disinfection practices.

Being aware of these items allows a system operator to note possible trouble areas and have response plans ready. It also provides an opportunity to remediate potential problems before they impact a water supply. The KRWA considers these source water

protection programs important enough that they added an assistance program for conducting such surveys in 1996.

In a subject directly related to wellhead protection is the issue of operator training and responsibility. For example, the City of Dodge City undertook considerable time and expense to remediate one of its public supply wells in 1997. A maintenance worker had been using a non-food grade, hydrocarbon, oil in the drip pot of an oil lubricated turbine pump. After a number of monitoring wells drilled around the supply well allowed the conclusive determination that the source of contamination was indeed within the supply well casing and gravel pack itself, lengthy physical and chemical remediation was initiated. The contamination of this groundwater source was directly linked to operator failure.

As an example of sheer negligence, I personally witnessed two industrial supply wells in Hutchinson that were simply atrocious. From a groundwater protection viewpoint, the casing was cut off at the basement floor in both wellhouses and there was no seal what-so-ever between it and the production (column) piping. The basement floor was absolutely filthy and there was no sump pump. Any water spilt from leakage or repair work simply ran across the basement floor and down the inside of the casing. Additionally, these wellhouses were rife with personnel safety hazards such as: unguarded floor openings between the ground floor and basement, homemade space heaters built with unshielded, bare conductors, and rewired motor controls, the faceplate of which could not be closed because of protruding bare conductors. How an operator could in good conscience (or legally) allow such conditions to exist in his wellhouse is beyond my comprehension. The protection of groundwater resources is a direct responsibility of the operators using those resources.

The need for public education is heard unremittingly in regard to countless subjects. It is difficult to jump on that bandwagon. Frequently, the only condition that motivates change is disaster. There are numerous sources of information available, for both public and private water supply operators, concerning best management practises and water quality protection. The real challenge is to apply in daily life the principles that are readily available.

Although groundwater contamination appears to be everywhere, and it certainly is widespread, there is cause for optimism. Identified sites are getting smaller and being contained. Past practises that resulted in widespread pollution have been disallowed. The environmental remediation business has began a state of contraction as the emphasis shifts to pollution prevention.

The impact of the Resource Conservation and Recovery Act (RCRA), as well as other legislation and economic constraints, have caused industry to reduce the amount and toxicity of raw material inputs, reduce waste emissions of all sorts, recover and reuse what were originally considered waste products, and generally move towards "closed loop" manufacturing processes. The goal of RCRA, whether attainable or not, is a "zero emissions" economy. Overall, there is a greater awareness of the process controls required to prevent the occurrence of and contain environmental contaminants.

A rather esoteric idea is the use of industry to solve environmental problems. A successful example is the use of discarded tires as supplemental fuel by a number of cement kilns in eastern Kansas. Destruction of the tires, even the metal cords, is complete and emissions minimal.

In many cases however, concentrations of contaminants high enough to elicit concern of environmental damage are not concentrated enough for industrial feedstocks. For example; upon learning in 1998 that Vulcan Chemicals in Wichita uses saltwater as a

raw material, I asked Brian Obr, environmental health and safety supervisor for Vulcan, whether the company had ever considered using the brines extracted from salt water contamination remediation efforts in Hutchinson or the Burrton and Hollow - Nikkel oilfields. He replied that the salt concentration was simply not great enough. The prospect of distilling what Vulcan considered a "dilute" brine to a useable concentration and the added transportation costs did not make economic sense.<sup>65</sup>

A similar event occurred in 1991 during a conversation with the general operations manager of the Sunflower Electric Generating Station outside of Holcomb. We were discussing the (then) new subtitle D requirements on municipal landfills when I asked whether it was feasible to simply pelletize the municipal solid waste of the surrounding counties and have Sunflower use it as supplemental fuel. Although Sunflower is a coal fired generation plant, he replied that the Btu yield of pelletized MSW was too low. Its possible use was outside of the engineered constraints of the facility.

While I fully understand the position of these two industrial plants, the future flexibility of facilities to alleviate environmental problems by their operation seems a worthy engineering consideration.

The subject of groundwater contamination in the state of Kansas has proven quite complex. The degradation of this resource has often occurred, in the case of salts and nitrates, precisely because of the economic activities its abundance made possible. Other contamination occurred unwittingly by not fully understanding the fate of synthetic compounds in the environment. Many will argue that technology is capable of providing drinking water from any water source. Mitigation of potential causes of pollution by land and water use practises is by far the less expensive option but more demanding of personal commitment.

## Glossary of Acronyms

ACL	-	Alternate Cleanup Level
BER	-	Bureau of Environmental Remediation (KDHE)
CDBG	-	Community Development Block Grant
CDC	-	Centers for Disease Control
CERCLA	-	Comprehensive Environmental Response, Compensation, and Liability Act (Superfund)
Cl	-	Chloride
CNS	-	Central Nervous System
CWA	-	Clean Water Act (Federal Water Pollution Control Act)
DWR	-	Division of Water Resources
FIFRA	-	Federal Insecticide, Fungicide, and Rodenticide Act
GMD	-	Groundwater Management District
HRS	-	Hazard Ranking System
IBT	-	<i>In situ</i> Bioremediation Trench
IGUCA	-	Intensive Groundwater Use Control Area
IOC	-	Inorganic Compound
ISL	-	Identified Sites List (KDHE)
IX	-	Ion Exchange
KCC	-	Kansas Corporate Commission
KDHE	-	Kansas Department of Health and Environment
KDOC	-	Kansas Department of Commerce
KGS	-	Kansas Geological Survey
KNRC	-	Kansas Natural Resources Council

KRWA-	Kansas Rural Water Association
MCL -	Maximum Contaminant Level
MGD -	Million Gallons per Day
mg/L -	milligrams per liter
MSW -	Municipal Solid Waste
NAPL -	Nonaqueous Phase Liquid
NO <sub>3</sub> -	Nitrate
NPL -	National Priority List (Superfund program)
OTA -	Office of Technology Assessment (federal)
POU -	Point of Use
ppb -	parts per billion
ppm -	parts per million
PRP -	Potentially Responsible Party
RCRA -	Resource Conservation and Recovery Act
RO -	Reverse Osmosis
RWD -	Rural Water District
SDWA-	Safe Drinking Water Act
SOC -	Synthetic Organic Compound
SWTR -	Surface Water Treatment Rule
TDS -	Total Dissolved Solids
THM -	Trihalomethane
TSCA -	Toxic Substances Control Act
ug/L -	micrograms per liter
USEPA-	United States Environmental Protection Agency (EPA)
VOC -	Volatile Organic Compound

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