A WATER RESOURCES MANAGEMENT STRATEGY FOR SURFACE AND GROUNDWATER IN OSAGE COUNTY, OKLAHOMA UTILIZED TO FORMULATE POLICY GUIDELINES FOR WATER RIGHTS AND RESOURCES PROTECTION AND MANAGEMENT FOR INDIAN LANDS

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in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 1993

OKLAHOMA STATE UNIVERSITY

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ACKNOWLEDGMENTS

I would like to sincerely thank the Chairman of my committee, Dr. Douglas Kent, who has given me support in technical areas as well as morally, intellectually and personally. His encouragement and mentoring have provided the impetus to complete this project. To Dr. James Lawler, I owe an unpayable debt for guiding me through the confusing labyrinth of the difficult legal concepts embedded in this study. To Dr. Donald Snethen, I owe much for his positive, friendly direction and enlightened instruction about the engineering nature of soils. To Dr. Brian Carter, I am grateful for maintaining a mental challenge which assisted me in seeing the possibilities that are part of an interdisciplinary effort. Together these committee members have been the technical foundation and support upon which this study has been built and insured its completion. Thank you.

My special thanks for many long hours of guidance through the maze of various data processing and GIS programs go to Mr. Joe Seig of the Center for the Application of Remote Sensing. Many thanks go to Mr. Mark Gregory for his enlightening assistance with the IDRISI program. Finally, a heartfelt thanks to Dr. Darwin Boardman who clarified the difficulty on the stratigraphy in the study by allowing me to use part of his work in the form of the stratigraphic columns in this study. These people represent the best ideas of the university well.

A special thank you is extended to Mr. Jack Chaney of the Bureau of Indian Affairs in Muskogee for his help in my endeavors. I also appreciate the assistance from Mr. Gordon Jackson, Superintendent of the Osage Agency and Mr. Wakon RedCorn, Mr. Nappy Cowan and Mr. Kenny BigHorse, Jr. also of the Osage Agency concerning the Native American restricted lands in Osage County.

Last, but not least, is my extreme, lifelong debt to my wife, Julie. She has been my main source of encouragement, support and took on an immense responsibility in helping me complete my post-graduate studies. I thank God for her daily. Without her and my children, Denise, Amethyst and Bethany, there is little likelihood that any of this work would be significant to me or would have been attempted. Thank you.

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CHAPTER I

INTRODUCTION

General Information

Water quality is a paramount issue in our modern, technological society. This is equally applicable to both surface water and groundwater resources. Water quality as well as sufficient quantities directly impacts the overall quality of life that is experienced in a region. All societies, particularly highly industrialized, technological ones, have a primary prerequisite of large quantities of high quality, fresh, accessible water for industrial applications, agricultural activities, residential, domestic and recreational uses. To insure that use demands are satisfactorily attained, there exists a necessity to have an adequate instituted water resources management strategy in force.

The principal objectives of a water resources management strategy are to provide adequate supplies of useable water for all applications for the foreseeable future and to insure that there is no adverse impact on the quality and quantity of water resources either on a local, regional or national scale. Many aspects will enter the overall equation for the water resources management strategy. These variables include stream development, land use, area of origin concerns, fish and wildlife, excess and surplus water, scenic and/or aesthetic considerations and environmental consequences such as point or non-point source pollution.

Osage County is obligated to meet the above objectives, but has an additional set of considerations. A majority of the mineral rights in the county are owned by the Osage Nation and are held in trust by the United States government. In this respect, the county is faced with meeting the criterion of the guidelines issued by the Bureau of Indian Affairs on water rights, resource management and protection for Indian lands.

Therefore, water resource management strategies need to address the issues of water quality and quantity of surface water and groundwater. The regulations and requirements consist of county and state imposed mandates which are in response to general federal rules set forth by Congress and its bureaucratic entities. The State of Oklahoma has defined most of the substance of a water resources management strategy by developing the Oklahoma Comprehensive Water Plan (OWRB Publication 94, 1980). There have been additional requirements to be met since the plan's development in 1980 and the associated problems will be discussed later in this paper.

The Bureau of Indian Affairs has an added set of regulatory guidelines which affect Indian lands in Osage

County. These guidelines are significant in view of the fact that the county contains approximately 166,000 acres of land which are restricted for the Osage Nation or individual Osage as allottees, by the Bureau of Indian Affairs. This additional factor will be an important criterion at a later stage in this study.

Objectives

The purposes of this study is to clarify existing information and to develop additional concepts which could be implemented to benefit the Osage Nation, other Indian tribes in the Western states, the people of Osage County and the State of Oklahoma. The major objectives are:

1) Use a review of existing literature, on geology, hydrogeology, soils, demography and physiography to define and characterize the major and minor aquifers in Osage County in areal extent, depth to fresh water and yield as well as establish land uses and surface water resources.

2) Establish basic water resources by determining water quantity of the surface water and groundwater, interstate compacts, water uses in the county, hydroelectric generation, water quality and the impacts on water quality such as oil and gas production, and agricultural pursuits.

3) Cover the definition of water, applicable water law concerning appropriation and use of surface water and groundwater and the federal and state regulations and agencies responsible for water quality.

4) Detail the nature and extent of Indian water rights and their application in the county, how they might be supported and the quantification mechanisms. Support the Native American demands by developing soil irrigability as a reliable barometer for water quantities in relation to cropping/livestock grazing and available lands.

5) Using remote sensing data and a geographic information system as tools to develop visual aids from acquired or generated data for the purpose of creating resource and constraint maps. This would allow incorporation of the Bureau of Indian Affairs policy concerning Indian water rights protection and resource management for Osage County. Prepare a generic water management strategy for Osage County.

Methodology

General

All pre-existing published literature was searched for any data concerning water quality, depth to salt water, depth to water, aquifer type and characteristics and quantity of water produced from wells. All available flow data and quality data for the major surface streams and rivers was utilized. This information was solicited from city, county and federal agencies. The data was correlated to provide an estimate of the quality and quantity of surface and groundwater for Osage County.

DRASTIC

A DRASTIC analysis for groundwater pollution potential of the major stream and river basins found in the county was generated. These analyses generated values or numbers by which each basin's pollution potential was compared to another's. DRASTIC is an acronym for seven characteristics which are:

1) Depth to water
2) Net Recharge
3) Aquifer media

4) Soil media
5) Topography
6) Impact of vadose zone media
7) Hydraulic Conductivity

A basin may be classified and a quasi-quantitative value may be assigned which relates that basin to others subjected to this technique. The four assumptions on which this effort was based are:

1) A contaminant enters the system at the ground surface

2) Precipitation flushes the contaminant into the groundwater system

3) The mobility of the contaminant is the same as water

4) The area of consideration exceeds one hundred acres (Aller, et.al., 1987)

The technique was developed by the National Water Well Association for the U.S. Environmental Protection Agency (E.P.A.) as seen in the E.P.A.-600/2-87-035 document authored by Aller, et.al. in 1987. The seven characteristics utilized for the generation of these values are as follows:

1) Depth to water - which determines how much material a contaminant must pass through to reach the water. The longer the time interval the greater the chance for decay of the contaminant or some form of attenuation to assist the mitigation of the impact of the contaminant. Significant, as well, is whether the aquifer is unconfined, semi-confined or confined (Aller, et.al., 1987). See Table 1.

2) Net recharge - the amount of precipitation which is available to move the contaminant downward into the groundwater. Recharge represents the amount of precipitation which percolates through the ground and reaches the water table. Man-made sources of recharge, such as irrigation, artificial recharge, or wastewater applications

must be considered (Aller, et.al., 1987). See Table 2.

3) Aquifer media - directly concerned with whether the material serving as the aquifer is unconsolidated or consolidated, massive or layered, fractured, undergone solution, has joint patterns or other preferential flow paths within it. Also, the potential for cation exchange in clay or shale materials, porosity, sorption, dispersion and other hydrodynamic criteria will be influenced by the media. Usually, this is under anaerobic conditions (Aller, et.al., 1987). See Table 3.

4) Soil media - often the uppermost portion of the zone known as the unsaturated, or vadose zone. Within this upper zone is the highest level of biological activity, oxidation occurs, volatilization can transpire, evapotranspiration is high and the highest level of organic matter are present. Characteristics such as Eh, pH, and liquid and plastic limits can be determined as well as their influence on contaminant movement. This is a region of aerobic activity (Aller, et.al., 1987). See Table 4.

5) Topography - a form of slope or slope variability expression. The significance of the slope is the amount of time the contaminant could remain on a surface which in turn influences the amount of infiltration and therefore the level of potential pollution for the groundwater. The higher a slope, the faster the runoff, and less infiltration to cause groundwater pollution (Aller, et.al., 1987). See Table 5.

6) Impact of the vadose zone media - based on the type of material present in this unsaturated or discontinuously saturated area. Some of the processes which may occur are volatilization, biodegradation, neutralization, dispersion, mechanical infiltration and chemical reactions. Activities such as biodegradation and volatilization tend to decrease with increasing depth (Aller, et.al., 1987). See Table 6.

7) Hydraulic conductivity - the ease with which the groundwater, and therefore the contaminant, is transmitted by the aquifer materials. This conductivity is influenced by solution paths, faults, fractures, bedding plains and intergranular porosity and permeability (Aller, et.al., 1987). See Tables 7 and 8.

TABLE 1

DEPTH TO WATER

Range (in feet)	Rating
0 - 5	10
5 - 15	9
15 - 30	7
30 - 50	5
50 - 75	3
75 - 100	2
100+	1
Standard Weighting:5	Pesticide Weighting:5

TABLE 2

NET RECHARGE

Range (in inches)	Rating
0 - 2	0
2 - 4	3
4 - 7	6
7 - 10	8
10+	9
Standard Weighting:4	Pesticide Weighting:4

(Aller, et.al., 1987)

TABLE 3

AQUIFER MEDIA

Range (of Material)	Rating Range
Massive Shale	1 - 3
Metamorphic/Igneous	2 - 5
Weathered Metamorphic/Igneous	3 - 5
Glacial Till	4 - 6
Bedded Sandstone, Limestone and Shale Sequences	5 - 9
Massive Sandstone	4 - 9
Sand and Gravel	4 - 9
Basalt	2 - 10
Karst Limestone	9 - 10
Standard Weighting:3	Pesticide Weighting:3

Also See Table 8

TABLE 4

SOIL MEDIA

Range (of Material)	Rating
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
Nonshrinking or Nonaggregated Clay	1
Standard Weighting:2	Pesticide Weighting:5

Also See Table 8

(Aller, et.al., 1987)

TABLE 5

TOPOGRAPHY

Range (in Percent Slope)	Rating
0 - 2	10
2 - 6	9
6 - 12	5
12 - 18	3
18+	1
Standard Weighting:1	Pesticide Weighting:3

TABLE 6

IMPACT OF VADOSE ZONE

Range (of Material)	Rating Range
Confining Layer	1
Silt/Clay	2 - 6
Shale	2 - 5
Limestone (Massive)	2 - 7
Sandstone (Massive)	4 - 8
Bedded Limestone, Sandstone, Shale	4 - 8
Sand and Gravel with Significant Silt and Clay	4 - 8
Metamorphic/Igneous	2 - 8
Sand and Gravel	6 - 9
Basalt	2 - 10
Karst Limestone	8 - 10
Standard Weighting:5	Pesticide Weighting:4

Also See Table 8

(Aller, et.al., 1987)

TABLE 7

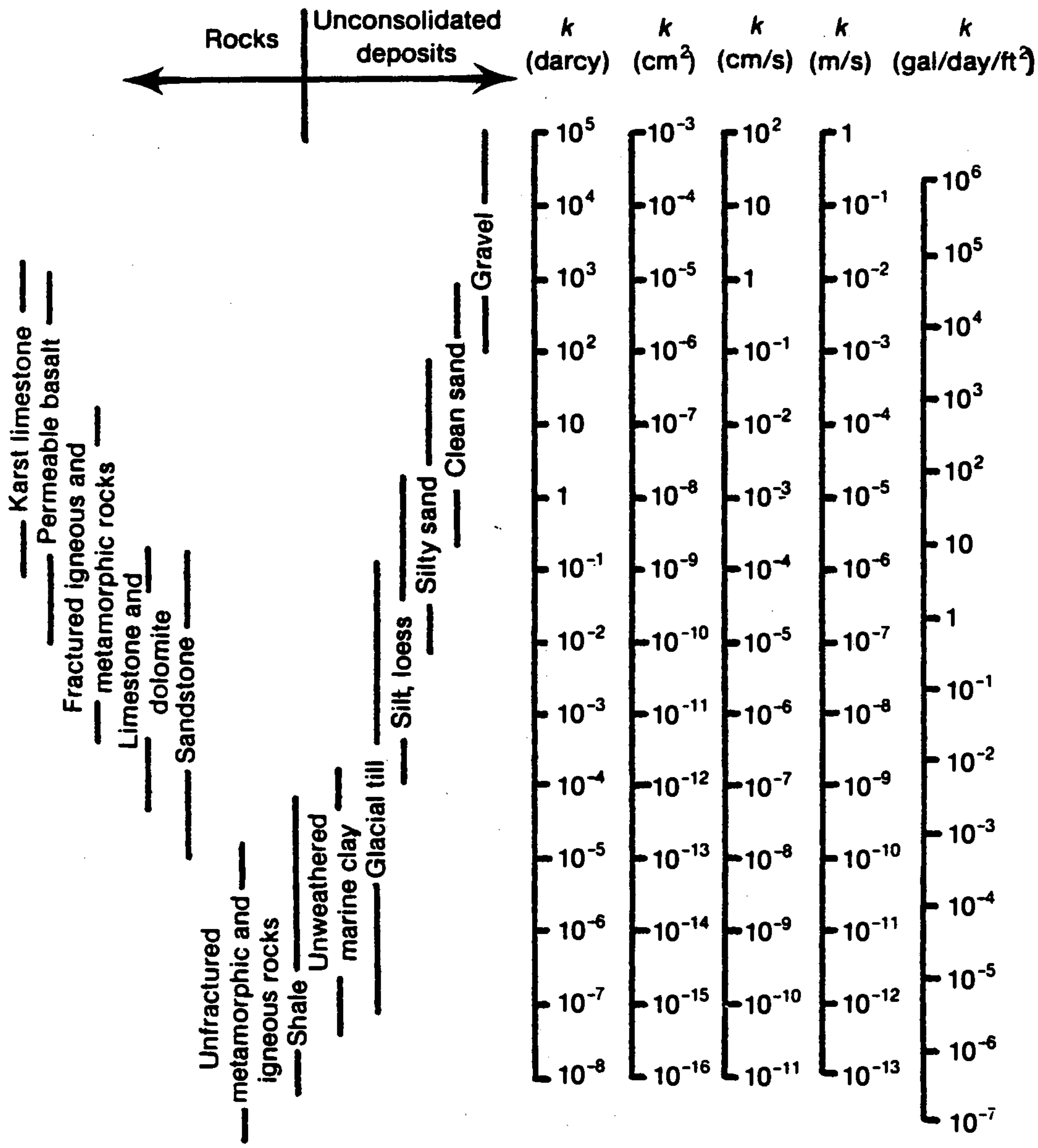
HYDRAULIC CONDUCTIVITY

Range (in GPD/Ft^2)	Rating
0 - 100	1
100 - 300	2
300 - 700	4
700 - 1000	6
1000 - 2000	8
2000+	10
Standard Weighting:3	Pesticide Weighting:2

(Aller, et.al., 1987)

TABLE 8

RANGE OF HYDRAULIC CONDUCTIVITY



(Freeze and Cherry, 1979)

The data for the various values were researched from previously existing work or acquired from local, state or federal agencies. These values were not absolutes and, in fact, display a range.

DRASTIC also has two different weighting schemes. These are pesticide and standard weighting (Aller, et.al., 1987). Both types of ratings were applied in any basin evaluation where agricultural practices which utilize pesticides or agricultural chemicals that justify the application of a pesticide weighting. See Tables 9 and 10.

Remote Sensing and Geographic Information System

Remote sensing utilizing multispectral scanner system imagery data, was processed by means of ERDAS Version 7.5. The multispectral scanner from which the data was derived was the Landsat series of satellites. There were five of these satellites in repetitive, circular, near-polar, sun-synchronous orbits. The multispectral data in Landsat 1, 2 and 3 were recorded on bands 4, 5, 6 and 7. While on Landsat 4 and 5, data were recorded on bands 1, 2, 3 and 4. Landsat 4 and 5 also contained the Thematic Mapper with seven separate bands. The band sensitivities were as follows:

1) Band 4 - 0.5 to 0.6 micrometers; the green band which yields blue on false color infrared composite images

2) Band 5 - 0.6 to 0.7 micrometers; yields green for the false color infrared composite images

TABLE 9

STANDARD WEIGHTING

Feature	Weight
Depth to Water	5
Net Recharge	4
Aquifer Media	3
Soil Media	2
Topography	1
Impact of the Vadose Zone Media	5
Hydraulic Conductivity of the Aquifer	3

TABLE 10

PESTICIDE WEIGHTING

Feature	Weight
Depth to Water	5
Net Recharge	4
Aquifer Media	3
Soil Media	6
Topography	3
Impact of the Vadose Zone Media	4
Hydraulic Conductivity of the Aquifer	2

(Aller, et.al., 1987)

3) Band 6 - 0.7 to 0.8 micrometers; a reflected infrared band

4) Band 7 - 0.8 to 1.1 micrometers; yields red on false color infrared composite images

The images have a resolution of seventy-nine meters^2 and cover the entire Earth in eighteen days or 252 orbits (Sabin, 1987 and Lillesand and Kiefer, 1987).

The data were initially processed by utilizing the ERDAS 7.5 version program. This is a raster based program which is menu driven and is user friendly. The data were subjected to a statistical analysis, georeferencing, a rectification process, classification scheme, an output phase (with hard copy and export files for IDRISI) and a post classification smoothing.

After the processing by ERDAS, the material was put into exportable files which were then imported to the IDRISI 4.01 version program for further development. This program is a geographic information system developed by Clark University and is a raster based system. A raster system is a grid system which provides more information as the grid interval gets finer. In this system the dominant information class for each cell is recorded in the data matrix. This is equivalent to a finite difference numerical model (Lillesand and Kiefer, 1987). The IDRISI program was utilized to develop land use maps, resource maps and constraints maps for use in development of the water resources management of Indian Affairs water rights protection and management (Eastman, 1992).

CHAPTER II

LITERATURE REVIEW

Demography

Osage County is a sparsely populated county located in the northeastern portion of the state of Oklahoma (see Figure 1). It has the largest land area but contains only 41,645 people as of the 1990 Census. This yields a population density of about 18.5 people per square mile. The county contains approximately 2,251 square miles of area or about 1,470,559.09 acres (Bellis and Rowland, 1976). The Osage Tribal Council or individual tribal members now own about 166,000 acres after controlling nearly all of the 1.5 million acres in the county.

The county is bounded by the Kansas State line on the north, Washington County to the east, the Arkansas River to the west and south and Pawnee and Tulsa Counties to the south as well (see Figure 1, page 16). Osage County lies between longitude 96°00'00" in the east to about 97°04'00" in the west and between latitude 37°00'00" in the north to approximately 36°10'00" in the south. The largest population centers adjacent to the county are Bartlesville to the east, Tulsa to the southeast and Ponca City to the west (Bellis and Rowland, 1976).

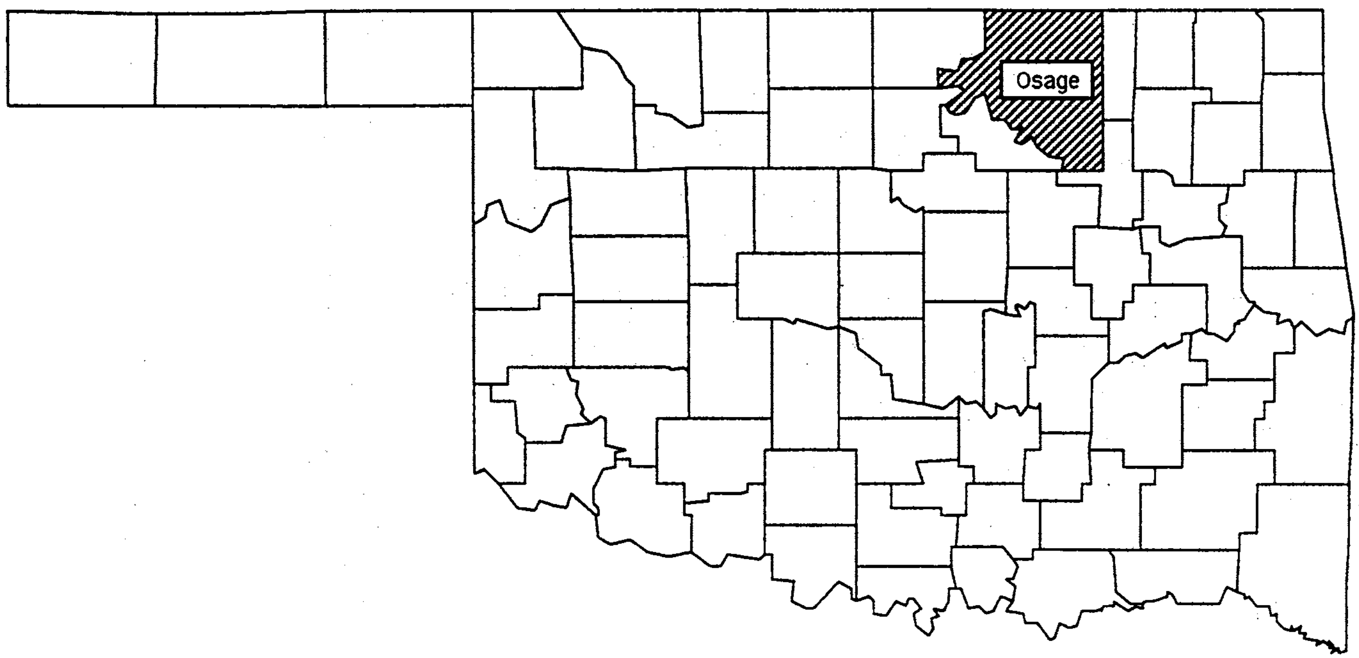


Figure 1 State Map with Osage County Delineated

The county seat is Pawhuska with a population of 3,825. This is also the headquarters for the Osage Tribal Council. Other areas of population are Hominy, McCord, Fairfax, Barnsdall, Wynona and Shidler which have populations between five hundred and two thousand people (1990 Census). The city of Tulsa has about 5,674 residents in Osage County also.

A significant point is, that although the county originally was a reservation of the Osage Nation, the total number of Indians listed within the county in the 1990 Census is only 6,161; which is 14.79 percent of the total population for the county. This is an unexpectedly small percentage considering the fact that the entire county was originally Indian land.

Geography

Osage County is in the Sandstone Hills and Red Bed Plains region in the state of Oklahoma. This is a portion of the broad Great Plains which slopes gently east and south. Eastern Osage County contains alternating sandstones and shales that give rise to rough and broken terrain that is covered by thick scrub oak growth. The western portion of the county contains less relief and is gently rolling, open tall grass prairie derived from alternating beds of limestones and shales which underlay the area. The western and southwestern margins of the county are bounded by the Arkansas River and its bottom lands can be up to several miles wide with heavily wooded sand dune areas (Beckwith, 1928).

The drainage direction in Osage County is principally to the south or southeast toward the Arkansas River or one of its tributaries. The Arkansas River comprises most of the western and southwestern boundary of the county. The Caney River dominates the northeastern part of the county. The other principal streams in the northeast and east are Sand Creek, Hominy Creek, Birch Creek, Bird Creek and Pond Creek. See Table 11. The only significant drainage in the western section of the county is Salt Creek. Most of the streams have steep gradients in their upper reaches and flow on bedrock (Beckwith, 1928).

The highest elevation in the county is over 1300 feet in the northwestern corner while the lowest level is in the southeastern corner at around 620 feet (Beckwith, 1928). The temperature ranges from 38° F in the winter to 92° F in the summer. Precipitation ranges from thirty-three to thirty-seven inches per year across the county (Bingham, et.al., 1980 and Boulier, et.al., 1979).

The county contains a large number of lakes impounded for flood control, recreation, hydroelectricity, water supplies, low flow augmentation and fish and wildlife habitat. The largest of the lakes were constructed by the Army Corps of Engineers. These lakes are Birch, Hulah, Kaw, Keystone and Skiatook (OWRB Publication 135). See Table 12.

TABLE 11

MAJOR STREAMS

Stream	Tributary to	Length in County
Arkansas River	Mississippi River	123.10 miles
Caney River	Verdigris River	26.80 miles
Birch Creek	Bird Creek	21.80 miles
Bird Creek	Hominy Creek	61.20 miles
Hominy Creek	Verdigris River	60.80 miles
Pond Creek	Caney River	21.31 miles
Sand Creek	Caney River	56.60 miles
Salt Creek	Arkansas River	65.12 miles

(County Map and OWRB Publication 135)

TABLE 12

CORPS OF ENGINEERS LAKES

Normal Pool Levels

Lake	Area (Ac)	Acre Feet Capacity	Percentage of Capacity Used for Water Supply	Acre Feet Equivalent
Birch	1137	19200	48	9216
Hulah	3570	31160	63	19631
Kaw *	17040	428600	53	74507
Keystone **	23610	557600	7	3903
Skiatook	10190	322700	20	64540

* 32.8% in Osage County

** 38.3% in Osage County

The smaller lakes have been constructed by various cities for water supplies and recreation. These lakes are Bluestem, Fairfax, Hominy, Hudson, Pawhuska, Shell and Waxhoma (OWRB Publication 135). See Table 13. For the purposes of this study, 1000 acre feet has been selected as the cutoff limit. The acre footage of each lake has been determined by the listing in OWRB Publication 135.

Soils

The general characteristics of the soils in Osage County are mixed, thermic, ustic to udic mollisols and alfisols (see Table 14). The soils in the western portion of the county formed under tall grass prairie vegetation where the soils in the eastern portion have more forested cover.

There are twelve primary soil associations detailed in the county. The first group contains two associations which are deep, loamy and sandy soils found on wooded flood plains and comprise around fourteen percent of the county. These soils when cleared are used for tame pasture and various field crops but are subject to flooding (Bourlier, et.al., 1979). The Verdigris-Mason-Wynona association consists of deep, nearly level and gently sloping soils which are generally well drained to somewhat poorly drained and loamy. These soils are capable of being the most fertile and productive found in Osage County (Boulier, et.al., 1979). The soils are classified as fine-silty,

TABLE 13

CITY AND PRIVATE LAKES

Normal Pool Levels

Lake & City	Area (Ac)	Acre Feet Capacity
Bluestem (Pawhuska)	762	17,000
Fairfax (Fairfax)	111	1,795
Hominy Municipal (Hominy)	165	5,000
Hudson (Bartlesville)	250	4,000
Pawhuska (Pawhuska)	96	3,600
Shell (Sand Springs)	573	9,500
Waxhoma (Barnsdall)	197	2,000
Adams (Private)	63	1,000

(OWRB Publication 135 and Unpublished Report)

TABLE 14

GENERAL SOILS SERIES FOR OSAGE COUNTY

Soil	Taxonomy
Apperson	Fine, montmorillonitic, thermic Vertic Argiudolls
Bates	Fine-loamy, siliceous, thermic Typic Argiudolls
Corbin	Fine-silty, mixed, thermic Pachic Argiudolls
Coweta	Loamy, siliceous, thermic, shallow Typic Hapludolls
Darnell	Loamy, siliceous, thermic, shallow Udic Ustochrepts
Dennis	Fine, mixed, thermic Aquic Paleudolls
Dougherty	Loamy, mixed, thermic Arenic Haplustalfs
Dwight	Fine, montmorillonitic, mesic Typic Natrustolls
Eufaula	Sandy, siliceous, thermic Psammentic Paleustalfs
Foraker	Fine, montmorillonitic, thermic Vertic Argiustolls
Grainola	Fine, mixed, thermic Vertic Haplustalfs
Kiomatia	Sandy, mixed, thermic Typic Udifluvents
Mason	Fine-silty, mixed, thermic Typic Argiudolls
Niotaze	Fine, montmorillonitic, thermic Aquic Paleustalfs
Norge	Fine-silty, mixed, thermic Udic Paleustolls
Parsons	Fine, mixed, thermic Mollic Albaqualfs
Pawhuska	Fine, mixed, thermic Mollic Natrustalfs
Roebuck	Fine, montmorillonitic, thermic Vertic Hapludolls
Shidler	Loamy, mixed, thermic Lithic Haplustolls
Steedman	Fine, montmorillonitic, thermic Vertic Haplustalfs
Stephenville	Fine-loamy, siliceous, thermic Ultic Haplustalfs
Stoneburg	Fine-loamy, mixed, thermic Udic Argiustolls
Summit	Fine, montmorillonitic, thermic Vertic Argiudolls
Vanoss	Fine-silty, mixed, thermic Udic Argiustolls
Verdigris	Fine-silty, mixed, thermic Cumulic Hapludolls
Wolco	Fine, mixed, thermic Pachic Argiustolls
Wynona	Fine-silty, mixed, thermic Cumulic Haplaquolls

(Bourlier, et.al., 1979)

mixed thermic Cumulic Haplaquolls and Typic Argiudolls. The Kiomatia-Mason-Roebuck association is the second of these associations and is comprised of deep, nearly level and very gently sloping soils which tend to be well drained to somewhat poorly drained and sandy to loamy. These soils are best suited to grasses, crops and trees but are low in fertility and easily eroded (Bourlier, et.al., 1979). These soils are classified as sandy, mixed, thermic Typic Udifluvents to fine montmorillonitic, thermic Vertic Hapludolls to fine-silty, mixed thermic Typic Argiudolls.

The next group of soils consists of seven associations that cover about fifty percent of the soils in Osage County and are deep to shallow loamy soils found on prairie uplands. These soils can be used to grow small grains, alfalfa, milo, soybeans and be held as tame pasture but are used mainly for native range, hay meadows and tame pasture (Bourlier, et.al., 1979).

Association one is the Dennis-Parsons-Bates which consists of deep and moderately deep nearly level to gently sloping soils which are loamy developed over acid sandstone and shale. These soils are potentially useful for cultivating small grain crops and grasses. If these soils are to be used for sanitary facilities or various recreational and building developments there is a need for special design criteria (Bourlier, et.al., 1979). These soils are classified as fine, mixed, thermic Aquic Paleudolls to fine, mixed, thermic Mollic Albaqualfs to fine-loamy, siliceous, thermic Typic Argiudolls.

Association two of this group is the Steedman-Coweta-Bates which contains moderately deep and shallow, very gently sloping to steep soils which are loamy and formed or sandstone and shale on ridge crests or side slopes. The predominant use of the soils is for native range, although some are mown for native hay where the slopes are gentle enough (Bourlier, et.al., 1979). These soils are classified as fine, montmorillonitic, thermic Vertic Haplustalfs to loamy, siliceous, thermic, shallow Typic Hapludolls to fine-loamy, siliceous, thermic Typic Argiudolls.

The third association is the Apperson-Wolco-Dwight group of soils which develops over limestones and are loamy soils that are deep, nearly level and very gently sloping. These soils can have a high shrink-swell potential and generally are given to native range and hay. There is fair potential for crops such as alfalfa, milo, small grains or soybeans as well (Bourlier, et.al., 1979). These soils are classified as fine, montmorillonitic, thermic Vertic Argiudolls to fine, mixed, thermic Pachic Argiustolls to fine, montmorillonitic, mesic Typic Natrustolls.

The fourth member of this group is the Shidler-Summit-Foraker association which is loamy soil developed over limestones and limy shales found on ridge crests and side slopes and range from very shallow to deep on very gently to steep slopes. The principal use of these soils is for native range or on gently sloping areas mown for native hay. These soils are classified as loamy, mixed, thermic Lithic Haplustolls to fine, montmorillonitic, thermic Vertic Argiudolls to fine, montmorillonitic, thermic Vertic Argiustolls.

The Grainola-Shidler-Stoneburg association is the fifth member and is comprised of moderately deep and very shallow loamy soils which slope very gently to steeply along ridge crests and side slopes over limy shales, limestones and sandstones. These soils are basically suited for native range but can be used in some areas for hay meadows or tame pasture (Bourlier, et.al., 1979). These soils are classified fine, mixed, thermic Vertic Haplustalfs to loamy, mixed, thermic, lithic Haplustolls to fine-loamy, mixed, thermic Udic Argiustolls.

The sixth association for this group is the Corbin-Pawhuska which is found over reddish limy shales and sandstones where loamy soils which are deep and very gently to gently sloping in nature develop. These soils can be utilized for cultivation of small grains, milo and cotton. However, they are best suited to native range (Bourlier, et.al., 1979). These soils are classified as fine-silty, mixed thermic Pachic Argiustolls to fine, mixed, thermic Mollic Natrustalfs.

The final component of this group is the Norge-Vanoss association. It is basically a loamy soil that is deep and well drained developed over loamy sediments and nearly level to sloping in its topography. Most of these soils are suitable for small grains, milo, soybeans, alfalfa, cotton and corn as well as tame pasture. These soils have the widest selection of crops and grasses of all other soils associations for the county (Bourlier, et.al., 1979). These soils are classified as fine-silty, mixed, thermic Udic Paleustolls to fine-silty, mixed, thermic, Udic Argiustolls.

A dominant feature of all the soil associations in this group is the necessity for special design criteria in relation to sanitary facilities, recreational or community developments. These soils have high shrink-swell potential due to montmorillonitic clays being present and the limitations imposed by these materials are the grounds for the additional design worked needed (Bourlier, et.al., 1979).

The final group of soils contains three associations. The soils in this group cover approximately thirty-four percent of Osage County. Generally, these soils are best suited for native range or tame pasture but in areas with deep or moderately deep soils the cultivation of small grains, cotton or milo is feasible. These soils are deep to shallow ones found on wooded upland and tend to be loamy to sandy in nature. The native vegetation is principally oak, either post or blackjack, and hickory with native tall grasses as understory (Bourlier, et.al., 1979).

The first association in this final group is the

Niotaze-Darnell. These soils range from moderately deep to deep and loamy ones which develop over shale and sandstone on ridge crests and side slopes that tend to be gently to steeply sloping. The Niotaze soils serve as pond reservoirs or lagoons as they developed on shales and have clayey subsoils. Principal uses are as native range, woodland or for wildlife purposes (Bourlier, et.al., 1979). These soils are classified as fine, montmorillonitic, thermic Aquic Paleustalfs to loamy, siliceous, thermic, shallow Udic Ustochrepts.

The Dougherty-Eufaula association is the second one in this group. It is composed of deep nearly level to moderately steep sandy soils which develop over sandy sediments. These soils tend to be well to excessively well drained due to their sandy nature. The largest portion of these soils have been cleared on nearly level to gently sloping areas and are used to cultivate small grains, cotton and milo. The steeper areas are mainly native range, woodland or wildlife habitat. These soils are classified as loamy, mixed, thermic Arenic Haplustalfs to sandy, siliceous, thermic Psammetic Paleustalfs.

The final association in this group of soils is the Darnell-Stephensville. The soils found in this association develop over sandstones and are moderately deep to shallow on very gently to gently sloping topography. These two tend to be well to excessively well drained and are best suited to native range. They can serve as tame pasture or in some places as areas of cultivation for small grains. Woodlands and wildlife habitat can occur in these soils (Bourlier, et.al., 1979). These soils are classified as loamy, siliceous, thermic, shallow Udic Ustochrept to fine-loamy, siliceous, thermic Udic Haplustalfs.

Geology

There are several major difficulties with the currently existing stratigraphic nomenclature and correlations as found in many of the publications concerning the geology and hydrogeology of Osage County. The first of these problems is that many authors have utilized names from east-central Oklahoma. The rocks in this area of the state are principally terrestrial while the same aged rocks in the study area are predominantly marine with some deltaic deposits in the southern portion of the county (Beckwith, 1928; Tanner, 1956; and Bellis and Rowland, 1976). To more accurately characterize these various rocks, the use of Kansas terminology would be appropriate as they were formed in a marine environment similar to Osage County. The second problem is the assignment of the Oklahoma names results in difficulties determining which lithologic units belong with which chronostratigraphic divisions in comparison to the Kansas groupings. See Figure 2 for a stratigraphic column that gives the Kansas correlations and the approximate Oklahoma equivalent. A final problem is concerned with the division

BOARDMAN AND OTHERS (IN PRESS)				OKLAHOMA GEOLOGICAL SURVEY			
System	Stage	Group	Formation	Formation	Group	Stage	System
PERMIAN SYSTEM	SAKMARIAN STAGE	CHASE GROUP	Wreford Ls	Wreford Ls	OSCAR GROUP	GEARYAN STAGE	PENNSYLVANIAN SYSTEM
		COUNCIL GROVE GROUP	Speiser Sh	Speiser Sh			
			Funston Ls	Funston Ls			
			Blue Rapids Sh	Blue Rapids Sh			
			Crouse Ls	Crouse Ls			
			Easily Creek Sh	Easily Creek Sh			
			Bader Ls	Bader Ls			
	ASSELIAN STAGE		Stearns Sh	Stearns Sh			
			Beattie Ls	Beattie Ls			
			Eskridge Sh	Eskridge Sh			
			Grenola Fm	Grenola Fm			
			Roca Sh	Roca Sh	VANOSS GROUP		
			Red Eagle Fm	Red Eagle Fm			
			Johnson Sh	Johnson Sh			
			Foraker Fm	Foraker Fm			
		ADMIRE GROUP	Janesville Sh	Janesville Sh			
			Falls City Ls	Falls City Ls			
			Onaga Sh	Onaga Sh			
PENNSYLVANIAN SYSTEM	VIRGILIAN STAGE	WABAUNSEE GROUP	Woodsiding Fm	Woodsiding Fm			
			Root Sh	Root Sh			
			Stotler Ls	Stotler Ls			
			Pillsbury Sh	Pillsbury Sh			
			Zeandale Ls	Zeandale Ls			
			Willard Sh	Willard Sh			
			Emporia Ls	Emporia Ls			
			Auburn Sh	Auburn Sh	ADA GROUP	VIRGILIAN STAGE	
			Bern Ls	Bern Ls			
			Scranton Sh	Scranton Sh			
			Howard Ls	Howard Ls			
			Severy Sh	Severy Sh			
		SHAWNEE GROUP	Pawhuska Fm	Pawhuska Fm			
			Vamoosa Fm	Vamoosa Fm			
	MISSOURIAN STAGE	OCHELATA GROUP	Tallant Fm	Tallant Fm	OCHELATA GROUP	MISSOURIAN STAGE	
			Wann Fm	Wann Fm			

Figure 2 Osage County Stratigraphic Correlation

(Boardman, 1993. Highly modified from unpublished Theses) between the Pennsylvanian and Permian rocks. This is currently a point of debate among the world experts and is far beyond the scope of this work. The problems addressed here are being worked on by James Chaplin of the Oklahoma Geological Survey and Darwin Boardman of Oklahoma State University.

The difficulties noted previously will be most significant when the hydrogeology is addressed later in this chapter. The surface geology is influenced as well but is only covered in the most general of terms to give a brief characterization for the county as a whole since the detailed surface geology or hydrogeology is outside the breadth of this study also.

The surface geology in the eastern two thirds of Osage County consists mainly of Pennsylvanian aged marine sandstones, shales and thin limestones and decreases in age moving westward. These beds are dipping at a gentle angle of thirty-five to fifty feet per mile to the north and west. In this portion of the county, the resistance to erosion of the sandstone as well as the strike and dip of the beds result in the development of a cuesta type topography. The sandstones are most abundant in the eastern part of the county. The western one third of the county has a surface geology which is dominated by shales, siltstones and marine limestones of Pennsylvanian age. In the far west, there is an outcropping of the Permian Wellington Formation but it has only a small areal distribution. The contact between the Pennsylvanian and the Permian is conformable and the transition between them is gradual. The strike and dip are basically the same as in the eastern two thirds but the thinner, less erosion resistant limestones give rise to a topography of gently rolling hills. The limestones are more abundant in the western part of the county (Beckwith, 1928; Tanner, 1956; Bellis and Rowland, 1976; and Bingham and Bergmann, 1980). Many of these marine limestones contain well preserved fossils while the shales and sandstones have some limited fossil representation. Also of note are a few thin lenticular noncommercial coals found in the southeastern portion of the county (Beckwith, 1928).

The final consideration of the surface geology is the presence of Quaternary aged alluvial deposits. These deposits consist of alluvial and terrace materials on the various creek and river drainages. The materials are not areally extensive and are composed of sands, sandy silts, clays and gravels. They are of significance from a hydrogeologic standpoint and will be discussed in that context later.

The subsurface geology of the county is principally Pennsylvanian aged shales, sandstones and limestones as seen in surface outcrops. The shales are the predominant thicknesses (see Figure 2). These rocks underlie the entire county and are about 1600 feet thick on the east side to approximately 3200 feet thick on the western margin. The dip is to the west at about thirty feet per mile but as one progresses to the west the dip increases to around forty-five feet per mile. There are several sandstones and limestones which are laterally extensive and have been used as horizons for correlation in the oil and gas fields of the county (Beckwith, 1928). A more detailed description of these various formations will be given under the hydrogeology.

Mississippian rocks represented in the subsurface are two hundred to three hundred feet of "Mississippi Lime" and up to forty feet of Chattanooga shale. The Mississippian limestone can be grayish to dark brown to black with varying thickness of cherty residual on top. The limestone can be very cherty also. The Chattanooga shale is dark to black fissle and carbonaceous in nature with considerable pyrite in localized occurrences. The large time gap between these beds and the Pennsylvanian is a probable indication of an episode of substantial erosion (Beckwith, 1928).

The Ordovician system is represented by the Simpson Group. These rocks have little presence in the county except under small areas of the south, southwest and west. The rest of Osage County has the basal Mississippian lying unconformably on eroded surface of the Arbuckle limestones (Beckwith, 1928).

The Cambro-Ordovician system is represented by a siliceous limestone known as the Arbuckle Limestone and has been penetrated by several wells in Osage County. Most of these have penetrated a thick Arbuckle Limestone section. The sediments have a varying thickness which can range from about six hundred to 1400 feet or has been absent altogether. The Arbuckle Limestone's upper surface is unconformable with all overlying strata (Beckwith, 1928).

The basement complex of the county is granite and possibly other igneous rocks. These rocks underlie the entire county and are Pre-Cambrian in age. The surface of the granite is very uneven and has isolated peaks or highs which penetrate the overlying sediments by several hundred feet or possibly as much as a thousand feet and more and is overlain by a granite wash in many cases. This probably represents a series of buried hills covered by an advancing sea (Beckwith, 1928 and Tanner, 1956).

The structural development found in Osage County begins with sediments being deposited over the uneven granite. There was a slight uplift and tilting to the southwest which was followed by a period of deposition in the Silurian-Ordivician times. At the end of this deposition there was another period of tilting and erosion. The formations were again tilted toward the southwest, probably in response to movement in the Ozark uplift. Following this activity was a new episode of erosion and this caused truncation of the folds in the formations. At the end of Mississippian time there occurred another period of emergence that was accompanied by some folding and faulting as well as an undeterminable amount of erosion. The extent of the structural movement at the end of this time is not known. After a hiatus, there was a period of renewed deposition where all the Pennsylvanian and Permian sediments were emplaced. The structural activity in the Pennsylvanian and early Permian was most likely a combination of settling over Pre-Pennsylvanian folds and faults and more intense stresses in the east and southeast. There were secondary effects from the Ozark uplift and the buried granite hills (Beckwith, 1928).

The mineral resources contained within Osage County are limited to a few thin noncommercial coals located in the southeast part of the county, shale and carbonate quarries and oil and gas production. The noncommercial coals are thin and not laterally extensive which gives them little value (Beckwith, 1928). There are numerous localities where quarries have been developed for extracting shale and carbonate for various industrial and building applications (Bellis and Rowland, 1976).

The shales have many industrial utilizations such as material for bricks, tile, roofing tile, terra cotta, clay pipe, art pottery and as cement. There are seven shales found throughout the county which have many attributes suitable to some of these many uses although part of them yielded nonsatisfactory products when tested (Bellis and Rowland, 1976).

The carbonate resources in Osage County are quarried out of four units. These carbonates are utilized for portland cement, lime products, flux material, concrete aggregate, glass manufacture, agricultural purposes, building stone and road stone. These carbonates consist of three limestones and one dolomite with reserves that are believed to be ample to meet long term demands (Bellis and Rowland, 1976).

The primary mineral resource found in the county is oil and gas reserves. The first well in the area was drilled in 1896 but was abandoned and plugged. By 1897, possibly the first commercial well in the State of Oklahoma was completed and then shut in until 1903 by Phoenix Oil Company operating on "the Foster Lease". The precedent of dividing and leasing the oil rights from the gas rights was begun in 1902 and persisted after the expiration of "the Foster Lease" in 1916 (Beckwith, 1928). There are approximately 245 oil and gas fields of varying sizes across Osage County. Within these fields there are in excess of 25,000 wells drilled throughout the history of exploration to date (Burchfield, 1985) with approximately 17,420 wells still active.

Hydrogeology

General

The difficulties with the stratigraphic nomenclature pointed out in the geology subsection and illustrated in Figure 2 become more apparent when examining the hydrogeology of Osage County. The hydrogeology requires that the study concern itself with the various formations and groups found within the county and the lithologic character of these divisions. The concept that the characteristics of the rock units differs with the depositional nature leads to the idea that with a change in depositional environment there should be a different unit name. That is, if the deposits are predominantly marine with some deltaic sediments to the south then these rock units are significantly different from the lithologic units laid down in a terrestrial environment and thus warrant another name. The Kansas nomenclature describes principally marine deposits whereas the Oklahoma names come from a terrestrial environment further to the south. These units should cross the state line.

As the Oklahoma names are established in current literature they will be utilized in this study but there will be references to the stratigraphic column in Figure 2. The stratigraphic nomenclature as portrayed in Kansas offers a more accurate and appropriate delineation than do some of the Oklahoma names. The correction of the deficiencies or inaccuracies are the focus of current research and work which will be published at some future date. The Vamoosa, Ada and Vanoss terminology will be dropped in Osage County as a result of this work.

Groundwater

The groundwater segment of the hydrogeologic section can be subdivided into minor bedrock aquifers, alluvial and terrace aquifers and the principal bedrock aquifer. Each of these aquifers will be discussed in terms of lithologic characteristics, thickness, areal distribution in outcrop and/or subcrop, depth to salt water, quality and quantity and relative location within the county, when available.

Minor Bedrock Aquifers. These aquifers are defined as those which yield less than twenty-five gallons per minute of water from shale and minor sandstones (Bingham, et.al., 1980). There are eight Pennsylvanian aged formations or groups which fall in this category. The formations or groups will be discussed from the oldest to youngest which generally covers the county from east to west, areally. These aquifers can be both unconfined and confined in nature.

The first of these formations is the Coffeyville Formation which outcrops in extreme southeastern Osage County. It is principally composed of shale with a few fine to medium-grained sandstones, and local thin coal seams. The Coffeyville Formation is capable of producing less than twenty-five gallons per minute of moderate to good quality water. The average depth to water is approximately thirty-five feet. The areal distribution, both surface and subsurface, is about 2,220 square miles and that is nearly entirely subsurface in nature. The Coffeyville Formation ranges in thickness from 175 to 470 feet (Bingham, et.al., 1980).

The second minor bedrock aquifer is the Nellie Bly Formation. It outcrops in southeastern Osage County and is composed of mostly shale with a few layers of fine to medium-grained sandstones. This formation has an outcrop and subcrop area of 2,194 square miles which is principally subcrop. The yield from wells in this aquifer is less than twenty-five gallons per minute of moderate to good quality water. The Nellie Bly Formation is from eighty to 550 feet in thickness (Bingham, et.al., 1980).

The third minor aquifer is the Chanute Formation. Primary outcropping of this formation occurs in the eastern portion of the county and has a distribution of about 2,128 square miles which is principally subsurface. These rocks are mainly fine-grained, micaceous sandstones and coarse-grained, crossbedded sandstones which are separated by shale. This minor aquifer yields from zero to twenty-five gallons per minute of good quality water. The total thickness ranges from about ten feet to 150 feet (Bingham, et.al., 1980).

The fourth of these minor aquifers is the Wann Formation, which consists of shale and fine to medium-grained sandstone as well as many thin, fossiliferous limestones. This formation outcrops in eastern Osage County but is predominantly a subcrop over most of its

2,086 square mile distribution. The thicknesses for these rocks range from fifty to 400 feet and they yield zero to twenty-five gallons per minute of good quality water (Bingham, et.al., 1980).

The fifth aquifer in this category is the Barnsdall Formation. This formation's lithologic composition is mainly fine to medium-grained sandstone overlain by shale. These rocks have a surface and subsurface distribution of around 1,860 square miles with the subsurface component dominant. This formation yields moderate to good quality water a a rate from zero to twenty-five gallons per minute from rocks that range from forty-five to 200 feet thick (Bingham, et.al., 1980).

Sixth of these min... Tallant Formation that is compo... fine to medium-grai... p area of about ... elds from zero ... ity water ... tely 75 to ... Osage County. ... Vanoss Group, ... yers of limestone and shale in ... tions of its distribution but grading into ...tone, shale and arkosic, fine-grained sandstone in the southern areas. This formation has an outcrop and a subcrop in the western third of the county and has an areal distribution of approximately 652 square miles. Thickness for the Vanoss Group is around 500 feet. These rocks produce lower quality water at a rate of less than twenty-five gallons per minute (Bingham, et.al., 1980).

The final aquifer in the minor bedrock aquifer class is the Oscar Group. This group consists of predominantly shales with many limestone and sandstone layers which are fine-grained and arkosic. The sandstones thicken and increase in number the further south the formation is encountered. The group is about 400 feet thick and yields less than twenty-five gallons per minute of lower quality water. The surface and subsurface distribution of this group is about 288 square miles in the western portion of Osage County (Bingham, et.al., 1980 and OWRB Stat. Report, 1990).

Minor Unconfined Aquifers. These Upland Alluvial Terrace aquifers are derived from the minor streams in Osage County. These are unconfined aquifers which have a thickness ranging from zero to sixty feet and are minor aquifers of unconsolidated sands, silts, local gravels and clays. The average depth to water is twenty feet and they have an areal distribution of approximately 195 square miles. The yields are twenty-five to fifty gallons per minute of good quality water (Bingham, et.al., 1980 and USGS Computer Print-out, 1992).

Major Bedrock Aquifers. These are two of these large regional aquifers which are considered the major groundwater suppliers for Osage County. The first of these is the Vamoosa Group which is composed of alternating shale and fine to coarse-grained sandstone layers. There are a few thin limestones contained in the group. The sandstones increase in number, thickness and coarseness in the southward direction. The total thickness of these beds found in the central portion of the county is about 630 feet. These rocks produce good quality water with yields of twenty-five to fifty gallons per minute. The surface outcrop and subcrop areal extent is approximately 1,523 square miles in Osage County. The Vamoosa Group is the county's most significant regional aquifer system (Bingham, 1980 and D'Lugosz, et.al., 1986).

The second of these aquifers is the Ada Group. This group is composed of shale with numerous limestone layers that thin and pinch out moving southward through the county. The southern expression is fine-grained sandstones which are thicker and more numerous. This group produces good quality water at a yield of twenty-five to fifty gallons per minute. These rocks have a surface and subsurface distribution of about 964 square miles and a total thickness of about 400 feet. This is the other significant bedrock aquifer for Osage County (Bingham, 1980 and D'Lugosz, et.al., 1986).

The Vamoosa and Ada Groups are considered to be a single aquifer system across the county. The Vamoosa-Ada aquifer can be either unconfined in the recharge areas to the east or confined further west in the county and its waters are suitable for municipal, domestic or stock use.

The occurrence and movement of water within this aquifer system is controlled by factors such as facies variations in the sandstones and shales, physical characteristics of the rocks composing the aquifer which influence the hydraulic properties and geologic structure on regional and local scale. Facies variation control water movement by causing beds to thin, thicken, pinch out, be more or less well sorted or fine or coarser-grained and is based on the environment of deposition. These variations can influence both horizontal and vertical movement. The regional and local structural geology is represented by a westward-sloping homocline that has a thirty to ninety feet per mile dip. Superimposed upon this homocline are a group of en echelon faults that extend across the county. These faults are generally normal and are found in parallel bands trending northwest or northeast. These faults are relatively short (less than three miles) and have vertical displacements of fifty to no more than one hundred feet. The en echelon faults can serve to retard water movement or be pathways for rapid recharge to the Vamoosa-Ada aquifer depending on the amount of brecciation, shearing and near surface fracturing along the different fracture zones. The physical characteristics of the rocks which influence water movement are the grain size distribution and orientation, porosity, lateral extent and vertical thickness of the sandstones and shales, lenticularity of the beds and amount of cementation (D'Lugosz, et.al., 1986 and Bingham, 1980).

There is only limited old data available for the determination of hydraulic properties for the Vamoosa-Ada aquifer. The data indicates a transmissivity value with a range of seventy to 490 feet squared per day. The transmissivity values decrease northward across the county due to decreasing saturated thickness and thickness of sandstones. There are unpublished storage coefficients from 1944 which give an average value near 0.0002 for the confined part of the system and a value of 0.12 is probably useable for the specific yield (approximately the same as storage coefficient) of the unconfined portion of the Vamoosa-Ada. The specific capacity measurements are not particularly significant as they are from gun perforated casing instead of screened wells thus the values are not representative (D'Lugosz, et.al., 1986).

The average aggregate thickness for the sandstones in the Vamoosa-Ada is about one hundred feet and thicken southward. Using a 1,500 milligram per liter of dissolved solids as the base of potable water there is an estimated sixty million acre feet stored in these rocks while about thirty-six million acre feet could be theoretically released from storage (D'Lugosz, et.al., 1986).

Major Unconfined Aquifers. The major unconfined aquifers represent the Arkansas River alluvium and terrace deposits which are confined to the areas adjacent to and within the floodplain of the river. These unconfined aquifers cover approximately one hundred ten square miles of area within the county along the course of the Arkansas River which flows along the west and south boundaries. The unconsolidated materials which compose the alluvium and terrace deposits are sand, silt, clay and local gravels with thickness ranging from thirty to eighty feet for the alluvium and up to seventy-five feet for the terrace deposits. Wells in these deposits yield from 400 to 1200 gallons per minute of good water. The quality can vary locally for these unconfined units which are easily contaminated by agricultural activity, discharge of municipal effluent or industrial wastes upriver (Bingham, 1980).

CHAPTER III

WATER RESOURCES

Introduction

An analysis of the water resources must address several key issues and concepts to insure an adequate data base to implement needed technology, institutions and measures. The basic result should yield sufficient information on water quality and quantity for groundwater and surface water which will allow a management strategy to be formulated to serve the needs of county, state and federal goals in the present and for the foreseeable future while protecting these valuable resources (Viessman and Welty, 1985).

Adequate water resources are important to encourage the development of economic opportunities such as light and heavy industry, mineral resources recovery or agricultural/livestock production while maintaining or improving water quality, promoting conservative water use and preservation and improvement of the general environment. Also of value are the development or enhancement of recreational facilities and activities, flood control and beneficial uses of excess and surplus water supplies. Public involvement should be a necessary component to facilitate committed support and cooperation in determining the types of resources for which the general public perceives a need (OWRB Publication 94, 1980).

The following areas of water resources were explored:

1) water quantity as it relates to the development and sustaining of agricultural use such as irrigation for crops or grazing lands for livestock, light and heavy industry, mineral/oil and gas recovery operations, public water supplies, conservation, flood control and lease or sale of excess and surplus supplies

2) interstate compact restrictions

3) hydroelectric power generation

4) water quality as it relates to waste disposal such as landfills/hazardous waste sites, septic systems, waste water treatment plants, pollution of non-point source and point source natures or natural pollution as opposed to man-made, oil and gas recovery or industrial needs versus pollution and urban runoff

5) aesthetics/recreation such as wetlands preservation and scenic river areas which protect fish and wildlife habitat and aid environmental enhancement and serve as a buffering mechanism against pollution.

Water Quantity

The primary influences in Osage County that could affect the quantity of surface water and groundwater available are the regional land uses such as any agricultural operations, use of water in light and/or heavy industrial activities, use in secondary recovery for oil and gas production, conservation and flood control, lease and sale of excess and surplus supplies and amounts consumed as municipal and rural water supplies. To understand the impact of these utilizations an idea of the amounts of surface and groundwater available must be determined.

Osage County encompasses a large area which contains a major river system and many sizable creeks or streams as well as lakes and ponds. The Arkansas River flows along the western and southern boundaries of the county for 123.10 miles and contains approximately 3,421,000 acre feet/year of water (Table 11 and USGS Water Data Report OK-91-1). The five major Corps of Engineers lakes in the county hold 3,737,000 acre feet of Osage County water (see Table 12). City and private lakes within Osage County are repositories for an additional 44,000 acre feet of water (see Table 13). From these surface water sources, the county has access to 7,925,000 acre feet of water.

The quantity of groundwater is more difficult to determine and subject to a greater uncertainty. The major bedrock aquifer system of the Vamoosa-Ada Groups is believed to have approximately 36,000,000 acre feet in available storage (D'Lugosz, et.al., 1986). This regional aquifer has about 29.1% of its volume within Osage County and is less thick which yields about 10,185,000 acre feet for the county. The major terrace/alluvial aquifers of the Arkansas River contain around 4,116,000 acre feet of water for Osage County (Kent, 1992). The minor Upland Terrace aquifers hold approximately 1,250,000 acre feet while the minor bedrock aquifers could possibly yield 9,465,000 acre feet of fresh water (Kent, 1992).

The net result of these manipulations is a total of about 32,941,000 acre feet of water available for all the possible uses within the county. This is a significant amount of water for a rural, largely undeveloped county and represents a very valuable and desirable resource requiring proper, diligent management.

The most important economic factor in Osage County is oil and gas recovery. There are 17,420 producing wells contained in over 240 fields located in the county and they represent a valuable source of tax revenue, jobs and income for the residents as well as mineral producers and owners. Currently a very small undeterminable number of acre feet of water per year are being used in secondary recovery for these producing fields. The demand for water derived from surface water or groundwater supplies will most likely rise as the production of salt water decreases for the hydrocarbon recovery wells.

Basically, municipal water districts derive their principal water supplies from surface water in the county. These waters are drawn from Corps of Engineers lakes or private city lakes. There are approximately 19,660 residents of the county living in cities and towns making use of these water resources on a regular basis. These various municipalities consume 12,360 acre feet per year of water assuming an average of seventy-five gallons per day per individual (Fetter, 1988).

Rural water districts or private water wells serve the remaining 21,985 Osage County residents. There are eleven rural or public water supply districts which serve around 11,850 people residing in outlying areas of the county (OWRB Publication 98, 1980). Six of these derive their water from county lakes and can provide about 6,280 acre feet in a year. The remaining five suppliers use groundwater for their customers. These districts produce 6,260 acre feet per year. Private domestic wells are pumped at approximately 1,290 acre feet of water consumption yearly. The quantity required in this category is 13,825 acre feet per year utilizing the same seventy-five gallons per day per individual (Fetter, 1988).

There is little light or heavy industry actually located in Osage County which would create any significant water use demand. The Bareco Petrolite facility in Barnsdall is the only large scale industry. The company produces polymers from the hydrocarbons pumped from county oil and gas wells. An estimated 16,750 acre feet per year of water might be required for plant operations. These supplies are probably derived from surface water as Birch Lake is located near Barnsdall. The presence of large refineries in Bartlesville, Tulsa and Ponca City might provide a ready market for excess and surplus water supplies.

Irrigation water for crops and stock use are other forms of utilization which occur in Osage County. The total acreage under irrigation in the county is approximately 500 acres which is derived from all surface water sources. There is no groundwater used for irrigation purposes. The crops irrigated are alfalfa, corn, a nut orchard and a golf course (Kiser, 1987). Assuming a use of twenty-five gallons per minute for four days per week in four months over the 500 irrigated acres for twelve hours per day, an estimated use of around 14,300 acre feet of water is obtained. The water needs of the other crops in the county are 189,000 acre feet for 87,700 acres which are being cultivated. See Table 15. This water is in the form of precipitation, not man-made application, such as some form of irrigation. Stock, on the other hand, are generally watered either from small ponds and lakes which are not part of the public water supply or small, low yield wells. Stock grazing on native or tame pasture encompasses a large segment of the land use in the study area. A rough approximation for the quantity of water consumed is 9,000 acre feet based on 127,000 head of livestock and a range of use values from three gallons per day per animal for sheep to twenty-five gallons per day per animal for dairy cattle. See Table 16 (Personal Communications with Animal Science Extension, 1993).

Interstate Compacts

Interstate compacts are a method of settling diversion rights conflicts which have constitutional authority from

TABLE 15

CROPS AND WATER USE IN OSAGE COUNTY

Crop	Acres	Feet	Acre Feet/Season
Wheat	38,000	1.583	60,154
Soy Beans	4,100	1.742	7,142
Sorghum	2,600	2.142	5,569
Alfalfa	9,000	3.423	30,807
Other Hay	34,000	2.500	85,000
Total	87,700		188,672

TABLE 16*

DOMESTIC ANIMALS AND WATER USE

IN OSAGE COUNTY

Animal	Head Count	Gallons/Day	Acre Ft/Year
Cattle	122,000	4 1/2-8 1/2	8,695
Swine	2,900	4 3/8	104
Sheep	1,300	2 1/2-3	33
Dairy	800	minimum of 25	168
Total	127,000		9,000

(OSU Cooperative Extension Unit Osage/Pawnee Print-out)
* (Personal Communications with Animal Science Extension and OSU Cooperative Extension Unit Osage/Pawnee Print-out)

Article 1, Section 10, Clause 3 that states "No State shall...without the consent of Congress...enter into any agreement or compact with another State or with a foreign power." (Goldfarb, 1984). These compacts which concern the allocation for consumptive use of interstate waters and their quality is a twentieth century occurrence. Since the

Colorado River Compact of 1922, there have been more than thirty interstate compacts that deal with many water resource problems (Goldfarb, 1984). The most prominent of the problems for these compacts to address are water allocation and pollution control. Private diversion rights are superseded in states which enter into interstate compact apportionment (Goldfarb, 1984).

The Arkansas River with its major tributaries has been compacted by two different, separate agreements ratified by Congress in 1966 and 1973. The 1966 compact concerns the basins of the Cimarron River, the Salt Fork of the Arkansas River from the confluence of the Grand or Neosho River to the Kansas portion of the Little Arkansas River as well as the confluences Verdigris and Grand or Neosho River. This agreement is between the states of Kansas and Oklahoma and divides the available water by limiting reservoir conservation storage. It also controls the new storage capacity for each tributary as well as the main stem of the Arkansas River (OWRB Publication 94, 1980). This is the compact with the most impact for Osage County.

The 1973 Arkansas River compact between Oklahoma and

Arkansas deals with the apportionment of the waters of the Arkansas River and its tributaries from Ft. Smith to the confluence with the Grand or Neosho River at Muskogee differently. The water allotment is predicated on stream flow instead of reservoir storage capacities as was the case of the 1966 Compact (OWRB Publication 94, 1980).

Water allotment or quantity is regulated by these agreements before it arrives in Osage County and after it leaves the county as well, and therefore exerts control on the total quantity available. These compacts were originated after the establishment of reserve rights for the Osage Nation and as a result do not control or affect Native American water claims.

Hydroelectric Generation

A final aspect which could influence water quantities available for Osage County is hydroelectric power generation. At the present time only one area reservoir has an hydroelectric generation capacity and that is Keystone.

The potential for developing hydroelectric generation in the county exists. It could be incorporated into the design of three reservoirs which were proposed but never constructed. The three reservoirs were Sand, Shidler and Candy. Sand Lake would have been on Sand Creek which is a tributary to the Caney River and was to have a flood control volume of 51,700 acre feet. It was to have had a water supply storage of 35,000 acre feet and a water supply yield of 13,450 acre feet per year. Shidler Lake would have been placed on Salt Creek which is a tributary to the Arkansas River with a flood control volume of 49,050 acre feet. It was to have had a water supply storage capacity of 54,900 acre feet and a water supply yield of 16,800 acre feet per year. Candy Lake would have been built on Candy Creek which is a tributary to the Caney River. It was to have had a water supply storage of 43,100 acre feet and a water supply yield of 8,620 acre feet per year (OWRB Publication 94, 1980).

These lakes were not constructed but could have provided another 38,870 acre feet of distributable water supply. The generated electricity could also provide an additional source of revenue from the water storage capability of these reservoirs, if the lakes were built, and incorporated a design element for hydroelectric power generation. The county would be more able to entice additional industry into the area by providing an available energy supply for the companies to utilize in their manufacturing activities.

Water Quality

Introduction

A wide range of activities and industries can exert an influence on the overall water quality of a region. These reasons can be as diverse as man-made pollution from oil and gas production derived from salt water injection wells, leaking tanks or brine pits to natural occurrences such as salt water springs and hydrocarbon seeps. They may be above ground as the storage tanks at the Bareco facility or any of the thousands of underground storage tanks for gasoline stations. There is urban runoff, municipal waste water treatment plant discharge, septic tank outflow, animal waste, agricultural herbicide/pesticide and fertilizer non-point source pollution and point source pollution from the landfills in Osage County.

Potable Water

The first priority is to define potable water and treatable water as they are used in this study. The term potable water is applied to water which is suitable for human or animal consumption. There are standards for drinking water which have been established by the Environmental Protection Agency under the guidance of the Federal Safe Drinking Water Act and contained in the Oklahoma State Department of Health's "Regulations Governing Operation of Public Water Supply Systems". There are maximum allowable levels for certain priority inorganic and organic chemical pollutants which are found in Table 17. These represent a threat of disease or serious health hazard to the population. Also listed are secondary standards which are recommended maximum levels that have been based on perception (i.e., color), taste (chloride) or the fact that

TABLE 17

MAXIMUM ALLOWABLE LEVELS

FOR DRINKING WATER

Inorganic Chemicals	Milligrams/Liter
Arsenic	0.050
Barium	1.000
Cadmium	0.010
Chromium	0.050
Lead	0.050
Mercury	0.002
Nitrate/Nitrite (as Nitrogen)	10.000
Selenium	0.010
Silver	0.050
Fluoride	4.000
Organic Chemicals	
Chlorinated Hydrocarbons	
Endrin	0.002
Lindane	0.004
Methoxychlor	0.100
Toxaphene	0.005
Chlorophenoxys	
2,4-D	0.100
2,4,5-Tr (Silver)	0.100
Trichlorocethylene	0.005
Carbon Tetrachloride	0.005
1,2 Dichloroethane	0.005
Vinyl Chloride	0.002
Benzene	0.005
Para Dicholorbenzene	0.075
1,1 Dichlorobenzene	0.007
1,1,1-Trichlorobenzene	0.020
Turbidity	5NTU

(OSDH Regulations Governing Operations of Public Water Supply Systems)

TABLE 18

RECOMMENDED MAXIMUM LEVELS

FOR DRINKING WATER

Chemical	Level
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corrosivity	Non-corrosive
Fluoride	2.5 mg/l
Foaming Agents	.5 mg/l
Hydrogen Sulfide	.05 mg/l
Iron	.3 mg/l
Manganese	.05 mg/l
Odor	3 Threshold odor number
pH	6.5-8.5 Standard units
Sulfate	250 mg/l
Total Dissolved Solids	500-1500 mg/l*
Zinc	5 mg/l

(OSDH Regulations Governing Operations of Public Water Supply Systems)
* (OGS Circular 87)

The base of potable water for Osage County is approximately two hundred fifty feet below land surface on the average (D'Lugosz, et.al. 1985). Knowledge of the base of fresh water is important as water wells completed below this level would yield water that is unsuitable for drinking supplies or some other domestic and industrial applications (D'Lugosz, et.al., 1985).

Treatable Water

The term treatable water is defined by the Oklahoma Corporation Commission as having a total dissolved solids concentration of less than 10,000 milligrams per liter and a chloride level of less than 5,000 milligram per liter (Personal Communication, 1993). These waters are not useable as a drinking water supply but are a source of water for light and heavy industrial pursuits and in secondary recovery techniques for oil and gas production. The base of treatable water has been referred to as the base of fresh water to differentiate it from the brine or salt water layers found at deeper depths in the aquifers. Work done by French and VanSchaik from electric logs has shown that an average depth of three hundred fifty feet below land surface is common in Osage County.

Typical Water Quality

A wide diversity of water quality is available from the various sources present in the county. Mean typical water qualities for major and minor streams, Corps of Engineers and city lakes and groundwater from major bedrock aquifers, minor bedrock aquifers and major alluvial aquifers are given in Tables 19, 20 and 21. These tables show that the general water quality available in the county is good and that there is little influence from the priority pollutants for the region.

Oil and Gas Impacts

The most significant impact on water quality for Osage County comes from the production of oil and gas. There are 17,420 producing oil and gas wells which yield large volumes of salt water or brine from 248 oil and gas fields. The by-product has been disposed of in many ways over the long production history which dates back to the early 1900's. There have been brine pits, surface dumping, pipelines, trucking and salt water disposal wells used to deal with this problem. These techniques have given rise to areas with elevated chloride levels derived from leaks in pipelines or brine pits or from faulty injection wells. Bromide occurs in analyses of some surface and groundwater supplies and the brine water from hydrocarbon production are its only source (D'Lugosz, et.al., 1985 and USGS Computer Print-out, 1992).

The revenue from oil and gas leases and production form a very substantial segment of the economy in Osage County, so the concept of eliminating this industry is

TABLE 19

MEAN TYPICAL WATER QUALITY

FOR STREAM WATER

Chemical	Major Streams (Mg/L)	Minor Streams (Mg/L)
Arsenic	.002	0
Cadmium	<.001	0
Chromium	.001	0
Lead	<.001	0
Mercury	<.001	0
Nitrate/Nitrite (as Nitrogen)	.180	0
Selenium	<.001	0
Silver	<.001	0
Fluoride	.400	.1
Chloride	198.500	132.25
pH	8.0	7.7
Sulfate	80.000	23.125
Total Dissolved Solids	661.000	435.875
Boron	.900	.600
Iron	.010	0

(USGS WRI 81-33 and Water Resources Data Oklahoma Water Year 1991)

TABLE 20

MEAN TYPICAL WATER QUALITY FOR LAKES

Chemical	Corps Lakes (Mg/L)	City Lakes (Mg/L)
Arsenic	0	.005
Cadmium	.006	.004
Chromium	.001	.002
Lead	.014	.001
Mercury	.0009	.0001
Nitrate/Nitrite (as Nitrogen)	44.0000	.2
Selenium	0	.003
Silver	0	<.002
Fluoride	.18	.29
Chloride	188.75	47.0
pH	7.79	7.3
Sulfate	85.0	25.5
Total Dissolved Solids	606.3	222.75
Boron	0	0
Iron	3026.52	.01

(Corps of Engineers Data and OWRB Publication 94 and Public Water Supply Report)

TABLE 21

MEAN TYPICAL WATER QUALITY

FOR GROUNDWATER

Chemical	Major Bedrock Aquifer (Mg/L)	Minor Bedrock Aquifer (Mg/L)	Major Alluvial Aquifer (Mg/L)
Arsenic	.003	.003	.003
Cadmium	.001	.001	.001
Chromium	.003	.003	.003
Lead	0	0	0
Mercury	0	0	0
Nitrate/Nitrite (as Nitrogen)	.8	2.16	1.82
Selenium	.001	.002	.002
Silver	0	0	0
Fluoride	.46	.38	.27
Chloride	35.7	56.8	23.4
pH	7.8	6.9	7.7
Sulfate	76.1	64.0	23.9
Total Dissolved Solids	477.4	808.7	286.0
Boron	0	0	0
Iron	.04	.3	.1

(OWRB Statistical Evaluation of Groundwater Quality Data for Oklahoma: 1986-1988; OWRB Technical Report 89-2 and OGS Circular 87) unthinkable and unworkable. To safeguard and improve the water quality for the county a program of restoration and remediation for contaminated surface water and groundwater would be necessary. There are probable areas which would be identified in the initial characterization phase which would be beyond feasible technology and economics to return to potable water levels but which might serve as treatable water supplies for industry or secondary recovery. The difficulties from leaking brine pits or pipelines only complicate the issue but need a remediation strategy to alleviate their polluting influence. Finally, the mechanical integrity of all commercial and non-commercial salt water disposal wells must be verified on a continuous basis and the identification and repair vigorously enforced.

The economics and technology of rectifying some of the brine pollution problems from hydrocarbon recovery must be balanced with the present and future water quality needs in the county. Decisions concerning the levels of water quality needs must be viewed in a hard economic perspective to arrive at an equitable, long term, workable use strategy which will not destroy one of the county's few sources of jobs and income.

<u>Agricultural and Livestock Impacts</u>

Farming and livestock herding constitute the second largest activity for Osage County. Table 22 demonstrates

TABLE 22

IMPORTANT FARMLANDS IN OSAGE COUNTY

Type of Land	Acreage
Prime Farmland	42,144
Pasture	54,203
Rangeland	111,568
Woodland	27,279
Farmland of State wide value	243,102
Farmland of Local value	933,267
Urban Areas on Prime Farmland	11,386
Urban Areas on Non-prime Farmland	21,191
Water	45,697

(Soil Conservation Service Important Farmlands of Osage County Map, 1980) distribution of agricultural land by its importance for the county and state while Table 13 points out that 87,700 acres of wheat, soybeans, grain sorghum, alfalfa and other hay are raised by local farming operations. As a result of this cropping effort numerous agricultural chemicals in the form of herbicides, pesticides and fertilizers are applied to these farmlands and could represent a serious non-point source pollution problem. Currently, 2,4-D, Lindane, 2,4,5TP, Endrine, Methoxychlor and Toxaphene are monitored for in the surface water and groundwater supplies and do not occur in detected quantities (Corps of Engineers data, OWRB Publication 94 and Public Water Supply Report).

If cropping activities were to be increased to make use of the available water supplies on irrigable lands then the effective enforcement of the controls on the distribution, application and disposal of these agricultural chemicals would need to be maintained and monitored. It would appear that at present levels of utilization where about six percent of the county's land area is under cultivation there is little reason for concern about these chemicals posing a notable risk to human health or water quality.

Livestock pasturing and husbandry is conducted on large areas of the county acreage. There are some 127,000 of beef cattle, swine, sheep and dairy cows raised on these lands (see Table 16). These numbers are spread across the county and do not represent a significant detriment to the water quality. A meat packing plant in Pawhuska could be a potential point source of animal waste pollution such as nitrate/nitrite as Nitrogen but there do not appear to be elevated nitrate/nitrite levels in the waters of Osage County (see Tables 19, 20 and 21). If controlled expansion of the herds is handled to avoid over-concentration and excessive grazing the livestock industry will be able to operate within the county without becoming a hazard. This would necessitate adequate monitoring and quality analyses on a regional, regular basis.

Urban Impacts

Urban areas in the county can serve as point and non-point sources of pollution which degrade the water quality. There are above ground and underground storage tanks which contain gasoline, diesel, oil, waste oil, all manner of chemicals and crude oil for vehicle use and industrial activities. There is leakage of ethylene glycol, fuel, oil and other contaminants from vehicles; storage batteries contribute heavy metals and chloride can be added from road salting. Septic systems from rural or urban areas can produce nitrate or fecal coliform bacteria to lower water quality standards. Household chemicals for cleaning, pest control and fertilizing reach municipal waste water treatment or septic tanks. Municipal sewage or waste water treatment plants require National Pollution Discharge Elimination System (NPDES) permits to operate but still can result in the release of fecal coliform bacteria, viruses, heavy metals and hydrocarbons from industrial processes which occur within the cities. Stringent regulation and monitoring waste water discharge and urban runoff as industry and urban areas expand could pinpoint developing problems which then could be addressed in a more timely and economically plausible fashion.

Landfill Impacts

Osage County has seven active and two inactive solid waste disposal sites which are presented in Table 23. These landfills are subject to monitoring and control by the Oklahoma State Department of Health. There are a set of regulations governing siting, constructing, opening, closing and monitoring promulgated to insure that these repositories cause minimal impact on the water quality. No data was encountered or found to exist which demonstrates any identifiable pollution directly attributable to existing or inactive landfills for the county. There are no known hazardous waste disposal sites within the county. If landfills are constructed under the constraints of current or upgraded future regulations they should pose little threat to Osage County's water supplies.

Natural Pollution Impacts

Pollution or degradation of water quality does not only occur as a result of mankind's diverse actions. There

TABLE 23

SOLID WASTE DISPOSAL LANDFILLS

Active Sites	Location
ABC Sanitary Landfill	Section 34, T21N R9E
City of Bartlesville Landfill	Section 30, T26N R12E
City of Fairfax Landfill	Section 12, T24N R5E
City of Pawhuska Municipal Landfill	Section 30, T26N R9E
C.R. Horine Sanitary Landfill	Section 34, T21N R9E
Hominy Landfill	Section 5, T22N R9E
Shell Creek Landfill	Section 36, T20N R10E
Inactive Sites	
City of Fairfax Landfill	Section 12, T24N R5E
Shell Creek Landfill	Section 36, T20N R10E

(Oklahoma State Department of Health Files) are naturally occurring pollution sources and in Osage County the principal sources are natural seeps of hydrocarbons or salt water. Conversations with EPA representatives in Pawhuska have shown that approximately two to six reports per year are filed about salt seeps or brine/oil contamination. It is reported that a majority of these incidents are natural salt water and oil springs that may have been flowing for long periods of time without notice or come and go in response to alternating wet and dry cycles of precipitation (Personal Communications, 1993). The United States Geological Survey (USGS) in Oklahoma City had a record of one spring in Osage County which had a chloride level of 470 milligrams per liter and two milligrams per liter of bromide. The conclusion was that this is a naturally occurring brine spring based on the lack of any oil and gas production nearby with a discharge rate of eight gallons per minute (USGS Computer Print-out, 1993). There was no report of any hydrocarbons with this spring.

Other Impacts

Finally, two last influences on water quality need consideration. Low flow augmentation from the various reservoirs and lakes across the county aid the improvement of the overall quality by diluting various pollutants such as chloride below drinking water standards in downgradient areas. The same may be said for the output of hydroelectric power generation facilities as these flows serve to dilute contaminants to levels which evince little concern. There is a negative aspect which results from the outflow having more dissolved oxygen, nitrogen and other gases which affect native aquatic life.

CHAPTER IV

WATER LAW, REGULATIONS AND AGENCIES

Introduction

It is necessary to have a clear understanding of how water is defined and how the laws, regulations and agencies which control its use and allocation operate within these circumstances before considering Indian water rights or water resources management strategies. The definitions of the classes of water that will be used are derived from Oklahoma statutes while the laws for use and allocation of water come from English Common Law and American legislation. The regulations and agencies come from current legislation and agency actions.

Definitions of Water

Oklahoma statutes give three primary categories for water. Category one is diffuse surface water or surface water derived from precipitation that fell as rain or snow. These waters are defined as water that occurs in its natural state in places on the surface of the ground other than in a definite stream channel or body of water such as a pond or lake. They may also flow overland in a vagrant manner (OWRB v. Central Oklahoma Master Conservancy Dist.

<u>464</u> P.2d 748, 1969 from OWRB Public 94, 1980).

The second division is stream water. This is water which exists within a "definite stream". A "definite stream" is defined as "a watercourse in a definite, natural channel, with defined beds and banks, originating from a definite source or sources of supply. The stream may flow intermittently or at irregular intervals if that is characteristic of the sources of supply in the area" (82 O.S. Supp. 1872, 105.1A). A "definite stream" need not have its source of supply as a spring but can be surface water collected over a watershed from precipitation in the form of rain or snow. It need not be continuously or constantly flowing either (<u>OWRB v. Central Oklahoma Master Conservancy Dist. 464</u> P. 2d 748, 1969 from OWRB Publ. 94, 1980). This allows an intermittent stream to be classified as a "definite stream".

The final class is groundwater which is water that occurs under the surface of the Earth irrespective of any geologic structure that contains it or through which it is moving as long as it does not occur within the cut bank of a "definite stream" (82 O.S. Supp. 1972, 1020.1A). Ground or subsurface water can be either infiltrating or percolating groundwater or underground streams. Percolating groundwater is water moving through the interstices of the soil or rocks whereas the underground stream has to have a "defined and known" channel under the Earth's surface (OWRB Publ. 94, 1980). In 1977, the Oklahoma Supreme Court held that a spring becomes Oklahoma "stream water" when the water from the spring gives rise to a definite stream (OWRB v. City of Lawton, 580 P. 2d 510, 1977 from OWRB Publ. 94).

Water Law

Basic water law covers the two principally different types of water. There is law governing surface water and groundwater. An initial step in understanding water law is to understand the origins of the statutes. The basic building block of the body of law dealing with water in the United States is English Common Law. Common Law is traditional legal precepts which have been laid down by court decisions over time. These laws are based primarily on precedent that may be overturned at a later date if societal needs change. The final arbitrator for common law cases is the highest state court or the United States Supreme Court. The traditional concern of water law has been quantity but in recent times quality has surfaced as a strong factor as well (Fetter, 1988; Goldfarb, 1984; Sax, 1968; and OWRB Publ. 94, 1980).

The second building block of water law is legislative law. This type of law has two components. There is statutory law which are acts that are passed by federal or state legislatures. Whereas, administrative laws is composed of rules and regulations written by administrative bodies and have the power of law (Goldfarb, 1984; Sax, 1968; Fetter, 1988; and OWRB Publ. 94, 1980).

Surface Water Law

Surface water rights are controlled by two central philosophies. These are the riparian and prior appropriation doctrines. The Eastern United States predominantly utilizes the riparian doctrine. Riparian doctrine is based in the common law and the riparian land owners (owners which are property holders adjacent to a surface body of water) have the first right to withdraw and use that water. The inherited concept from the common law is that riparian rights were defined by "natural flow doctrine". The import of this was that each riparian owner was granted the right to have stream flow over the property in its natural condition which precluded any material retardation, adulteration or diminishment by others. Uses allowed under this system were a drinking water supply, gardening supply, household, stock water and other domestic activities, but restricted "artificial uses" such as irrigation, power generation, mining, large scale stock watering or other industrial uses to mouths of waterways. As a result of this line of thinking being antidevelopment there has been a replacement by the "reasonable use rule". The end result of these concepts is that riparian rights are "correlative" or mutually interdependent, not only of benefit to one user (Goldfarb, 1984). Thus, the current practice is that riparian owners have equal rights to use reasonable amounts of water and the water rights are held with ownership of the riparian property. This use is often controlled by the state by a permit system. A water right is a legal right to use water in a manner dictated by law.

Primarily, water quality is the principal problem in the Eastern United States, not quantity as a direct result of higher levels of precipitation (Fetter, 1988; Sax, 1968; Goldfarb, 1984; Smith, ed., 1979; and OWRB Publ. 94, 1980). Riparian systems suffer serious disadvantages in times of shortage and are not useful in the western states where there are frequent spells of very low precipitation and shortages (Goldfarb, 1984).

Prior appropriation doctrine is dominant in most of the Western United States. It resulted from the fact that early users of western water were gold and silver miners and they applied the same principle to water as they did the mines. This method of control and use for water rights is based on the "first in time, first in right" principle of beneficial use. The first person to use the water has the primary water right.

There are several significant points about prior appropriation which need to be delineated. These are:

1) Rights are passed to successive owners and are often separate of other property rights.

2) There may be some limitations to the transfer of appropriative rights which will vary from state to state.

3) Riparian owners may not have any water rights and the water rights owners need not be riparian land owners.

4) Generally, junior water rights holders have lesser rights and in times of shortage may receive no water at all.

5) Appropriative rights exist for a definite volume of water and is not correlative with other users' rights. If the primary user needs all the flow in times of drought then it may be done within the law.

6) Water rights may be lost through non-use. If the rights are not exercised within a statutory time period the owner loses control.

The main area of concern in the west is quantity of water not so much quality as a direct result of lower levels of precipitation and thus water availability (Goldfarb, 1984; Sax, 1968; Fetter, 1988; and OWRB Publ. 94, 1980).

The idea of preferred uses has arisen from the beneficial uses concept found within the structure of the prior appropriation doctrine and is not normally found to exist in a riparian system. Many western states' constitutions or statutes have established social priorities or order of preference which rank water use. Domestic use is given highest preference followed by agricultural applications, industrial or power generation need and finally fish and wildlife or other recreational/aesthetic uses. There is an obvious tendency to bias choices to developmental criteria which are advantageous to domestic or economic endeavors. This leads to ignoring the important considerations of ecological and recreational applications making it necessary to have legislative guidance for minimum flow restrictions (Goldfarb, 1984).

The arid western states of Colorado, Arizona, Idaho, Montana, Nevada, New Mexico, Utah and Wyoming abandoned any riparian rights completely in favor of prior appropriation.

These states are commonly referred to as "Colorado doctrine" states. States where riparian rights coexist with prior appropriation are said to follow the so-called "California doctrine". This occurs in California, Kansas, Nebraska, North Dakota, Oklahoma, Oregon, South Dakota, Texas and Washington (Goldfarb, 1984 and Sax, 1968).

As noted, Oklahoma is a state which utilizes both the riparian and prior appropriation doctrines to govern surface water rights although prior appropriation is dominant. Osage County water rights are handled under appropriative methods, but these lands have an additional nuance as part of the mix. All the land within Osage County was, at one time, a federal reservation for the Osage Nation. As such, there was established a Winters Federal Reserve water rights claim for the reservation lands based on practically irrigable acreage. Much of these lands have been alienated and passed into non-Indian ownership and are subject to prior appropriation control and use, although some Winters rights may have survived the change to non-Indian hands and still be available for Indian use (Lawler, 1990; Goldfarb, 1984; and OWRB Publ. 94, 1980).

Groundwater Law

There are five governing doctrines which cover groundwater utilization. These five doctrines or rules are as follows:

1) Absolute ownership is the absolute control of the water under the landholder's property. The owner may use the water at any rate even to the detriment of adjoining owners without bearing any responsibility to the neighbors. The water need not be put to beneficial use either which encourages waste. The biggest pump wins. This doctrine, often called the English Rule, is based on the outdated and invalid assumption that groundwater movement is not predictable or definable. There are about ten states which use this legal rule and all but Texas are in the east (Goldfarb, 1984; Sax, 1968; and Fetter, 1988).

2) Reasonable use is the same as absolute ownership except that waste is prohibited and the water is required to be used on overlying land except where it can be used or sold elsewhere without injuring other overlying owners. Reasonable use as it is applied to groundwater is not the same as the rule applied to surface water. The fact is, proportional sharing is imposed with a preference given to prior users even though the theory is that comparative reasonableness (less reasonable uses may be curtailed in times of drought) is the standard. Thus, an overlying user may pump any amount of water as long as it is applied to overlying lands without waste. Again, the biggest pump wins. This doctrine is found in about eleven eastern states and Arizona and is commonly referred to as the American Rule (Goldfarb, 1984 and Fetter, 1988).

3) Correlative rights rule is derived from an admixture of riparian and appropriation surface water law with origins in California. As the rules are applied to groundwater during times of shortage the following statements govern distribution:

    a) the overlying owners are to receive no more than their "fair and just proportion" for use on the overlying lands

    b) disputes between out of basin transport entities are settled on a "first in time, first in rights" basis

    c) transporters are subordinate to overlying users

The rights granted under the correlative doctrine are very different from absolute ownership or reasonable use in that it prorates supply among owner-users. The issue of comparative reasonableness is another component which concentrates on determining the requirements of competing users and the degree to which each use is beneficial. Several eastern states including Florida and New Jersey ascribe to this doctrine (Goldfarb, 1984).

4) Prior appropriation in the western states basically excluded or ignored groundwater. Yet a trend is evolving toward inclusion of groundwater in a permit system based on prior appropriation. The western states are applying appropriation-permit rules to all their groundwaters or at least particular sources or controlled areas and the control is by state agencies or local boards. The states of Texas and Nebraska are the only ones which do not use prior appropriation in conjunction with any of their groundwater (Goldfarb, 1984).

5) Restatement of Torts rule is a formulation by legal scholars on what the law should be and is most influential in areas undergoing change. This rule is one of comparative reasonableness which resembles correlative rights although there are two differences. The restatement rule makes no distinction between overlying users and transporter and establishes three guidelines for determination of unreasonable interference. The three guidelines are:

   a) well interference

   b) pumping in excess of "fair share"

   c) interference with stream or lake levels that are dependent on groundwater (minimum flow)

   The only state to have adopted this rule is Wisconsin (Goldfarb, 1984).

The Oklahoma statutory control of groundwater use is embodied in the 1972 Ground Water Law which took effect on July 1, 1973 and is found in 82 O.S. Supp. 1979, 1020.1-1022.22. The basic premise was the establishment of a permit system controlled by the state where allocation was on a reasonable use basis while honoring prior appropriation rights acquired before July 1, 1973. There is also a clause which stipulates prevention of waste so as not to allow loss of water that could be put to beneficial use (OWRB Publ. 94, 1980).

A future direction which must be taken for water use is conjunctive use or management. This is the management of surface water and groundwater as a single source. Comprehensive management will require change in the laws to remove the legal dichotomy existing between groundwater and surface water and facilitate an integrated plan covering both water quality and quantity. Thus, legal and administrative distinctions and impediments must be set aside in favor of a unitary water-use type of permit in order to develop rational water resource management strategies that take into consideration impacts on quality and quantity for all divergent uses, present and future (Goldfarb, 1984).

Water Regulations and Agencies

Water regulations, either federal or state, are concerned primarily with water quality maintenance, preservation or improvement. The overall intention is to prevent, through careless use or misuse, the pollution or degradation of surface water and groundwater supplies. There are many avenues for this contamination to occur such as industrial and manufacturing activities, leaking hazardous waste or landfill sites, agricultural fertilizer and chemical applications, underground storage tanks, septic systems, municipal waste water disposal systems, oil and gas production and transportation, illegal dumping of toxic wastes, mineral production activities, excessive municipal utilization and numerous, nearly limitless, possibilities.

The federal, state and local responses to concerns about water quality have been the creation and enactment of a growing body of legislative and administrative laws seeking to stem any further degradation. The scope and extent of these laws are far beyond those of this study and will only be addressed in brief as they pertain to the concepts in a water management strategy.

Federal Level

A significant starting point for all ensuing federal legislative actions on water quality and quantity is found in the National Environmental Policy Act of 1969. This act was the first spurt of policy that arose from the growing environmental conscience of the late sixties (Kraft and Vig in Vig and Kraft, eds., 1990). The basic contributions of this law was the requirement of detailed environmental impact statements on any federal activities of major proportion and the establishment of the Council on Environmental Quality (Kraft and Vig in Vig and Kraft, eds., 1990).

NEPA can be seen to be a major instrument for forcing governmental agencies to look at possible environmental consequences of the actions. Many attorneys have viewed it as a procedural item to be used as a delaying tactic for special interest groups by relying on extensive litigation. There is little or no resolution of issues and as the act lacks explicit constitutional referent it is more easily ignored by bureaucrats and politicians (Caldwell, 1989 and Kraft and Vig in Vig and Kraft, eds., 1990).

The Council on Environmental Quality was the source of many policy innovations but was unable to fulfill its mandate due to lack of receptivity on the part of the Legislative and Executive branches. The actions by the CEQ did not have the force of constitutional authority (Kraft and Vig in Vig and Kraft, eds., 1990 and Caldwell, 1989).

As a means of establishing an enforcement mechanism for NEPA, the Environmental Protection Agency was created. It had the mandate to enforce the environmental impact study requirement on all entities. The later years were to see more enforcement responsibilities given to the Agency over a growing body of legislative activity but it was only sporadically able to operate effectively due to lack of public support as well as resistance from the Legislative and Executive branches (Kraft and Vig in Vig and Kraft, eds., 1990 and Caldwell, 1989).

Next to address water pollution prevention and control was the Federal Water Pollution Control Act of 1972 (FWPCA) and its Clean Water Act Amendments of 1977 (CWA). The primary focus of these acts was "to restore and maintain the chemical, physical and biological integrity of the nation's water". The direct goal was to achieve a degree of water quality which would return the surface waters to a state where they were safe for swimming and fishing by 1983. Also contained in these actions was the elimination of discharge of pollutants into the waters by 1985. There were water quality standards, minimum national effluent standards (requiring discharge permits) and grant money for construction of sewage treatment plants established under these two acts. The end result of the two acts has been a positive improvement in surface water quality for many parts of the United States (Fetter, 1988 and Environmental Law Statutes, 1990).

The Safe Drinking Water Act of 1974 and its amendments of 1986 were directed at groundwater quality. This law established standards for safe drinking water, protection for drinking water aquifer from pollution arising from the underground injection of hazardous waste and safe guards for "sole source" aquifers (the only source of available drinking water). It is the 1986 amendments by Congress with directed states to develop wellhead protection plans to prevent contamination by agricultural chemicals, hazardous wastes and problems such as underground storage tanks in public water supply wells. The idea was to insure that the surface area near the water wells was free of possible polluting sources. Finally, the act is responsible for control of the underground injection of hazardous wastes so they are not introduced into or above potable water (Environmental Law Statutes, 1990 and Fetter, 1988).

The fourth law is an outgrowth of the Solid Waste Disposal Act (SWDA) which is called the Resources Conservation and Recovery Act of 1976 (RCRA). This act establishes "cradle to grave" control on hazardous wastes using a permit and manifest tracking system. Those who generate hazardous wastes, transport it, or store, treat or dispose of it are regulated. These facilities cannot be placed within a recharge zone of a "sole source" aquifer and must have a groundwater monitoring system constructed when new or retrofited to existing sites. The disposal areas must be double-lined containment areas and monitoring programs for leachate derived from the pits. The scope of these laws is to provide protection for groundwater quality from active hazardous waste disposal landfills by governing siting, construction and closure and from manufacturing or transportation companies which use transport, treat or store hazardous wastes (Fetter, 1988; Environmental Law Statutes, 1990; Hanson, 1989; and Kraft and Vig in Vig and Kraft, eds., 1990).

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and Superfund Amendments Reauthorization Act of 1986 (SARA) are the next laws to be considered. The Superfund/SARA were developed to provide the federal government authority to act in hazardous waste emergencies and clean-up of inactive or defunct waste disposal sites. It was born in the controversy over areas such as Love Canal or the Valley of Drums. The clean-ups were aimed at hazardous wastes released in the air, on land or in water. A central concept was the establishment of the National Priorities List (NPL) of sites which were targeted for remedial actions. The remediation was to emphasize the reduction of the toxicity, volume or mobility of the hazardous substances and pollutants as much as practically feasible to avoid further public health endangerment through air, land or water vectors (Environmental Law Statutes, 1990 and Fetter, 1988). Little has been accomplished in this regard as most of the money and time has been spent in endless, futile, fruitless litigation and inaction trying to assess blame and financial responsibility.

There are two final federal acts which concern water quality in relation to toxics which are of concern within the scope of this study and they are 1) Toxic Substance Control Act of 1976 (TSCA) and 2) Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and its amendments. The Toxic Substances Control Act regulates the use, testing, research, development, manufacture and handling of chemicals or toxic compounds which might cause or have caused groundwater contamination. The Federal Insecticide, Fungicide and Rodenticide Act places restrictions on use, manufacture distribution and disposal of these pesticides where they might affect the groundwater quality of a region (Environmental Law Statutes, 1990 and Fetter, 1988).

All of the foregoing acts are under the auspices of the Environmental Protection Agency. Many of these laws are aimed at private industry and its regulation to preserve water quality but several address federal agencies and state governments as subject to the restrictions. The EPA is charged with a wide-ranging, nearly overpowering task to enforce the body of legislative and administrative law surrounding surface water and groundwater quality.

A final federal law which should be mentioned is the Surface Mining Control and Reclamation Act of 1977. This act was intended to prevent endangering public health and adversely affecting the surface water and groundwater quality. It also contained provisions concerning the impact on the hydrologic regime as a result of burial of toxic by-products during land reclamation. These toxic materials or acid forming wastes could be in the form of mine spoils or mill tailings. The agency charged with the responsibility for enforcement is the Bureau of Mines (Environmental Law Statutes, 1990 and Fetter, 1988).

State Level

The State of Oklahoma has seven agencies which are responsible for various aspects protection and maintenance of water quality for the state. Three of these agencies have only a minor role in Osage County. These three state entities are the Department of Wildlife Conservation which is concerned with preventing wildlife losses from habitat loss or pollution, the Conservation Commission which does some minor groundwater monitoring and technical aid to prevent surface and groundwater contamination by managing soil and water and the Department of Mines that has jurisdiction over leachate and runoff from above ground or underground mining operations.

The remaining four agencies are charged with significantly more critical areas of effort that yield an impact on overall water quality in the state and Osage County. First is the Department of Agriculture that is responsible for fertilizers, animal wastes other than from dairy operations and pesticides from agricultural and non-agricultural applications. Second is the Water Resources Board which handles any industrial waste water disposal other than as a result of oil and gas production, abandoned water wells and establishes water quality standards within the state. The agency has an antidegradation policy which states that the waters of the states are a valuable resource and are to be protected from any degradation. This agency has its own set of regulations and have their authority from 82 O.S., Sections 926.3, 926.6 and 1085.2. Third, the Department of Health has jurisdiction over septic systems, sewage lagoons, water supply testing, injections wells for materials other than oil and gas production by-products, dairy waste, hazardous materials spills and solid and hazardous wastes. They have developed Public Water Supply regulations and Standards for Public Water Supply Facilities as the operating mechanisms. The agency derives its authority from 63 O.S. 1981, Sections 1-901 et. seq. Fourth is the Corporation Commission that is responsible for any oil and gas production, waste products. Injection of those products, abandoned oil and gas wells and petroleum storage tank whether above ground or underground. The extensive set of regulations controls a significant industry in Oklahoma and in particular Osage County. Their authority is from 52 O.S. 88-320, 524-558; 500-525.

Each of these agencies has promulgated a set of regulations with which it enforces the mandates of federal and state law. There are actions within the state to establish a Department of Environmental Quality which will place all the diverse agencies and often contradictory regulations under one roof with the intention of eliminating inconsistencies, loopholes, gaps and problems which will allow the State of Oklahoma to work toward a healthier environment for all of its residents and neighbors.

CHAPTER V

INDIAN WATER RIGHTS

Introduction

The issue of Native American water rights is highly contentious, especially in the more arid central and western segments of the United States. The conflict is between the Native American tribes and the non-Indian water users that are laying claim to the same surface water and groundwater for municipal water supplies, agriculture and industrial applications. Indian water rights are generally considered inchoate (i.e., unexercised and unquantified). As a result of this policy the Native Americans can be entitled to enormous and unpredictable amounts of water. The very broad and vague purposes embodied in most treaties or legislation creating the reservations which established permanent homelands and livelihoods for the tribes leads to the problem of changing water requirements. These alterations could result from a change away from fishing and hunting where a minimum low flow without consumption is needed to an irrigated agricultural economic base using very large seasonal diversions (Goldfarb, 1984).

The origin of Native American claims to the surface water and groundwater arise from treaties between the

United States government as the superior sovereign power and the lesser sovereign nations of the various tribes or from legislation or executive authority as a result of Congressional or Presidential action. The treaties or legislation created homelands for the tribes. These activities are all superior to any state laws or regulations and preclude any control or management by any state authority (Goldfarb, 1984 and Lawler, 1990).

The establishment of a reservation or enclave for the tribes carried with it a federal reserved water right. These water rights were set aside to provide the Native Americans an opportunity to pursue "the arts of civilization" and were implicitly reserved for all the water reasonably necessary to provide for the economic and social development of the homelands that had been established (Lawler, 1990). The principal intent for giving these homelands was for the tribes to make the land productive and develop agriculture and pastoral activities (Cohen, 1982). Other uses for these reserved water rights are preserving hunting and fishing, oil and gas or other mineral resources development and recovery, timber management, recreation, hydroelectric power generation or any unforeseeable future technology which might assist in the development of the tribes' interests (Swan, 1990).

There are several principles of statutory construction which courts basically follow in relation to construing treaties and statutes developed for Native American

(Deloria and Lytle, 1983). These principles are supported by case law and two of them are as follows:

1) statutory language must be liberally construed on behalf of Native Americans

2) ambiguities must be resolved in the favor of the Native Americans

These point to the bias or liberal interpretation which should allow rulings favorable to any reasonable Indian claims.

Winters Doctrine

The *Winters* Doctrine is the basis for the federal reserve water rights in the United States and is found in the United States Supreme Court's decision *Winters v. United States* (207 U.S. 564, 1908). This ruling laid the legal foundation for the reserve water rights by holding that the federal government's intention when establishing the various reservations for the tribes from public lands was that there were to be adequate quantities of water available for the purposes of the reservations. This was an implicit right and not directly written into the treaties (Shupe, 1990; Wallace, 1990; Lawler, 1990; and Smith, 1979).

The United States Supreme Court found the main reason for creating the reservation was to transform the Indians into a "pastoral and civilized people" (207 U.S. 564, at 576), but this was not feasible without water for irrigation. While irrigation was not specifically addressed by the Court it was held that the Indians had the right to use water for a variety of purposes (and these need not be beneficial) including the "arts of civilization" (207 U.S. at 576) re-enforcing the implied nature to these rights.

Winters Doctrine rights are not based on prior use as seen in prior appropriation but are concerned with the future needs. These rights are also defined by the reservation rather than under the framework of state law. The rights obtained by Winters Doctrine are not lost due to non-use and are "open-ended" as concerned with future needs or uses (Lawler, 1990). These reserve water rights are subject only to private appropriative rights which were vested prior to the establishment of the federal reservation. The rights are not subject to state law as they were created independently and are, thus, not subject to state conditions stipulating beneficial use or priority of diversion (Goldfarb, 1984 and Lawler, 1990).

There are some aspects of Winters Doctrine rights which resemble riparian rights, as well, but they are not contingent on being located on a watercourse. They do not need reasonable use and result from creation of a reservation from public domain land rather than passage of title to property (Lawler, 1990). In fact, Winters rights "can be invoked to divert a stream onto non-riparian lands" (Hundley, 1982).

There are subsequent cases which develop the aspect that the implied federal water reserve rights are not limited to the land uses in existence at the time the reservation was established (Skeem v. United States, 273 F.93, 9th Cir., 1921), but that it is to serve the ultimate requirements which were the goals for creating the reservation (United States v. Ahtanum Irrigation District, 104 F.2d 334, 9th Cir., 1956; Arizona v. California, 373 U.S. 546, 1963). Winters Doctrine and its "progeny" cases relate to the future of the reservation, unforeseen technology and uses unknown at the time of the establishment of the reservation (Lawler, 1990 and Cohen, 1982), not merely the past or present techniques and applications.

The Winters Doctrine has its roots within the Commerce Clause, the Property Clause and in some cases the Treaty Clause of the United States Constitution. Many cases exist which demonstrate that the federal government reserved the water while others suggest that the Indians reserved these rights (Lawler, 1990).

The real significance is not which entity reserved these rights but that the Native American federal reserve water rights are different from other such federal reserve water rights. They have a different legal status compared to those in existence from the creation of a national forest or national park like Yellowstone (Lawler, 1990). The Winters Doctrine originally extended to Indian reservations but at a later date was applied to other non-Indian federal reserved rights. Still, Native American reserve rights differ due to the fact that these rights are held in trust for the tribe by the United States and not owned by the government. The federal government is able to sell, lease, release, quit claim or dispose of in other manners its federal reserve rights, but is constrained from doing so in relation to the Native American reserve rights as a result of its fiduciary duty to the tribe which are beneficiaries of the trusts (Cohen, 1982 and Lawler, 1990). A major difference between Indian and non-Indian federal reserved rights is that non-Indian lands extend only to the primary purpose where Indian rights are extended to secondary purposes (U.S. v. New Mexico).

The primary reason for creation of a reservation for Native Americans was to make the land and resource useable for its inhabitants whereas most other reserves are protective in nature (Cohen, 1982 and Lawler, 1990). As a result of the express nature of the Native American federal reserved water rights, they "should enjoy broader uses than other federal reserved water rights" (Schapiro, 1986-87) and "should be more broadly construed than federal rights" (Hostyk, 1982).

It can be seen from the foregoing that a multitude of purposes are put forth for the reservations created for the Native Americans and not strictly confined to irrigated agriculture. The opinion delivered by the Supreme Court in the Winters decision does specifically say that water rights are reserved by the Native Americans for "all their beneficial uses, whether kept for hunting and grazing roving herds of stock, or turned to agriculture and the arts of civilization" (207 U.S. at 576). The domestic use or household applications of water are definitely included as well as water to protect fish and maintain fishing grounds, use of groundwater for oil and gas drilling, production and secondary recovery, hydroelectric power development, recreation, tourism and municipal use could arguably fall under the concept of the "arts of civilization" (Lawler, 1990).

The application of the Winters Doctrine to groundwater as well as surface water has considerable support in case law. The case of Nevada ex rel. Shamberger v. United States (165 F. Supp. 600) was decided in the United States District Court in Nevada and it held that the Navy was not required to comply with state mandates in order for the military reservation to use groundwater necessary for the installation's operations. This case was in reference to a non-Indian military reservation but should apply a fortiori to Indian reservations stemming from the special fiduciary responsibilities (Lawler, 1990). According to Rarick "it would seem that the Reservation Doctrine is equally applicable to groundwater" (Rarick, 1976). The case of Cappaert v. United States (426 U.S. 128, 1976) decided that although the pool containing the endangered fish in Devil's Hole National Monument was surface water the injunction against off-reservation diversions that depleted the pool, "whether the diversion is of surface or groundwater" should be upheld (426 U.S. at 143 and Lawler, 1990).

Many other cases acknowledge that the federal reserve water rights are applicable to underground water or groundwater. The Congress of the United States gave credence to the Native Americans' claim to groundwater by passing Public Law 32 (Act of July 28, 1978, Pub.L. No. 95-328, 92 Stat. 409, 1978), which dealt with the Ak-Chin Indian Community's claim to groundwater on its reservation in Arizona (Hostyk, 1982; Lawler, 1990; and Wallace, 1990). All of these responses deal with an established, existing reservation on which the concerned tribes were living and functioning and thus fulfilling the purposes of a reservation.

The purpose for creating or establishing reservations for Native Americans need not be identified as "single essential purpose", United States v. Adair (V723 F. 2d at 1410, 1983) or, for that matter, the "primary purposes" test is not felt to be directly applicable to Indian reserved rights. It can serve as a useful measure if broadly construed (Lawler, 1990). The Ninth Circuit Court held that "the general purpose (of an Indian reservation to provide a home for the Indians) is a broad one and must be liberally construed", Coleville Confederated Tribes v. Walton (647 F. 2d 42, 9th Cir., 1981). The result of most Native American reservations being provided as a means of developing economic self-sufficiency as well as a place of residence, they are entitled to significantly larger quantities of water than would be granted other federal lands (Cohen, 1982).

Osage Water Rights

The Osage Nation composed of the Great and Little Osage were granted a reservation under the Act of Congress of June 5, 1872 (17 Stat. 228). This act and earlier ones from 1868 and 1870 authorized the removal of the Great and Little Osage from diminished reservations in Kansas to the Indian Territory in what was to become Oklahoma. "These laws, construed in the light of their statutory language, legislative history and accepted principles of statutory construction, provide the bases for identifying the purpose for which the Osage reservation was created and for which water is, therefore, reserved under the Winters Doctrine" (Lawler, 1990). The ultimate purpose of the reservation was to establish a homeland for the Osage Nation. Commissioner Nathaniel G. Taylor, president of the commission authorized to negotiate a treaty with the Osage in 1868 repeatedly mentions home as it pertains to the lands which the government proposed to purchase for them from the proceeds of the sale of the tribe's Kansas lands. The intent of the various communications was the removal of the Osage in order for the government to establish a homeland where the tribe might develop economically and socially as well as be protected and advanced. President Grant's "Peace Policy" supported the movement of Indians toward civilization and citizenship which was encouraging and fostering their assimilation into Anglo-American culture (Lawler, 1990).

The 1870 Act called for "a permanent home" which was also stipulated in the unratified 1868 treaty. This permanent homeland was to remove the Osage from the settler controlled state legislature of Kansas and should most likely be interpreted to be the same thing as the "reservation" found in the 1872 Act (Lawler, 1990). The land that was to become their reserved, permanent homeland was poorly suited to agricultural endeavors for the most part. As livestock raising was part of the traditional Osage economy and the bluestem grasses of these prairie land was well suited to grazing for animals such as horse, cattle and sheep there was the ability to develop a range cattle industry. The Osage were able to lease their acreage for pasture as a source of revenue (Lawler, 1990).

A major economic resource was encountered under the Osage homeland in the form of oil and gas reserves which, although not mentioned in the act giving the tribes their land, was presumably included. The Osage Allotment Act of 1906 confirmed the rights of the tribe to develop and exploit oil and gas, coal or other minerals on the reservation. Therefore, it must be understood that in light of the language and legislative history of this Act the lawmakers intended for the Osage to utilize all the available resources found on the reservation to develop and prosper as civilized people (Lawler, 1990). This would necessarily include the water resources of their homeland.

The Osage were given, by express grant of the federal government, title in the river bed to the main channel of the Arkansas River above the confluence of the Grand River as this is a non-navigable reach before Oklahoma entered the Union. The primary rulings here are in support of the fact that the tribe had the exclusive rights as concerned the mineral resources of the river bed. It follows that if the Osage had title to half of the bed of the Arkansas River along their reservation, then they had rights to the water in the alluvium underlying the bed and in the banks. This groundwater was allocated to them from the same federal source as their right to the bed and is independent of state laws and regulations as they were in existence prior to statehood and are derived from the federal government (Lawler, 1990).

Thus, the Osage _Winters_ rights can be seen to be established by statutes and title documents. The implication is that in creating a permanent homeland for the Osage in the form of a reservation the federal government conveyed the reserved water rights to develop the resources to the fullest extent. The objective was to allow the Osage to advance themselves to a civilized state while practicing the "arts of civilization". The reserved water rights have a priority date of June 5, 1872 for the statute identified by the United States Supreme Court as the source of the Osage title (Brewer-Elliott Oil and Gas Co., 260 U.S. 77, 1922 and Lawler, 1990).

Further, these reserved water rights could be utilized where necessary for the development of oil and gas, coal or other minerals, as in-stream flow, to maintain fishing and hunting, hydroelectric power generation, stock water, recreation, light or heavy industry, stock or agricultural uses and municipal or domestic water supplies (Maxfield, Dieterich and Trelease, 1977 and Lawler, 1990). This water could be either surface water or groundwater and still be considered "appurtenant" to the reserved lands of the Osage (Lawler, 1990).

A substantial portion of the Osage reserved water rights are felt to have survived the Osage Allotment Act of 1906 and the passage of Indian lands into non-Indian hands. This is a direct result of the nature of the Act which differs from the General Allotment Act or Dawes Severalty Act of 1887.

The General Allotment Act was an outgrowth of the assimilationist concepts which were prevalent in Post Civil War United States. The Act authorized the allotment of tribal land in severalty to individual tribe members. This division of lands was meant to help the Native Americans to develop a work ethic as well as make them employed in a gainful manner on their individually owned property (Getches, 1981 and Lawler, 1990). A secondary aspect of the Act was the fact that the unallotted or "surplus" lands would be made available to non-Indians for settlement. This was most likely the actual motive which instigated the passage of the Act.

The Osage Nation and the Five Civilized Tribes established an early opposition to this allotment policy. In 1881, the Osage National Council adopted a Constitution of the Osage Nation which had a clause stating that the lands of the Osage were to remain common property until the National Council requested their allotment. The Osage voiced their opposition to the Dawes Act by petition delivered in 1884 by the Indian Agent Laban Miles. They tried to impress on Washington that the land was their home, purchased with their money and they chose to protect the communal ownership. As a result of the opposition by the Osage Nation and the Five Civilized Tribes an exemption from the Dawes Act and its amendments was obtained (Chapman, 1942 and Lawler, 1990). The Curtis Act of 1898 resulted in the allotment of the lands of the Five Civilized Tribes and only the Osage Tribe continued to resist allotment.

As the number of mixed blood Osage grew, their influence increased until they were able to force the full bloods to accept an invitation from the federal government to send a delegation to discuss allotment of the Osage homeland. Finally, on June 28, 1906, the Osage Allotment Act became a fact. In the process of negotiations it was settled that each enrolled member would get a selected homestead and the remaining acreage of the Osage Reservation would be equally divided among the tribe's members. The division was to take into account acres for farming, mineral and grazing lands per individual. The rights to oil, gas, coal or other minerals under the Osage homeland were not divided but held in common for twenty-five years. The reservation of the minerals could be extended and, in fact was later extended to perpetuity (Lawler, 1990).

Therefore, it can be seen that the Osage Allotment Act of 1906 was distinctly different from the Dawes (General Allotment) Act. The Osage Allotment Act did not allow the unallotted lands to be opened for settlement by non-Indians, but did in fact equally divide the property among the tribal members and it held the minerals separate from the land in common for all Osage. The Dawes Act gave only an allotment of a small homestead with its minerals to the Native American and opened the remaining lands to non-Indian settlers.

The significant difference between the Osage Allotment Act and the Dawes Act can be carried on important step further. The Act did not extinguish the Osage Reservation of Oklahoma. Case law supports the fact that despite allotment the lands which were formerly the Osage reservation are still Indian country. The United States Supreme Court in the criminal jurisdiction suit of United States v. Ramsey (271 U.S. 467, 1927) held that land which had been part of the Osage Reservation and is under the restricted allotment of a Native American that does have authorization to alienate it, is Indian land. This same basic premise was upheld in relation to public highways within Osage country in Townsend v. United States (265 F. 519, 8th Cir., 1920). The point of contention in DeCoteau v. District Court was whether or not the Lake Traverse Reservation had been terminated. The Supreme Court ruled that the intent of Congress must be clear to establish termination and this test was followed in Rosebud Sioux Tribe v. Kneip (430 U.S. 584, 1977). Thus, Pipestem and Rice have the following to say concerning the Osage Reservation:

> Under the present test expounded by the Supreme Court in DeCoteau and Kneip, there is no reason to believe that the Osage Reservation has been diminished or extinguished. Clearly all Osage allotments still restricted and all of the Osage villages, such as Grey Horse, continue to be Indian country (1978).

A final salient point is whether "water" is a "mineral" or not and the relationship this implies to the unique in common reservation of minerals from the Osage Allotment Act. Also, the fact of the principles of statutory construction as they are applied to Native Americans will be incorporated.

Water is not specifically addressed in the Act nor does it occur in the legislative history which lead to the Act, but in reserving oil, gas, coal and other minerals "covered by said lands" the reserved water rights were conveyed. The water which as a result of ordinary principles of statutory construction could be a "mineral" reserved to the Osage would be groundwater as it is "covered by said lands" (Lawler, 1990).

A mineral can be defined as a naturally occurring inorganic substance with a definite chemical composition and an ordered internal structure (Dana, 1969) or any class of substances occurring in nature of definite chemical composition and usually definite crystal structure (Random House College Dictionary, 1988) and "water" and mercury are defined as the only minerals that occur as liquids at ordinary temperatures (Webster's 2nd ed., 1958). Courts have treated water as a mineral in many rulings, most particularly groundwater, in a range of contexts. As stated in Corpus Juris

> Unless it appears that the term used in a more restricted sense, the term "mineral" had been held to embrace water, particularly subterranean water, irrespective of the character and quality of the salts and gases which may be in solution.

Therefore, the overall definition of a mineral is generally quite vague and encompasses numerous different substances. The courts have held that water is a mineral and if the term "mineral" is liberally construed to the benefit of Native Americans as is considered accepted normal practice by the principles of statutory construction, then water should be held within the Osage Nation's mineral reservation. If this is the case, then the federal reserve rights preclude control by western appropriative water law or any county/state agency (Lawler, 1990).

The Supreme Court ruled that "some portion of tribal waters essential for cultivation" were due to the non-Indian successors to allotted land in United States v. Powers (305 U.S. 527, 1939). The portion was limited to "farming and home making" uses. It would apply a fortiori to the individual allottees governed by the Osage Allotment Act of 1906, particularly as a result of the Act being much more explicitly interested in the protection of the communal mineral resources (Lawler, 1990).

The end result as stated by Lawler is, "Given the history and purpose of the Osage Allotment Act, the most reasonable construction is that the Act reserved the rights to all groundwater (as a mineral) in Osage County to the Osage Nation, plus any additional surface water appurtenant to the reservation (implied Winters rights) to develop the mineral and other non-agricultural resources of the Osage Reservation (i.e., of Osage County) and that portion of the water for cultivation of the practically irrigable acreage on lands owned by non-Indian successors to allottees which was not actually irrigated during the trust period or perfected by reasonable diligence afterwards."

CHAPTER VI

IMPLEMENTATION OF WATER RESOURCES MANAGEMENT STRATEGY

Introduction

The Bureau of Indian Affairs is the federal government's representative in its trust responsibility to Native Americans and the tribal governing bodies for the vested property rights of these peoples. This responsibility concerns land and minerals (to include water). In keeping with this trust responsibility, the Bureau has issued guidelines for management and protection of water resource which executes its duties in regard to Native American federal reserved water rights.

The program has legal support from Congress in the form of the Indian Reorganization Act of 1934, the Oklahoma Indian Welfare Act of 1936, the Snyder Act of 1924, the Self-Determination Act of 1972 and the Self-Governance Act. There are executive directives such as the 1980 Ten Year Plan and judicial decisions which also help derive the overall program policy (B.I.A. Print-out, 1991).

The 1980 Ten Year Plan is aimed at preparing the assertion and defense of Indian reserved water rights. This may be achieved by negotiations or litigation. A comprehensive plan must assess present as well as future water requirements.

The management and development of Native American water resources have not kept pace with the more rapidly progressing assertion of Indian water rights. As seen in Chapters IV and V, Native American water rights have a solid case law and legislative base but little is encountered in relation to the development or management of water resources (B.I.A. Print-out, 1991).

There are Integrated Resources Management Plans (IRMP's) which involve many other natural resources that, in turn, require water resource planning to succeed. Osage County does not have an IRMP in existence. Therefore, in creating a water resources management and development strategy, an integrated action with mineral resources consideration, hydroelectric power generation, interstate compacts restrictions, recreation and aesthetic as well as agricultural activities needs consideration (B.I.A. Print-out, 1991).

There are four categories which assist in plan formulation; these are delineated as follows:

1) considering problems, needs and demands in the area
2) identification and development of alternatives
3) comparison and contrast of alternatives, and
4) selection of those which are environmentally, technologically and economically suited to the preservation and enhancement of the water resources on Native American lands

Their intentions are to derive the maximum benefit for the trust lands while insuring the protection of areas of historical, spiritual or archaeological significance (B.I.A. Print-out, 1991).

B.I.A. Policy Guidelines

Guideline One

The first guideline to be considered must be the perspective on Indian water rights. The overall Native American population of Osage County has a right to considerable quantities of surface water and groundwater under the *Winters* Doctrine and other case laws as demonstrated in Chapter V. These rights survived the Osage Allotment Act of 1906 and remained under Osage Nation control based on the fact that water can be interpreted to be a mineral and all minerals were held in common for the tribe in perpetuity. The non-Indians who succeeded the original Native American allottees are given a "portion" of the water for domestic and farming uses while the rest stays in Indian hands. Also, as the reservation was never officially terminated or diminished in the language of any act or law Osage County remains Indian country. The Native American rights to these waters are not subject to beneficial use restrictions of state regulations, state water policy, are not lost by non-use and have a future needs component which gives access to undefined quantities of water arising from change in uses or new technologies (see Chapter V).

Guideline Two

The second guideline for consideration is the nature of the county, its population and their needs. Osage County is predominantly a rural county of about 1.5 million acres and a population of less than 42,000 people. The few small towns contain 23,000 residents and the remaining 19,000 are widely scattered across the rest of the expansive county.

There are around 6,000 people identified in the 1990 census as Native Americans residing in the confines of the county. As a result of the Osage tradition of holding livestock as a sign of wealth and prestige as well as treaty intentions to develop agriculture as an "art of civilization", there is a strong attachment to livestock grazing and agriculture within the Native American as well as non-Indian population. Little light or heavy industry is found in Osage County except those related to oil and gas (see Chapters III and IV).

Guideline Three

The third guideline to be dealt with is the existing water uses, supply and pollution problems and current needs for the county. At the present time the primary water uses in Osage County are municipal and rural water supplies, limited industrial applications, oil and gas production including secondary recovery and agricultural and stock grazing. These uses consume perhaps 60,000 to 70,000 acre feet of water per year as opposed to the fact that in excess of 30,000,000 acre feet of surface water and groundwater could be available. Whether all of it is economically or technologically accessible would require future inquiry (see Chapters III and IV). Problems of point and non-point source pollution from oil and gas production, natural pollution sources, industrial activities, urban runoff, waste water treatment, septic tanks, underground storage tanks, animal waste and agricultural chemicals could impact these quantities by lowering qualities to levels where the waters (either surface or ground) have no safe utilizations (see Chapter III).

Guideline Four

The fourth guideline encompasses land and water resources. This is one of the guidelines which will be addressed by IDRISI in the following section. It covers the methodology to acquire, study, analyze and interpret data concerning the quality and quantity of the resources as well as how to protect them.

Guideline Five

The fifth guideline is concerned with demands and needs of present conditions as well as future predictions. Technologically, legally and economically feasible alternatives which are consistent with tribal necessities, goals and objectives must be projected. This guideline will also be covered by IDRISI in the following section.

Guideline Six

The next guideline is number six and it incorporates public participation. The citizens must be involved in these proceeding by being given all the existing information along with its interpretations. If needed, educational sessions, seminars and explanatory meeting must be conducted to inform the population about the on-going attempts to generate an integrated comprehensive strategy. In doing this, a knowledgeable public will be able to contribute significantly in the development of a feasible, workable plan will be willing to live with the resulting outcome. It will be their decision and they will make it work for the protection and management of the resources.

Guideline Seven

The last guideline is formulation of the final or recommended strategy. This is the culmination of all the preceding detailed study, discussion, work and effort. A comprehensive water, mineral and related land resources management strategy should be the end product. It must have the Native Americans leadership and cooperation to be successful, for without it, there will be resentment, anger, distrust and non-support. A strategy met with these negative energies, no matter how well conceived, is condemned to failure.

IDRISI

The geographic information system, IDRISI, can most effectively be applied to guidelines four and five. Resource and constraint maps can be developed to delineate valuable commodities or activities and the potential threat to their use by pollution or loss from unwise practices.

Resources

The fourth guideline encompasses land and water resources which are the first criteria addressable by the IDRISI developed data. Figure 3 is Osage Land Use and gives a representation of the land uses found in Osage County. This data was derived from multispectral scanning system data and was processed through ERDAS 7.5 version software which yielded an image that was georeferenced, rectified, underwent a supervised classification, was reclassified and then ground truthed to develop an output which was exported to IDRISI. The end result was an image which is too detailed with categories for native and tame pastures, deep and shallow water, urban/inert areas, crops, bare ground, wetlands and trees/vegetation. To be of more use on a regional basis it would be necessary to look at large scale trends in the data.

Figure 4 shows a county-wide distribution of DRASTIC values which were developed along lines outlined extensively in the Methodology section of Chapter I. The DRASTIC ratings were developed with a strong bias toward

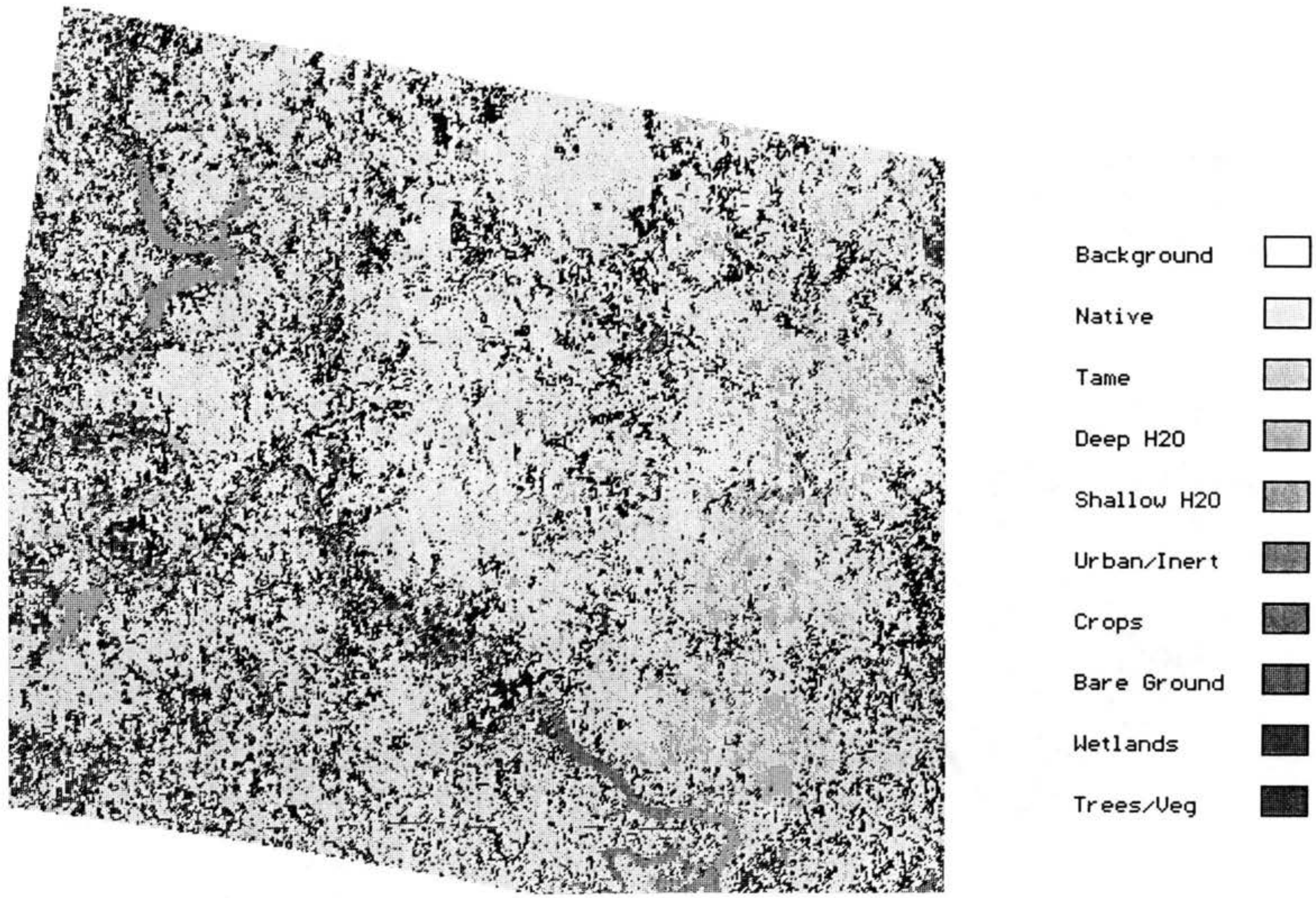


Figure 3 Osage Land Use

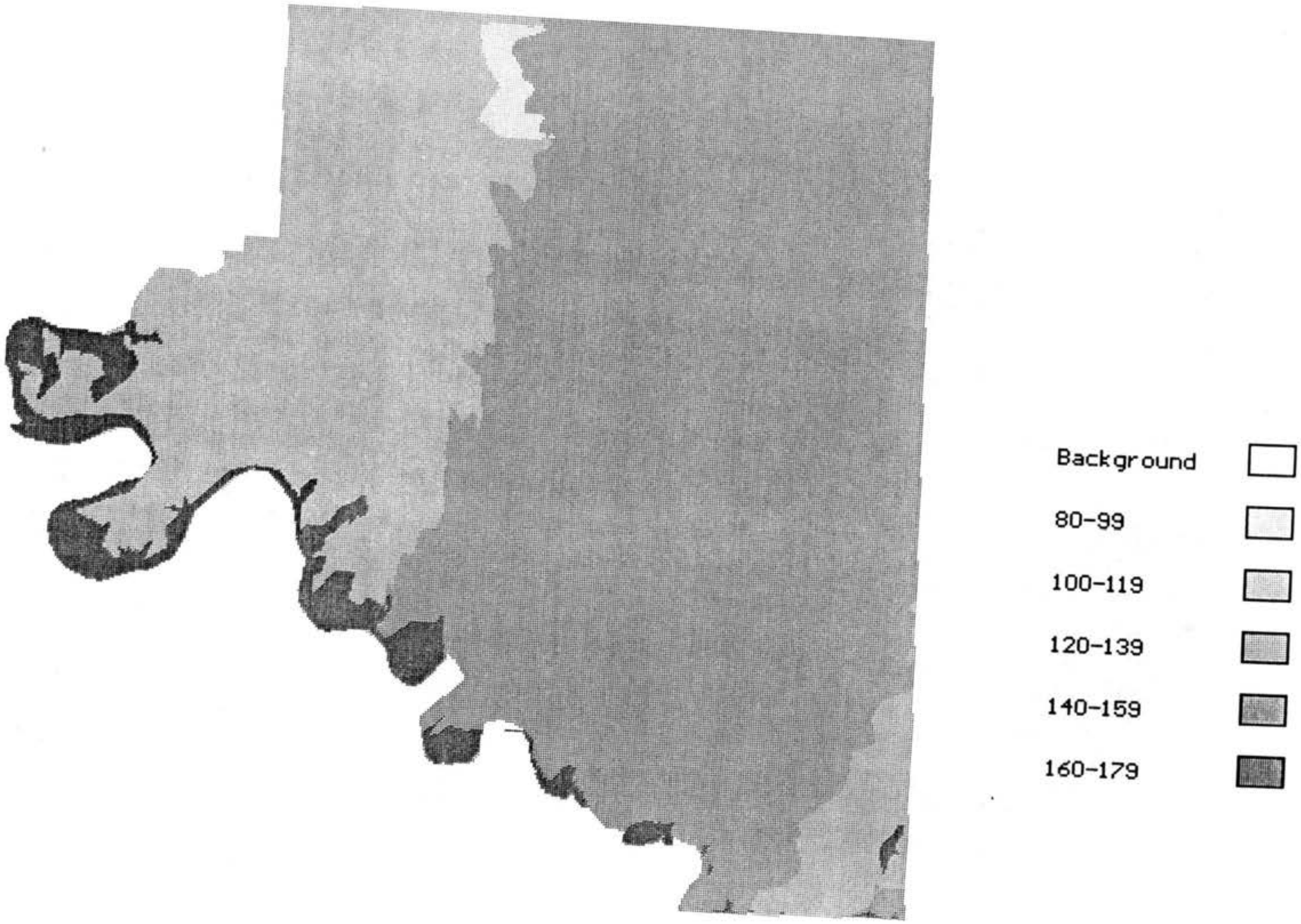


Figure 4 Osage DRASTIC Values

(Modified from French and VanSchaik)

aquifer media and drainage basin control and are derived from work by French and VanSchaik. The data was digitized in ERDAS 7.5 and exported to IDRISI for manipulation. The DRASTIC values are subdivided into five classes with the lowest number representing the least potential for pollution and conversely the highest number being most susceptible to polluting influences. These values serve as a mechanism for constraining development of uses which could pollute in highly susceptible locales resulting in damage to aquifers or agricultural lands.

Oil and Gas Fields in Figure 5 delineates the areas of Osage County where there is oil, oil and gas, gas only or no activity in terms of hydrocarbon production. The significant aspect of this image is the large amount of area impacted by hydrocarbon production and the fact that there are only four classes of data. The value of this data is that as hydrocarbon production is a source of pollution it would be feasible to gauge potential hazards to fresh water aquifers or urban or agricultural areas across the county.

Figure 6 represents the soil irrigability aspect for Osage County. It identifies the fact that only a small portion of the county is truly not irrigable which would allow consideration of large scale agricultural expansion (either irrigated or non-irrigated) as well as possible conversion of the dryland pasture to irrigated alfalfa or hay grasses for feed.

Figure 5 Osage Oil and Gas Fields

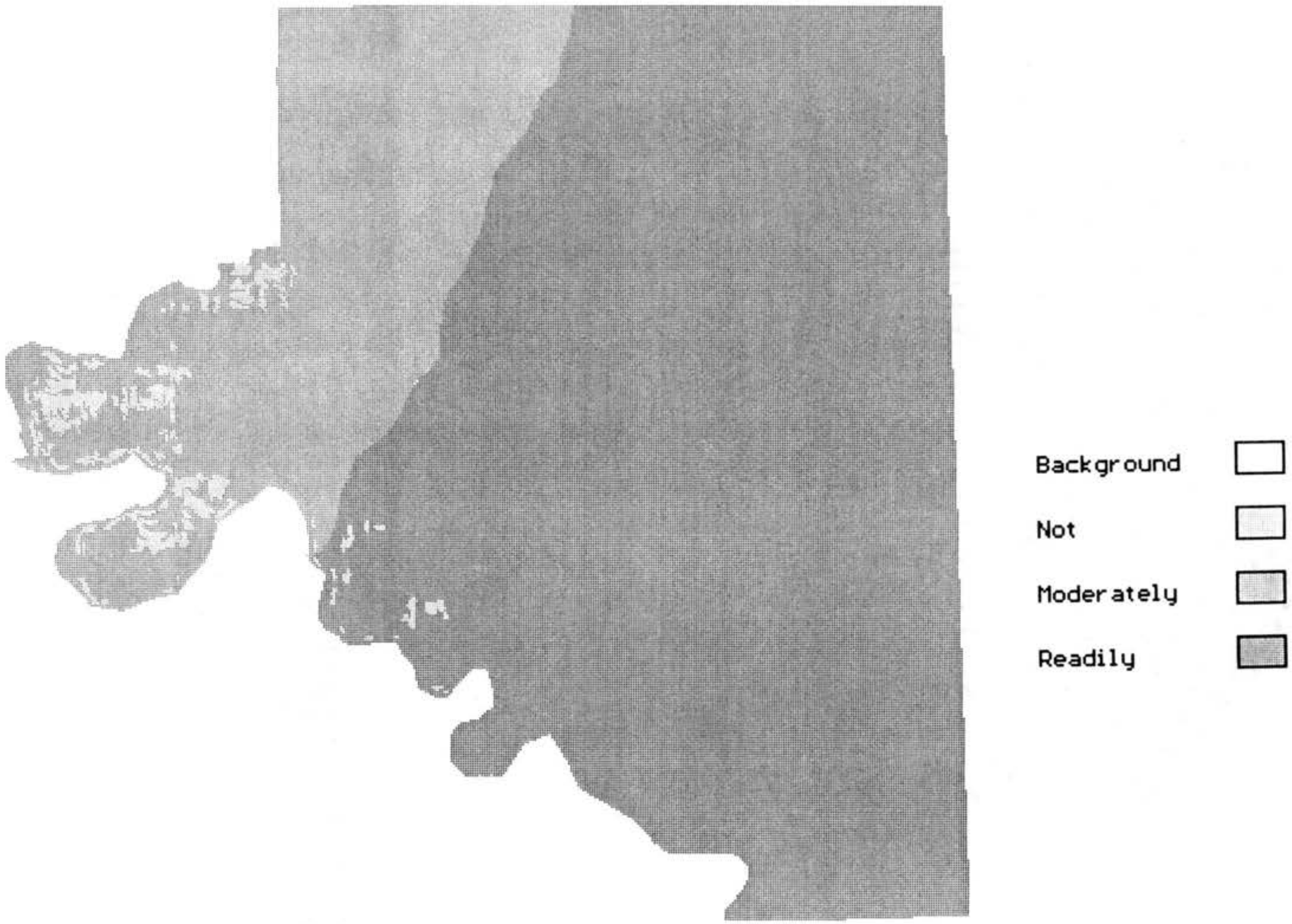


Figure 6 Osage Soil Irrigability

Osage Aquifer Areas in Figure 7 covers the areal distribution of the various aquifers and the different percentages in Osage County. These illustrated aquifers are either bedrock (whether major or minor) and unconsolidated. This data was derived from reclassification of the outcrop geology typical of the county and lends itself to a clearer interpretation than the straight geologic arrangement when put into an overlay.

These five figures delineate many of the major land resource areas and also pinpoint distribution of surface water and groundwater resources. The next step in process was to overlay these images to generate alternatives which is the content of the next guideline.

<u>Overlays</u>

The fifth guideline, therefore, is a projection of future demands and alternatives for improvement. This component makes use of IDRISI's overlay function which allows two attributes to be stacked upon each other to give a composite image from which an interpretation may be made relative to one another. There is a capability of overlaying composite images, but the resultant figures are not useable. The study's intention was one of broad generality so the following overlays are being considered in a broad brush context. The overlays will compare soil irrigability, oil and gas, aquifers and DRASTIC. Land use proved to be an ineffective attribute at this level due to too fine a

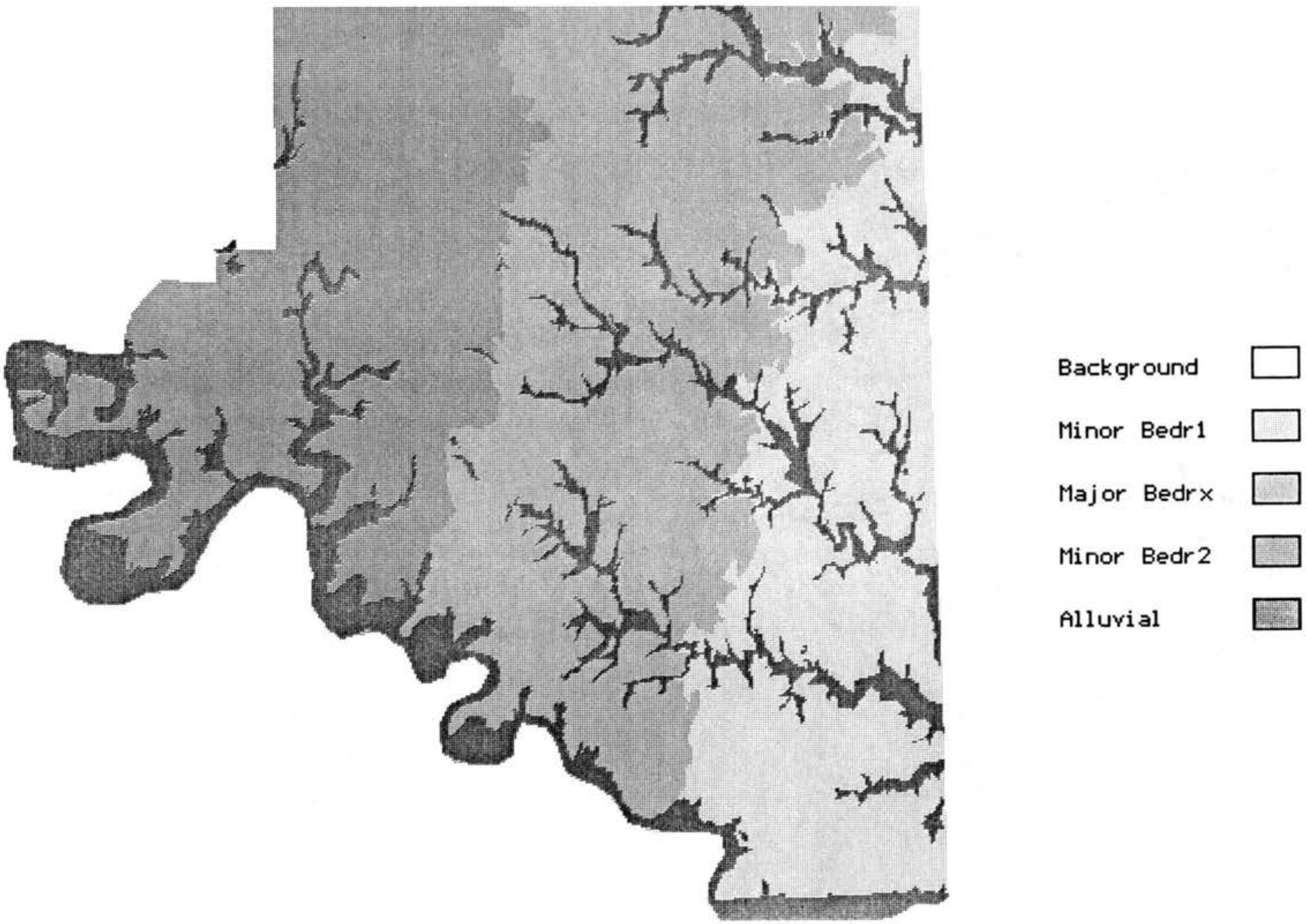


Figure 7 Osage Aquifer Areas

level of detail and will be discussed in more detail later. These overlays will allow an interpretation to use and development of land and water resources.

Looking at the DRASTIC/Aquifer overlay which is Figure 8, several important observations can be made. The central area of the county underlain by the major bedrock aquifer system has a relatively high DRASTIC rating of 120-139. The extensive alluvial aquifers scattered across the county also have the two highest DRASTIC ratings. These aquifers are valuable sources of water yet are relatively susceptible to pollution as indicated by the DRASTIC indices. On the other hand, the western and eastern thirds are underlain by minor bedrock aquifers which have lower DRASTIC values. These low yielding aquifers are also less susceptible to pollution.

Considering Figure 9 covering soil irrigability overlain on the aquifers, it can be noted that a significant portion of the county containing readily irrigable soils is also underlain by the major bedrock aquifer or the alluvial aquifers. Figure 10 is concerned with soil irrigability and DRASTIC index. These criteria delineate the fact that the readily irrigable soils represent a valuable resource which could be developed to benefit the Osage Nation. The presence of aquifers which are moderately to highly susceptible to pollution represent a valuable resource and demonstrate that caution must be exercised in this development and utilization. Excessive

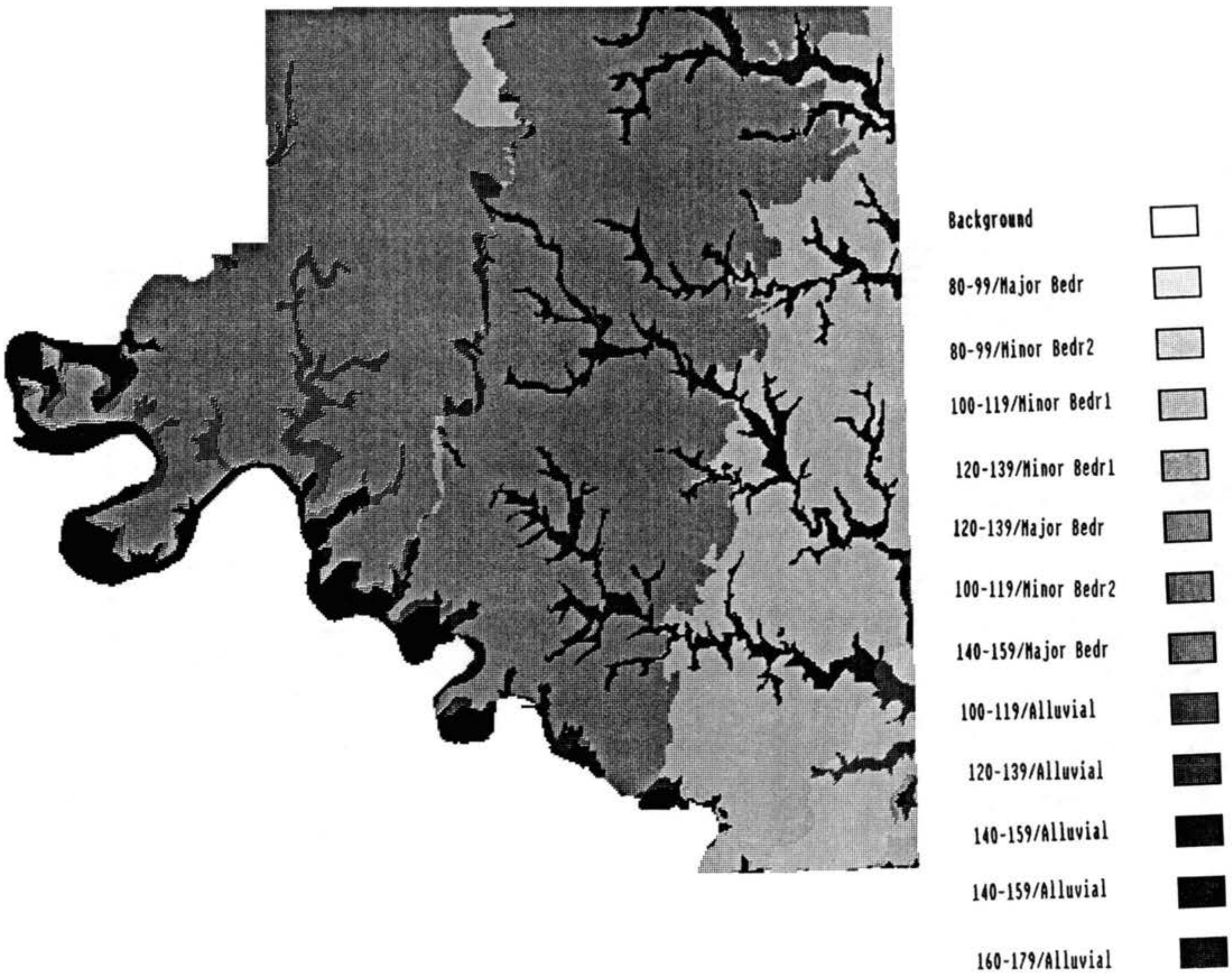


Figure 8 DRASTIC/Aquifers Overlay

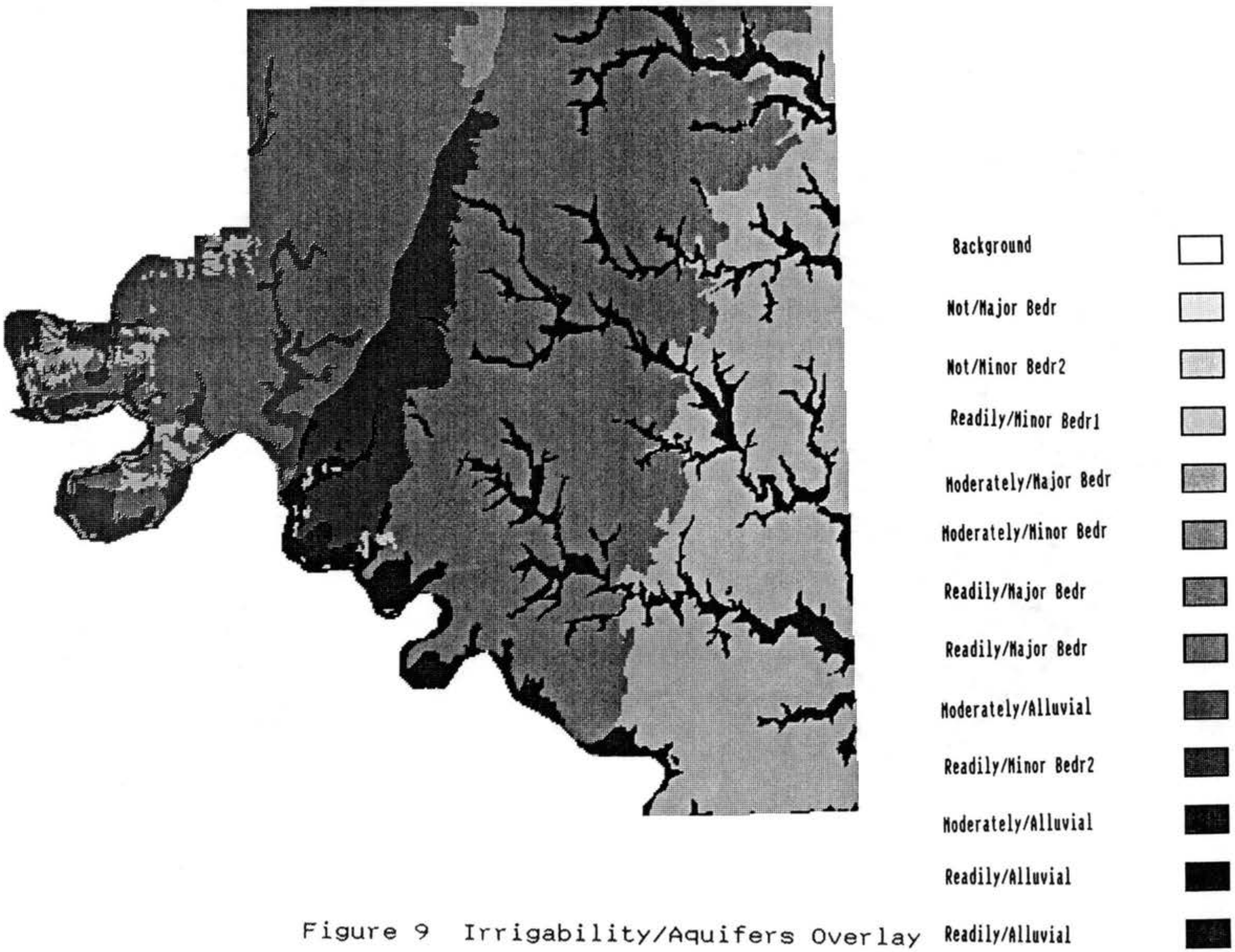


Figure 9 Irrigability/Aquifers Overlay

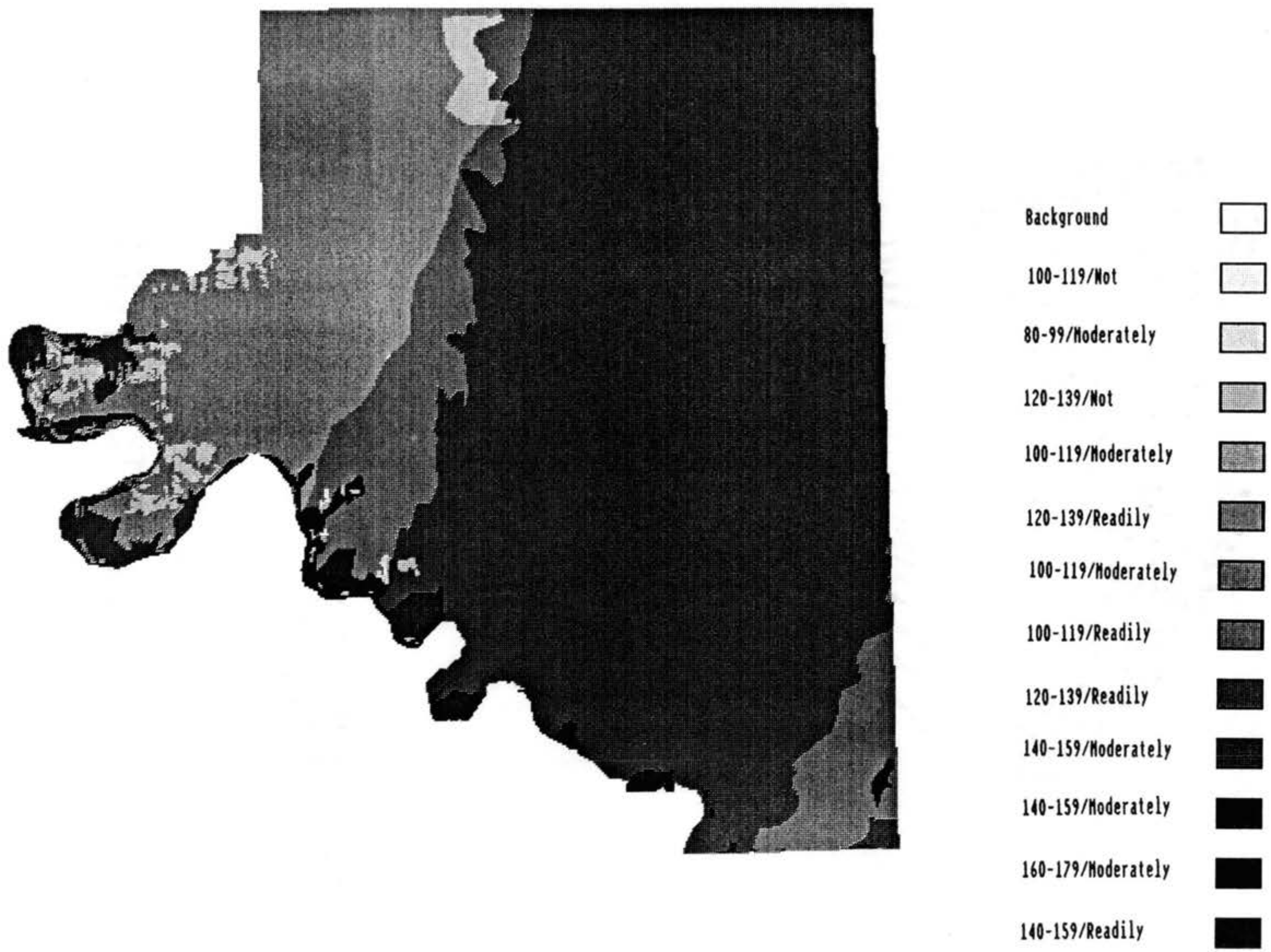


Figure 10 Irrigability/DRASTIC Overlay

use of herbicides or pesticides on the crops in the irrigable soils could lead to degradation of water quality in the major bedrock and alluvial aquifers. The decreased quality could result in the inability to exploit the readily or moderately irrigable soils which would result in a negative economic impact for the residents of Osage County as well as elsewhere in the state where people depend on these waters for their supplies.

An additional constraint for any development is oil and gas production in the county. Figures 11 and 12 present evidence that a large amount of hydrocarbon production activity takes place over these aquifers and again are highly susceptible to pollution. These indicators necessitate more careful planning and control if development is to proceed and the valuable water resource protected while continuing to extract the economically necessary oil and gas.

Finally, Figure 13 demonstrates the fact that the readily irrigable soils contain large areas of oil and gas production. This could impact crop activity by brine contamination forcing curtailment of these lands for agricultural or grazing activities that could lead to significant economic losses.

An integrated interpretation then, implies the necessity to establish controls on oil and gas production to limit pollution from this source damaging the economic gain which might be derived from the large area of readily

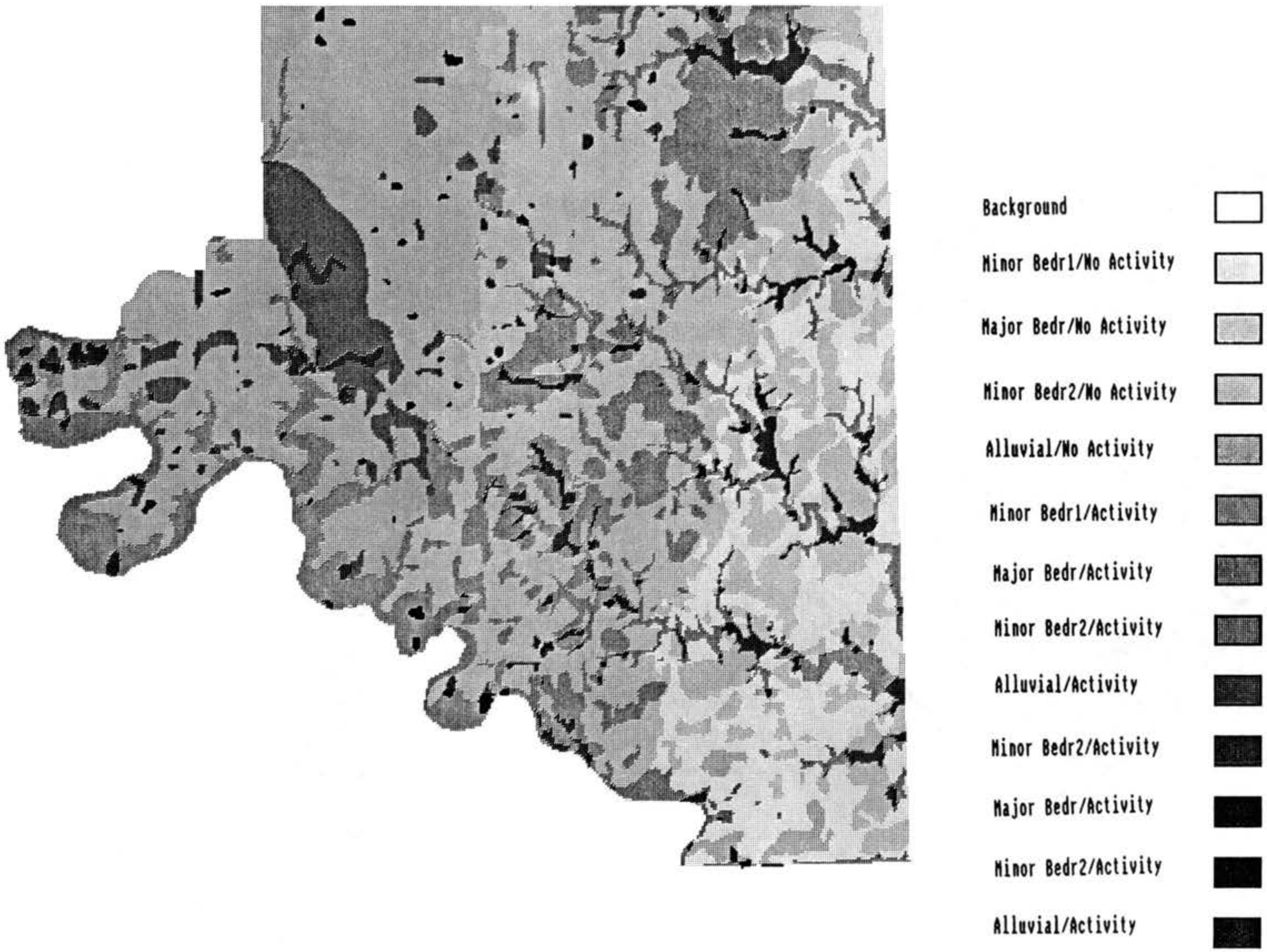


Figure 11 Oil and Gas/Aquifers Overlay

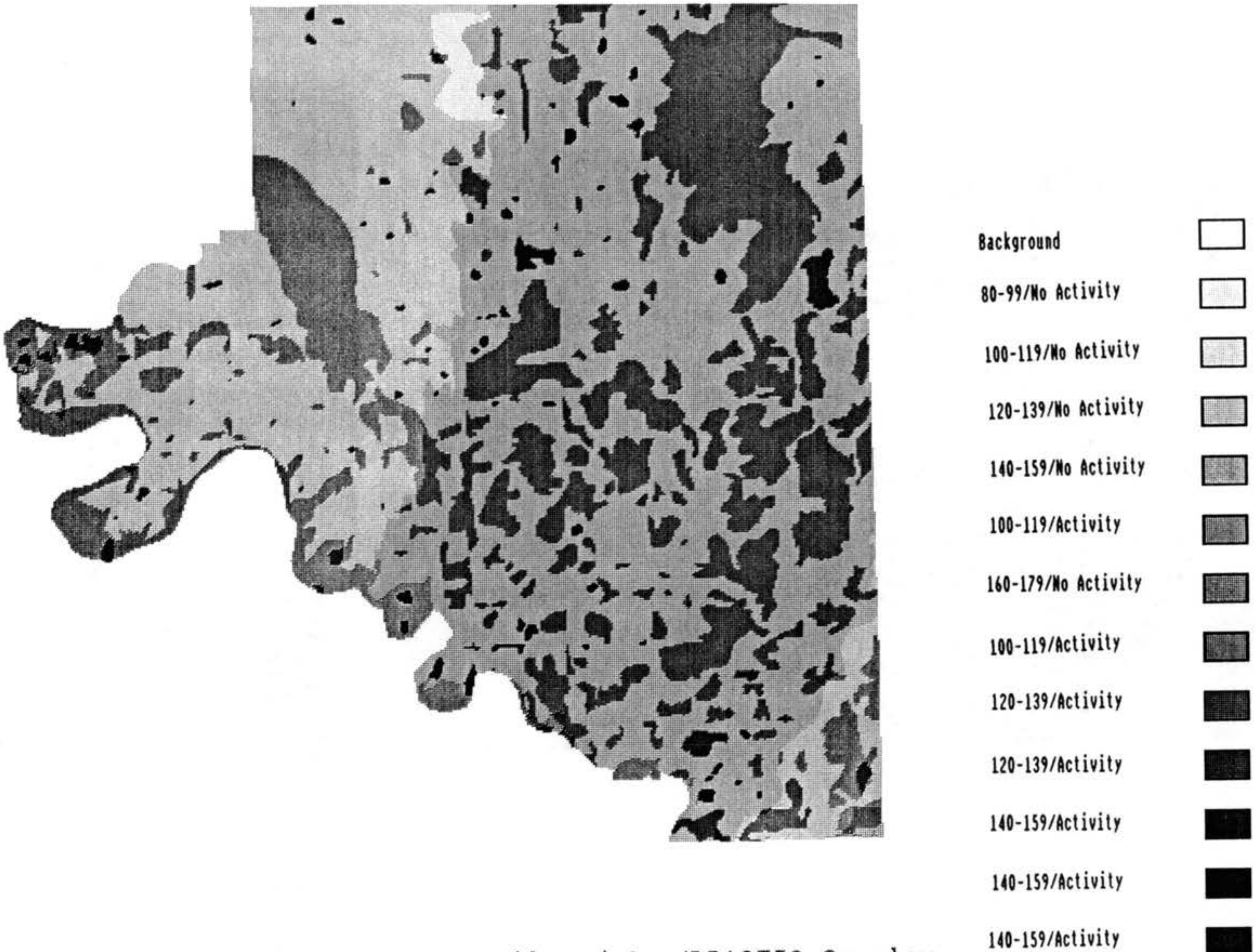


Figure 12 Oil and Gas/DRASTIC Overlay

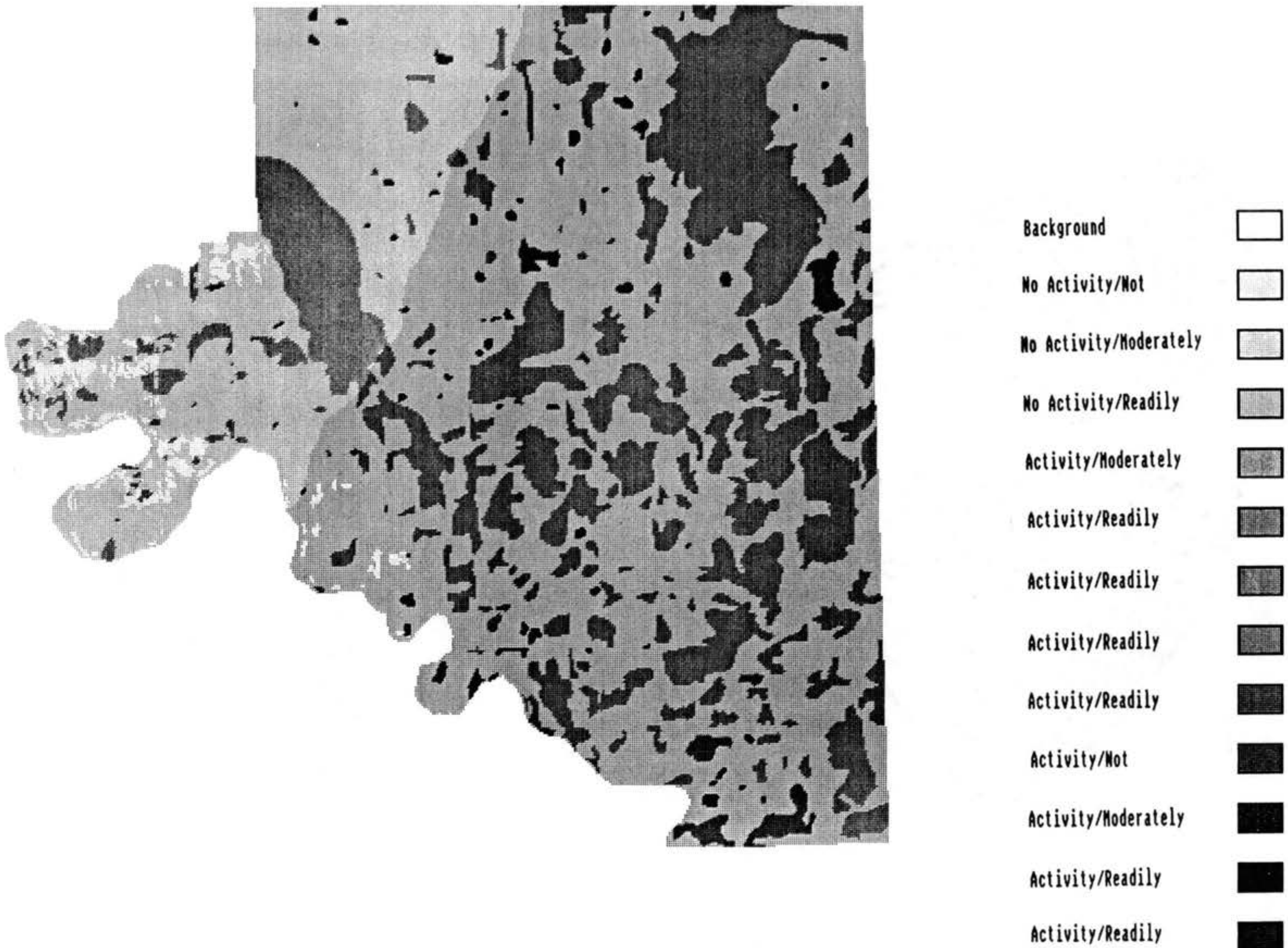


Figure 13 Oil and Gas/Irrigability Overlay

irrigable soils that could be irrigated by the significant water resources. These aquifers are also relatively to highly susceptible to pollution from hydrocarbon recovery as well as agricultural chemicals or animal wastes from cropping/grazing endeavors on the irrigable soils.

The land use and water resource decisions must be interlinked. The impact of each segment must be weighed against its economic value and the overall gain from the numerous interconnected possibilities.

Quantification of Osage Nation Water Rights

Practically Irrigable Acreage

The next issue which arises is the quantification of Native American water rights. The only currently acceptable methodology for quantification of Native American water rights in the eyes of most of the courts in the United States is Practically Irrigable Acreage (PIA). The rationale for this approach is that the reservations were established to function on an economy predicated on irrigated agriculture (Lawler, 1990 and Harvey, 1990).

There are many problems associated with the PIA technique. First, it is extremely vague and subjective with no set method for arriving at the quantities necessary for irrigating the Indian land. Second, it is basically a cost-benefit or feasibility analysis dealing with the amount of water needed to be applied in combination with the cost of getting the water to the crops, the suitability of the land for agriculture (in other words, the crop yield) and the value of the crops that are sold. This is self-defeating when irrigated agriculture returns a low value for water used in comparison to other high value uses such as manufacturing. Third, it defeats the idea of achieving economic independence and raising the standard of living by restricting the Native American water quantities to irrigated agriculture on lands which were and are only marginally suited to cropped agriculture (Harvey, 1990).

The essential criteria for establishing Practically Irrigable Acreage then, is a cost-benefit analysis which is not an exact science. The analysis which yields a value equal to or greater than one would be economically feasible and anything less would not be economical. Included in the scope of a cost-benefit analysis are many subjective choices which are important to the outcome of the analysis. Some of these criteria are price estimation for primary or secondary benefits, crop selection, and appropriate discount rates (Lawler, 1990). Embedded in the concept of cost-benefit analysis is the important distinction between economic feasibility and financial feasibility, especially as the cost-benefit methodology addresses Native American reservations. The distinction is as follows:

1) Financial feasibility contains the consideration of repayment

2) Economic feasibility "is independent of repayment consideration"

The idea is that the Native American considerations would fall under the economic feasibility criterion, implying liberal application of the previously mentioned principle of resolving doubt in the favor of the Indians. Therefore, the "practicability" of resource utilization and development in Osage County can be looked at in this manner (Lawler, 1990). The general concept is to consider higher value uses such as recreation, services or manufacturing to provide economic credibility and diversification for the tribe (Harvey, 1990), not low value agriculture. Perhaps, consideration for which crop or crops would be most significant should be the guiding principle and up the value of agriculture for the Osage.

Soil Irrigability

A different approach was to look at soil irrigability as it was applicable to the twelve soil associations encountered in Osage County. Within these twelve soil associations there are twenty-seven soil series. The definition of a soil's irrigability is based on its ability to take in water. The criteria for a soil being irrigable is that it must be able to intake .2 inches per hour (Schwab, 1990). The soils were evaluated for their typical thickness and extent of slope. Very thin or steeply sloping soils did not receive the same consideration. Using these parameters Table 24 was created for Osage County. This table shows that there are two soil

TABLE 24

SOIL IRRIGABILITY

Soil	Infiltration Rate (Inches/hour)	Irrigability
Roebuck	<.06	not irrigable
Pawhuska	<.06	not irrigable
Wyona	.06-.2	moderately irrigable
Grainola	.06-.2	moderately irrigable
Foraker	.06-.2	moderately irrigable
Dennis	.06-.2	moderately irrigable
Steedman	.06-.2	moderately irrigable
Wolco	.06-.2	moderately irrigable
Apperson	.06-.2	moderately irrigable
Dwight	.06-.2	moderately irrigable
Summit	.06-.2	moderately irrigable
Niotaze	.06-.2	moderately irrigable
Verdigris	.6-2.0	readily irrigable
Mason	.6-2.0	readily irrigable
Kiomatia	.6-2.0	readily irrigable
Parsons	.6-2.0	readily irrigable
Bates	.6-2.0	readily irrigable
Coweta	.6-2.0	readily irrigable
Shidler	.6-2.0	readily irrigable
Stoneburg	.6-2.0	readily irrigable
Corbin	.6-2.0	readily irrigable
Norge	.6-2.0	readily irrigable
Vanoss	.6-2.0	readily irrigable
Darnell	2 - 6	readily irrigable
Dougherty	2 - 6	readily irrigable
Stephensville	2 - 6	readily irrigable
Eufaula	6 - 20	readily irrigable

(SCS Soil Survey of Osage County, Oklahoma 1979) series which are not irrigable (much less than .2 inches/ hour) or 7.4% of the soils in the county. There are ten soil series which are in the category of moderately irrigable (less than or equal to .2 inches/hour) as their intake values range up to the value of .2 inches per hour and they represent 37% of the county's soil series. Finally, there are fifteen soil series which are readily irrigable (greater than .2 inches/hour) and this represents 55.6% of the county soil series (Bourlier, et.al., 1979).

There are only five soil series which are not capable of raising crops within Osage County. The two soils which are not irrigable are among them. These soils are found in the southwest third of the county and represent steep upland to upland silt loams to silty clay loams. The remaining soil series can be cultivated for one or more crops. In fact, Table 22 on Important Farmlands in Osage County shows that there are 933,267 acres of farmland of local value. If a crop such as alfalfa or a hay type grass were to be grown, this would be advantageous for the significant livestock grazing industry. There are twenty-one of the soils series which can grow either alfalfa (fourteen series) or grass for hay (seven series) which is 77.8% of the county's soil series (Bourlier, et.al., 1979).

These figures show that it could be feasible to grow either alfalfa or hay grasses on much of the 933,000 acres in Osage County which are considered to be locally important. Referring to Table 15 for the crop water needs, it is noted that alfalfa requires 3.423 feet of water per acre per season and other hay requires 2.5 feet of water per acre per season. Irrespective of whether it is economically feasible to get suitable irrigation water in adequate quantities from surface water or groundwater sources across the county, the water demand for the 51.9% of the county where one might grow alfalfa (484,000 acres) would be approximately 1,656,000 acre feet per year and the 25.9% of the county suitable for hay grasses alone (241,000 acres) would be around 604,000 acre feet per year which takes into consideration areas with too thin soil or too steep slopes. The total water volume would be about 2,261,000 acre feet per year considering only two crops on the available acreage.

These figures put into perspective the potential water demand for this one use. The irrigable lands in Osage County, either Native American or non-Indian, represent a poorly utilized resource, particularly as there is adequate surface water and groundwater supplies within the confines of the county to meet a vastly greater demand from all possible sources of consumption.

Land Capability

An alternative mechanism which could be supportable is an adoption of the land capabilities classification. The land capability classification was developed by the U.S. Department of Agriculture and is in use with the Soil

Conservation Service. This classification scheme has eight land capability classes going from Class I as least susceptible to erosion through Class VIII which is most susceptible to erosion. The principal strength of this system is its comparison between intensity of use and the erosion susceptibility of the soils (Brady, 1990). The subclasses are by the letters e (erosion) or c (climatic limitations) (Brady, 1990).

The classes are as follows:

1) Class I - soils with few limitations and can be cropped extensively, put to use as rangeland, pasture woodlands or as wildlife habitat. These are deep, well drained fertile soils which are nearly level.

2) Class II - soils with some limitations that restrict choice of crops or mandate moderate conservation practices. They must be less extensively cropped.

3) Class III - soils with severe limitations which reduce choices of crops and/or require special practices to avoid erosion. Crops such as legumes and grasses would be suitable for these soils.

4) Class IV - soils can be used for crops, but have severe limitations. These require careful management but can be used for close-growing crops.

5) Class V - soils are not suited for crops due to other reasons besides erosion. Some of these limitations can include frequent flooding, stony or rocky soils, ponded areas or too short a growing season.

6) Class VI - Soils are extremely limited; which would be pasture or range, woodlands or wildlife habitat.

7) Class VII - soils are severely restricted and are not really suited to grazing, woodlands or wildlife habitat.

8) Class VIII - Soils are not useful for any commercial production of crops. They may serve for

recreation, wildlife habitat, water supply or various aesthetic purposes.

The Classes I through III are most suitable for regular cultivation while Class IV is marginal and Classes V through VIII are not generally felt to be suited to normal cropping practices, but should be pasture, rangeland or wildlife habitat (Brady, 1990).

From the foregoing discussion, it may be determined that the soils in Osage County which fall in land capability Classes I, II, and III are adequate for any crop and Class IV is able to be utilized for crops such as hay grasses or alfalfa. There are seventy mapping units in the county and these have been condensed to form Table 25 which illustrates the number of acres and total percentages in Classes I through III, Class IV and Class V.

Close examination of Table 25 reveals that Classes I through III contain over 274,000 acres which is 18.5 percent of the soils in the county. If Class IV is added, the acreage rises to nearly 506,000 and represents 34.3 percent of the soils. There is a possibility that other acreage could be actively cultivated for hay grasses and alfalfa if consideration were given to some of the Class VI through Class VIII lands which have slopes of one to three or four percent. These classes contain in excess of 600,000 additional acres, some of which could potentially be amenable to raising alfalfa and/or hay grasses.

These values demonstrate that if all the acreage were planted with alfalfa and irrigated, the water demand would

TABLE 25

LAND CAPABILITY ACREAGE AND

PERCENTAGES IN OSAGE COUNTY

Class	Acreage	Percentage
Class I	33,351	2.3
Class II	141,624	9.3
Class III	99,860	6.9
Class IV	231,075	15.8
Class V	60,335	4.1
Class VI	421,428	28.6
Class VII	464,108	31.4
Class VIII	0	0

(Bourlier, et.al., 1979)

be around 1,730,000 acre feet. This technique gives us a second possible quantification and helps establish a range of amounts which could be arrived at more objectively than in a cost-benefit analysis. It would appear that at least approximately 509,000 to at most about 604,000 acres could be used for irrigated alfalfa and hay grass cultivation. These activities could potentially consume between 1,730,000 and 2,261,000 acre feet of water per year.

The infrastructure for extensive irrigation and the money or political power to force its construction do not exist in Osage County. The likelihood of a Central Valley Project or Central Arizona Project is nonexistent. The dollar volume for the potential crops is very low and this economically depressed area, that is so thinly populated, has absolutely no chance of building the needed canals, transfer pumping stations and other massive public works necessary for large scale water delivery and irrigation projects. The funds for such a massive project do not exist at the state or federal level.

Water Management Strategy

The strategy for the county must control and manage numerous possibly conflicting demands for the surface water and groundwater resources. First priority, in terms of the economic health of the region, is oil and gas production areas and the handling and disposal of the produced brine water as well as the hydrocarbon. There must be consideration given for the future needs of treatable water which will eventually be required in the secondary recovery of these valuable resources. Also necessary is insuring that there is no degradation of the overall water quantities and water quality as a result of this activity. This would mean an adequate staff of inspectors and field personnel which could oversee these efforts, enforce existing rules and regulations and sample all areas on a continuous, revolving basis to insure compliance is maintained. If violations are detected they must be dealt with in a succinct and expeditious manner to rectify the errors and avoid further damage. The damaged or impacted areas must receive immediate attention aimed at remediating the problem and returning the waters to a pre-impact state if economically feasible.

The second largest priority for the county is the effects of agriculture and animal grazing on water quantity and quality. The county's agricultural base could easily stand a significant increase in the numbers of acres of all crops grown and the numbers of animals grazed within the confines of the county. This increase is justifiable in terms of land available as well as the quality and quantity of water to support the increase. To safeguard the county's water resources, control would have to be exercised on the type and quantity of agricultural chemicals such as pesticides, herbicides and fertilizers. The location of feedlots, packing houses, dairies and other animal concentrations would need monitoring to prevent nitrate/nitrite accumulations that lead to lowering of water quality and quantity safe for human or animal consumption. The mechanisms are in place at the federal level for the protection and monitoring of these activities and need to be routinely and conscientiously enforced.

Third in priority is developing a conservation re-use and recycling mentality for the urban areas as well as the light and heavy industry located in Osage County. The urban areas can be responsible for a large number of pollutants as runoff from storm drainage as well as from underground or above ground storage tanks. The tanks are currently subject to regulations and control as are the municipal waste water treatment facilities, but the other aspects of the urban runoff are generally uncontrolled. The implementation of a strong and effective recycling and re-use program containing positive re-enforcement and inducements as well as stringent penalties for violations could stem this point and non-point source of dangerous pollutants from degrading county water quality which would affect the quantities available for human use or transfer from the area of origin if the foreseeable future needs are being met in the county.

The final component would be to insure that the capability of Osage County's reservoirs and lakes to store adequate supplies of water of acceptable quality for foreseeable future needs, interbasin transfer, lease or sale of excess and surplus waters, or water for the generation of hydroelectric power would be undiminished. There were plans for three Corps of Engineers lakes which should be revived and upgraded to include hydroelectricity as a segment of their design. This less expensive source of power could be used to induce businesses to relocate within the county and the lakes, reservoirs and streams could provide adequate water supplies for manufacturing processes.

The water resources management strategy for Osage County would need to take into account:

1) the oil and gas production and pollution effect both in terms of quantities and qualities of surface water and groundwater

2) the cropping and livestock needs and effects on the overall components of quantity and quality

3) the effects of urban runoff, municipal waste water treatment demands and above ground and underground storage tanks

4) light and heavy industrial requirement for the manufacturing processes as well as potential pollutant outputs

5) the capability and capacity of the area reservoirs and lakes to store the waters carried by the rivers and creeks of the regions beyond those quantities under interstate compact control, and

6) an adequate program of development and enforcement of technological innovation and regulatory safeguards to protect and improve water quantity and quality which are insured by a thorough monitoring, sampling and analysis scheme handled on a regular basis.

CHAPTER VII

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

Summary

The study was conducted on Osage County which is located in north-central Oklahoma. It is the largest county in the state with about 1.5 million acres but has less than 42,000 inhabitants. There are few industrial activities except oil and gas exploration and production and the only other significant income is based on agriculture and livestock grazing.

Across its slightly dipping Pennsylvanian-Permian sandstones, shales, and limestones flow numerous creeks and rivers. The Arkansas and Caney Rivers flow along the edges of the county and six major creeks drain into these rivers from the interior of the county. There are five Corps of Engineers lakes located partially or totally within Osage County and give a large storage capacity of 1,359,000 acre feet for flood control, recreation, water supply and hydroelectric power generation. Seven municipal and one private lake in excess of 1,000 acre feet with a storage capacity of 43,895 acre feet are maintained as water supplies and recreational areas. These surface waters are an extensive, valuable, quality resource.

The primary activity of an economic nature in the county is oil and gas production. There are about 17,420 producing oil and gas wells in over 240 fields across Osage County. The revenue from these wells goes to the Osage Nation as they hold all the mineral rights in the county.

Groundwater can be derived from eight minor bedrock, two major bedrock and two unconsolidated aquifers. The minor bedrock aquifers are capable of producing less than twenty-five gallons per minute while the major bedrock aquifers yield large quantities of good water as do the unconfined aquifers. The two major bedrock aquifers are the Vamoosa Group and the Ada Group which are often considered a single system.

A preliminary assessment of water quantities in Osage County indicates that in excess of 30,000,000 acre feet of surface water and groundwater resource might exist within all the aquifers, lakes and streams. The demands existing currently in the county come to approximately 70,000 acre feet per year for all currently identified utilizations.

Interstate compacts affect the water resources by either limiting new storage capacity (the 1966 Kansas-Oklahoma agreement) or apportionment of the waters (the 1973 Oklahoma-Arkansas agreement). These agreements originated after the federal reserve rights were established for the Osage Nation, so do not affect them, but they do somewhat regulate the quantities in the county.

Currently, only one dam generates hydroelectricity. That is Keystone Lake on the south edge of the county. There were three proposed lakes which were approved but never built, Candy, Sand and Shidler Lakes. Candy Lake had hydroelectricity in its design criteria and it is feasible Sand and Shidler Lakes could incorporate it as well.

Water quality in Osage County tends to be good. There is some problem with naturally occurring brine/chloride elevating these levels in the surface water and groundwater. The quality can be impacted by oil and gas production with its brine waters which are a source of bromide and chlorides as well as hydrocarbons and in this county the impact could be severe. Other man-made sources of water degradation are septic systems, underground and above ground storage tanks, urban runoff, municipal waste water treatment plants, animal waste, agricultural chemicals as well as seven active and two inactive landfills.

An understanding of water law is absolutely necessary to develop any strategy in relation to water resources development or management. The definition of water in a legal context takes into account its location. There is diffuse surface water that does not flow in a "definite channel"; there is stream water which exists in a "definite, natural channel"; and there is groundwater which occurs under the surface of the Earth.

Surface water law is controlled by two central philosophies which are the riparian and prior appropriation doctrines. Riparian doctrine is based in common law and gives riparian land owners first rights to the water. This doctrine transfers ownership of the water with the property and is not lost by non-use. Prior appropriation, on the other hand, is the norm in the western United States and is based on the "first in time, first in right" principle of beneficial use. A characteristic of these rights is that they are passed to successive owners, often separate of property rights. Riparian owners may have no water rights, junior water rights holders have lesser rights; they exist for a definite volume of water and, most importantly, they may be lost through non-use.

Groundwater is subject to more types of doctrine than is seen in surface water law. Groundwater water law has absolute ownership where the owner may use as much of the water in whatever manner he decides, even to its being non-beneficial; reasonable use, which is designed to curtail waste, correlative rights that combines riparian and prior appropriation facets, prior appropriation in western areas and the restatement of Torts rule which is a formulation by legal scholars on what the law should be. Oklahoma honors the prior appropriation doctrine but has established a permit system with a reasonable use clause. Most of this does not apply to Osage County as it was an Indian reservation and comes under federal reserve water rights.

Native American water rights are at the center of considerable controversy in the United States. It is particularly true in the western states. The Native Americans have claims to large quantities of water as a result of the Winters Doctrine which was a Supreme Court ruling that said the establishment of a reservation as a homeland for the Indians to pursue the "arts of civilization" reserved water rights for the reservation created a federal reserved water rights. This has been applied in case law to surface water and groundwater. The waters under this federal reserve umbrella are not subject to any state or local control and are not lost by non-use and are unquantified. The courts also use the principles of statutory construction which say that statutory language must be liberally construed on behalf of Native Americans and any ambiguities must be resolved in favor of the Native Americans.

To assert and defend Native American reserved water rights, the Bureau of Indian Affairs (B.I.A.) has developed a set of policy guidelines to protect and manage them. The policy guidelines plan formulation included considering problems, needs and demand for the area, identification and development of alternatives, comparison and contrast of alternatives and selection of environmentally, technologically and economically suited alternatives which allow preservation and enhancement of the water resources. The seven guidelines are:

1) Look at the perspective of Native American water rights as the Indian population has a right to large unquantified amounts of groundwater and surface water while the non-Indian successors to

Indian allottees have rights only to a "portion" for domestic and farm use

2) Consider the nature of reservation, its population and their needs

3) Detail the existing water uses, supply and pollution problems and current needs of the area

4) Determine the land and water resources

5) Projection of future demands and determination of alternatives for improvement

6) Incorporate public participation in order to foster support and acceptance of the developed strategy

7) Creation of a final plan

These seven general guidelines are liberal enough to allow large amounts of latitude to fit full scale reservations or areas such as Osage County which, although not called a reservation, is Indian land.

Finally, a general water resources management strategy was considered next. The principal components of water resources management are water quantity and quality, interstate compact restrictions, hydroelectric power generation and recreation/aesthetics.

Conclusions

The first conclusion that can be drawn is that Osage County contains a significant surface water and groundwater resource which far exceeds any present or future foreseeable need. A rough estimate of 30 million acre feet of water is potentially available from all sources for a wide range of uses, from oil and gas production, other mineral extraction, municipal and rural water supplies, light/heavy industry, hydroelectric power generation, agriculture and livestock grazing. The total consumption for future needs might rise to 10,000,000 acre feet which will leave in excess of 20,000,000 acre feet for various uses as excess and surplus water.

The second conclusion is that there are between 509,000 and 604,000 acres of land within the county which could be utilized for raising hay-type crops such as alfalfa and other grasses. There are two mechanisms which give these values. The first one is soil irrigability which can be used to demonstrate that much of Osage County is moderately to readily irrigable and a majority of the soil series are acceptable for raising these type of crops. Therefore, there is a possibility that as much as 604,000 acres of land in the county could be put to cultivating these crops to fully use the soil and water resources and create an economic boost for the county. The second mechanism is land capability classes. This technique points out that around 509,000 acres could be put into these crops. Obviously, not all the soils on all the acreage could be developed, as well as, not all the water could be retrieved or used for irrigation. The main aspect is that a large land and water resource could be tapped if the demand for crops could be encouraged and adequate, economical technology used to supply water from the abundant sources.

Another conclusion is that Osage County is still

Indian country and the Native Americans are entitled to a large portion of the water under the Winters Doctrine concerning federal reserved water rights. The non-Indian successors to the Osage allottees can claim a "portion" of the county's water resources but the majority belongs to the Osage Nation. These rights are not subject to any state agency or regulations governing use or distribution and do not lapse from non-use. They are the tribe's in perpetuity as are the other minerals which the tribe held in common. As a result, the rights to the excess and surplus water resources could be leased to non-Indian consumers outside the area of origin. This would provide a continuous source of income for the Osage Nation.

It can further be concluded that if the three Corps of Engineers lakes that were proposed and approved, but never built (Candy, Sand and Shidler), incorporated hydroelectric power generation and were built, the local economy would benefit. If an inexpensive power source were readily available this could be used, in conjunction with the water resources, to induce light/heavy industry to consider Osage County as a site for manufacturing facilities. Perhaps, the Osage Nation would be able to claim some of the revenue from the power generation as it is derived from their water resources.

A fifth conclusion is that the geographic information system IDRISI is a workable teaching tool, but has several restricting limitations as a research tool. The Image submodule does not allow for fractional or negative numbers which would permit a screen dump image to be printed on a normal sheet of paper instead of being approximately five feet by five feet making it necessary to use a 300 dpi laser printer to get useable images. In the Overlay submodule only two images can be overlain at one time, requiring overlaying two overlays to get a four image composite. The Reclassification module does not allow values to be out of sequence which dictates retaining more attributes than might necessarily be needed. The digitizing program TOSCA supplied with the program was unworkable so everything was digitized in ERDAS version 7.5 and then exported to IDRISI. The module explanations and manuals were not "user-friendly". If one were unfamiliar with IDRISI many of the features and concepts are so well hidden as to be inaccessible. Finally, an overlay can not be viewed layer by layer, or a point reference found and the layers at that site considered. Also, the limitation on the text length for the legends needs expanded. The Unix based GRASS geographic information system developed by the U.S. Army and the Corps of Engineers and expanded by the Soil Conservation Service is more flexible with more capability as a research tool, but is expensive as it requires a Sparc workstation to function properly.

Recommendations for Further Study

A wide range of activities are necessary to adequately prepare a water management strategy and water rights protection effort. The first aspect is a drilling program which would install monitoring wells in minor and major bedrock aquifers and the unconsolidated alluvial aquifers in order to understand their characteristic in sufficient detail to derive useable hydrogeologic data. These wells would be cored or sampled with a split spoon sampler for identification and correlation. Water quality samples for the E.P.A. indicator group would be taken initially and after equilibrating the wells. The samples will be taken on a regular basis, over long periods of time to determine historical water quality. This could aid in pinpointing pollution problems. The monitoring wells would also have a suite of slim-line geophysical logs conducted using such logs as natural gamma, gamma-gamma, conductance and neutron if they are logged through casing. The intent would be to look at lithologies, thickness of layers, density/porosity, depth to water, depth to treatable water and/or depth to salt water as well as areal extent. Water levels should be measured on a frequent basis to establish potentiometric surfaces.

Aquifer testing would need to be conducted where the aquifers are stressed by pumping. They should be conducted and monitored in all aquifers. The objective would be to obtain realistic transmissivity, hydraulic conductivity, pumping rate and specific yield values. Other values could be determined or supported by slug tests. These answers would give an accurate picture of the overall aquifer characteristics and provide a better base for estimation of the amount of acre feet available for utilization.

A more thorough and frequent sampling routine is needed for surface water quality. There needs to be more gauging stations to include all the major streams in Osage County.

Surface geophysical techniques such as D.C. resistivity, electromagnetic conductivity, seismic reflection and ground penetrating radar are needed. These techniques provide large quantities of data about the subsurface and establish a better understanding of layering, thicknesses, depth to water, depth to bedrock, depth to salt water and many other attributes. This would aid in interpreting areal extent, subsurface structural control and could delineate the presence of pollutants which are not detectable from surface indications.

Finally, commuter modeling such as Konikow or some solute transport model should be included as well as a more advanced and flexible geographic information system such as GRASS (Geographic Resources Analysis Support System). Numerous analytical and numerical models exist to aid the quantification of groundwater and contaminant movement and a more flexible GIS would provide a more accurate basis for land and water resources development and management decisions.

The funding for these efforts would have to come from federal sources such as the Bureau of Indian Affairs, the Environmental Protection Agency or other federal agencies. This is a direct result of the fact that the state and county agencies have no authority over surface or groundwater in Osage County as previously discussed. The burden of these necessary studies thus falls to the United States government.

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APPENDIX

TOWNSHIP/RANGE OVERLAY

The Township/Range Overlay found on the inside back cover is to be placed over the IDRISI computer generated images to allow orientation to the Public Land Survey System and various towns within the county. The Public Land Survey System consists of townships which are established north and south of baselines and ranges which are established east and west of meridians.

The overlay covering Osage County has townships which begin with Township 20 North (T20N) and extend to Township 29 North (T29N). The ranges cover Range 12 East (R12E) through Range 3 East (R3E). Six of the more prominent towns are listed in the overlay as well.

The IDRISI program data utilized Universal Transverse Mercator coordinates (UTM) and had no reference to the Public Land Survey System as it was not established on the work maps. The relationship is only an approximate one and will require additional development.

2

VITA

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