The

Ogallala

Aquifer

The Kerr Center

Section 1: Introduction

"We know the value of water when the well runs dry."
– Benjamin Franklin

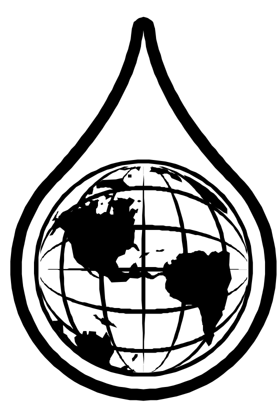
The purpose of this section is to introduce the prevailing water requirements in the United States. Further the section focuses on the declining as well as deteriorating water conditions in the Ogallala Aquifer. This aquifer plays an important role in fulfilling the needs of the American people.

The Ogallala[1] Aquifer (also known as the High Plains Aquifer) is now facing declining water levels and deteriorating water quality. More than 90% of the water pumped from the Ogallala irrigates at least one fifth of all U.S. cropland. This water accounts for 30% of all groundwater used for irrigation in America. Crops that benefit from the aquifer are cotton, corn, alfalfa, soybeans, and wheat. These crops provide the Midwest cattle operations with enormous amounts of feed and account for 40% of the feedlot beef output here in the U.S. Since the advancement of agricultural irrigation in the earlier part of the 20th century, the Ogallala has made it possible so that states such as Nebraska and Kansas can produce large quantities of grain required to feed livestock.[2]

If the High Plains Aquifer were unaffected by human activities, it would be in a state of equilibrium in which natural discharge from the aquifer would be approximately equal to natural recharge to the aquifer. However, activities such as pumpage from wells, surface-water diversions for irrigation and hydroelectric-power generation, and cultivation and grazing practices result in non-equilibrium in the aquifer. The result is that discharge does not equal recharge in many areas. This non-equilibrium results in substantial changes in groundwater levels.[3]

Half of the U.S. population and almost all of those in rural areas draw water from underground aquifers for their domestic needs. Additionally farmers depend on it for irrigation. Once thought an unlimited source of pure water, these sources are increasingly threatened. While toxic waste dumps, cesspools, landfills, and septic tanks contribute their share of wastes to groundwater, agricultural chemicals contribute the most in sheer volume and affect the greatest area. Excess nitrates from fertilizer (and manure), can leach into ground water, and in high enough concentrations make such water dangerous to drink. Other farm run-off can also reduce water quality. Furthermore, some farm pesticides pollute ground water in agricultural areas.[4]

Conservation of water is therefore imperative. It is extremely important that we search for solutions to deal with the problem. We also need to urgently explore the alternative approaches that could be taken instead of those being implemented now.

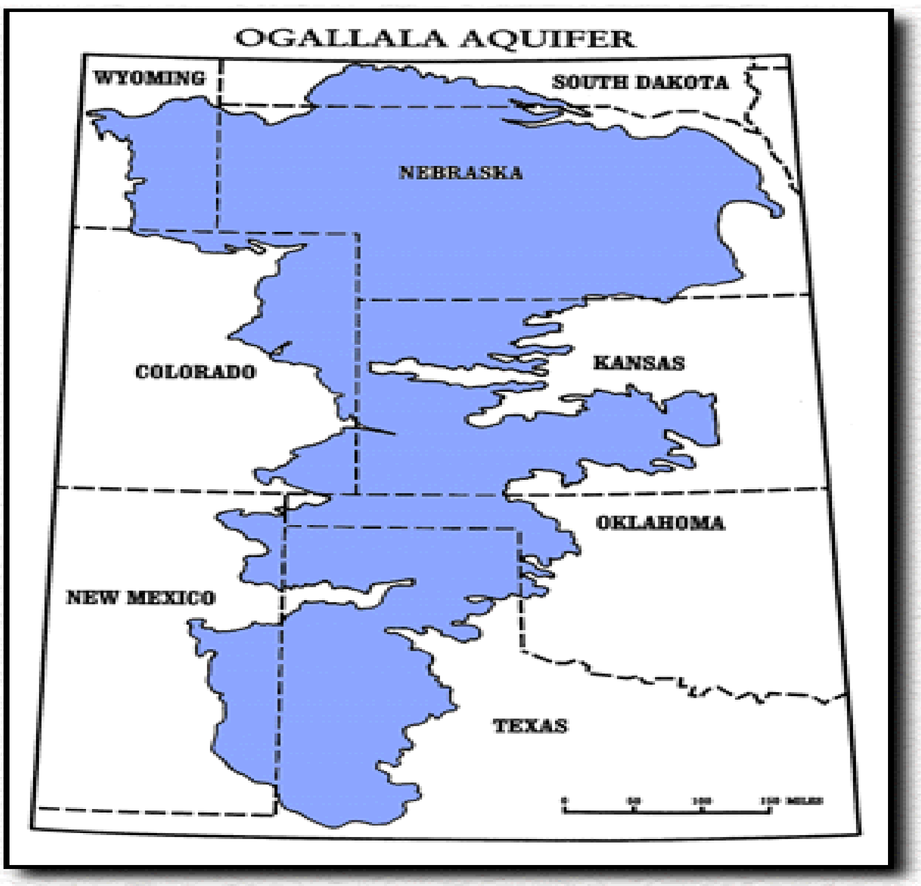


Section 2: The Ogallala

In this section we shall be looking into the past and present water usage conditions surrounding the Ogallala Aquifer. Studies conducted in this area to date will also be briefly examined.

2.1. Physical Characteristics

Figure 1: Areas covered by the Ogallala Aquifer.
Source: *The Ogallala Aquifer*.[5]



The Ogallala ranges in thickness from less than one foot to 1300 feet from one place to another. The average depth, however, is 200 feet. The aquifer underlies a considerable portion of the Great Plains region, particularly in the High Plains of Texas, New Mexico, Oklahoma, Kansas, Colorado, and Nebraska (see Figure 1). The depth of the aquifer from the surface of the land, and its natural thickness, vary from region to region.[6]

As a whole the aquifer covers 174,000 square miles and has long been a major source of water for agricultural, municipal, and industrial development. The surface area of each state covered by the Ogallala formation varies in about the same proportion as the volume of water in storage. Nebraska with 64,400 square miles and Texas with 36,080 are the largest. New Mexico, Oklahoma, South Dakota, and Wyoming all have less than 10,000 square miles of surface area underlain by the Ogallala.[7]

Table 1: Characteristics of the High Plains Aquifer. Source: USGS, 1997.[8]

Charac-teristic	Unit	Total	CO	KS	NE	NM	OK	SD	TX	WY
Area underlain by aquifer	mi^2	174050	14900	30500	63650	9450	7350	4750	35450	800
% of total aquifer area	%	100	8.6	17.5	36.6	5.4	4.2	2.7	20.4	4
% of each state underlain by aquifer	%	--	14	38	83	8	11	7	13	8
Avg. area weighted saturated thickness in 1980	Ft	190	79	101	342	51	130	207	110	182
Volume of drainable water in storage in 1980	Mil. acre -ft	3250	120	320	2130	50	110	60	390	70

The amount of water in storage in the aquifer in each state is dependent on the actual extent of the formation's saturated thickness. In 1990, the Ogallala Aquifer in the eight-state area of the Great Plains contained 3.270 billion acre-feet of water. Out of this, about 65% was located under Nebraska, Texas had about 12% of the water in storage or approximately 417 million acre-feet of water, Kansas had 10% of the water, about 4% was located under Colorado, and 3.5% was located under Oklahoma. Another 2% was under South Dakota and 2% was under Wyoming. The remaining 1.5% of the water was under New Mexico.[9]

The Ogallala Aquifer was formed over twenty million years ago. The formation process began when gravel and sand from the Rocky Mountains was eroded by rain and washed downstream. Those sediments soaked up water from rain and melted snow forming a sponge-like structure.[10] Most of the water has been held within the aquifer for millions of years.[11]

2.2. History of Use

Use of the Ogallala began at the turn of the century, and since World War II reliance on it has steadily increased. The withdrawal of this groundwater has now greatly surpassed the aquifer’s rate of natural recharge. Some places overlying the aquifer have already exhausted their underground supply as a source of irrigation. Other parts have more favorable saturated thickness and recharge rates, and so are less valuable.

Reasons to tap the water are many. American farmers suffered and failed during the 1930’s because they did not have the technology to reach it. After the government’s initial failure to get farmers to move elsewhere, the New Deal committed the federal government and society to take drastic steps to keep farmers on the Plains. The miracle of new irrigation technologies did much to protect farmers from the harshness of drought during the 1950's, early 1970's, and in the late 1980's. In addition it helped create today's highly productive industrial farming and feedlots in the plains.

Many people assume that large groundwater formations may temporarily run low, but will fill again when rainfall is plentiful – as do lakes, rivers, and reservoirs. However, unless the areas impacted are unaffected by the factors that contribute to high evaporation – such as minimal rainfall, abundant sunshine, low humidity, and periodic strong winds – this assumption is not even remotely correct. Therefore, it is imperative that we find solutions through research to water problems and maintain the aquifer as a continuing resource.

By the time we know whether today's conventional High Plains farmers can live with less groundwater, it may be too late to save enough to keep them on the land. Pumping the Ogallala is still a one-time experiment, unrepeatable and irreversible.

2.3. Why is the Ogallala in its Current State?

Nationwide, irrigation has always been treated as a farmer panacea almost beyond credibility. Not until the late 1940's did the combination of efficient deep-well pumps, low-cost energy to run gasoline or natural-gas engines, inexpensive aluminum piping, center-pivot sprinklers and other watering technologies, new management skills, an increased scale of operation, and, not least, the existence of vast water-filled gravel beds from the Ogallala Aquifer, allow farmers to ignore the lack of rain. From then onwards, the Ogallala has been increasingly used for agricultural purposes.

Prior to the 40's and 50's, the lack of water was so severe a problem that there were repeated attempts to declare the region sub-marginal and redundant, off-limits to further attempts at farming. Much of the land, like the sandhills of southwest Kansas, seemed more suited to light cattle grazing than wheat production. By the 1960's, water was being pumped out from hundreds of wells at the rate of one thousand cubic feet a minute to water quarter sections of wheat, alfalfa, grain sorghum, and corn.

Irrigation on the High Plains was not merely a response to climate, but its replacement. While in the beginning the farmer tapped groundwater only as a last resort when rains failed, and often applied the water when it was too late, by the 1960's irrigation was integrated into the farming routine as the single most important activity to guarantee big yields. Most consumers of the High Plains groundwater treat it as a “free good,” available to the first-taker at no cost for the water itself. Hence this free water has been generously consumed on profligate levels, and there are forces at work that encourage excessive use.

Irrigation for the farmers in the High Plains region made possible yields that matched or surpassed corn or sorghum production in Iowa or Illinois or California. As late as the 1850's American commercial farming relied on large tracts of cheap land. High Plains agriculture seemed destined to remain such a big-acreage, low-yield region until the farmers discovered the Ogallala. While in 1950 the Ogallala irrigated 3.5 million acres of farmer land, today it is irrigating 16 million acres.[12] As a result of the factors discussed above, for thirty years the High Plains irrigators have been consuming aquifer water at a rate conservatively estimated to be ten times the rate of natural recharge.

2.4. Water Quality Issues

Industrial agriculture with its reliance on chemicals and its failure to adequately address soil erosion problems is guilty of depleting water resources. Ignorance and carelessness are in fact the main factors behind the increasing water quality deterioration.

While industrial contamination is important, some agricultural activities are exceptionally likely to pollute the groundwater, which then flows into an aquifer and may be drawn into a well. Irrigation, which does not permit improvements of water quality after usage before returning to a source, as municipal/sewage water would, changes the content of dissolved salts and adds agricultural chemicals and eroded sediments. For a typical soil, water returning to a source after irrigation is more saline than prior to an irrigated application.

Nitrates in fertilizer, used on farms and also on home lawns and gardens, can seep into groundwater, and this can be very harmful to pregnant women and children.[13] Pesticides too are harmful in many cases. They can pollute ground water in agricultural areas exceeding the water quality standards. And according to the EPA there is no known way to remove pesticide residues from ground water. Groundwater may also be polluted by outflows from polluted rivers and streams or saline estuaries, in cases where the groundwater has been depleted to an unusually low level.

While farm chemical wastes are a problem nationwide, in areas where confined feeding operations of cattle, hogs, and chicken is common (it's common in all the states blessed with Ogallala waters) animal wastes have become a major source of water pollution. Agricultural runoff is the greatest non-point source of water pollution in the U.S.[14] Besides sediment, agriculture contributes pesticides, chemical fertilizers, and animal manure to surface water such as streams, rivers, ponds, and lakes. Animal manure is rated with commercial fertilizers and atmospheric deposition as one of the three primary non-point sources of nitrates in surface and ground water according to the national Water Quality Assessment done by the United States Geological Society (USGS).[15]

The quality of water in the High Plains Aquifer generally is suitable for irrigation use but, in many places, the water does not meet U.S. Environmental Protection Agency drinking water standards with respect to several dissolved constituents (dissolved solids/salinity, fluoride, chloride, and sulfate). Only a small fraction of Ogallala groundwater is known to be contaminated such that it fails to meet drinking water standards. Communities that rely on groundwater for drinking are subject to federal monitoring requirements. In most other areas, however, groundwater monitoring is infrequent or nonexistent. Effective monitoring is expensive, and there are plenty of potential sources of groundwater contamination. For example, many on-site domestic waste disposal systems in the country contain nitrates, phosphates, pathogens, inorganic contaminants, or other toxins that could leak into neighboring groundwater supplies.[16]

Potential sources of groundwater contamination include landfills, abandoned waste sites, oil and gas brine pits, and the chemicals applied to most of the acres typically planted to crops each year. Only sparsely scattered water quality data (except in Texas) are available for pesticides, volatile organic compounds, and trace metals in the High Plains Aquifer system. Nutrient data are available, to a varying degree, across the aquifer.[17]

2.5. Studies Conducted

With relatively low natural recharge rates and the dramatic increase in the use of groundwater throughout the region, declining water levels were noticed in parts of the region as early as the 1940's and 1950's. By the 1970's, farmers and officials at all levels of government were expressing a need to more closely examine the issue of aquifer depletion.

In the mid-1970's the U.S. Congress authorized two assessments. The first was a national effort, the Regional Aquifer-System Analysis, which examined the hydrogeology of all the major aquifers in the U.S. The second assessment process brought together federal, state, local government agencies with private consultants within the High Plains region to analyze the potential economic and social impacts of aquifer depletion and management options. This assessment was done in parallel with hydrogeological studies conducted by the U.S. Geological Survey (USGS). Motivation for these studies at the national level centered on national food security issues.[18]

The local and state concerns focused on potential negative local and state economic and demographic impacts of partial or total depletion of the aquifer. At the time, increased pumping costs, due to both the increasing depth of water and the energy price shocks of the mid- and late- 1970's, as well as the potential social disruption due to the abandonment of irrigated farming in the region placed concern for the aquifer high on the public's agenda.

Section 3: Case Studies

This section examines the impacts of the increasing use of the Ogallala – with specific focus on the situation in the Oklahoma and Texas Panhandle regions. These regions were selected for close scrutiny because of their proximity to the Kerr Center.

3.1. Case of the Oklahoma Panhandle

The Oklahoma Panhandle, which is composed of Cimarron, Texas and Beaver counties, is a 5,680 square mile semi-arid area in western Oklahoma. Prior to 1950, crop production in the area was almost exclusively dry-land wheat and grain sorghum. However, with the introduction of irrigation practices, principal crops in the area now include grain sorghum, corn, and alfalfa which are produced to supply feed for the large beef feedlots in the area, and wheat which is produced primarily for the export market.

With the discovery of a significant quantity of high-quality groundwater underlying most of the region, came the development of irrigated production practices. Development of agricultural crop production under irrigated conditions has contributed to increased economic activity in the Oklahoma Panhandle and surrounding regions. Acres irrigated in the Oklahoma Panhandle increased from 11,500 in 1950 to 427,000 in 1973, and totaled 405,700 in 1979 (see Table 2).

Table 2: Irrigation statistics for Oklahoma Panhandle area.

Year	No. of farms	Total acres	No. of farms gravity system	Acres gravity system	No. of farms sprinkler system	Acres sprinkler system	No. of irrigation wells	Total acres irrigated - groundwater
1979	1223	405679	898	297649	350	97215	2227	403619
1977	1155	385900	896	301650	259	85700	2172	384000
1975	1094	404610	901	329460	193	75150	2112	402550
1973	1530	427000	1360	324500	175	102500	2207	422680
1971	1375	356360	1165	302938	255	54422	1846	344040
1969	960	315518	835	282618	141	32900	1634	213518
1967	1150	263000	1010	224850	145	38150	1358	261000
1965	745	138000	586	122000	104	16000	972	135500
1963	304	84500	241	71560	75	11940	409	83020
1959	275	71500	--	65820	46	5680	365	69520
1958	279	69575	--	62623	53	6960	--	67375
1957	267	76500	--	68360	49	8140	359	75225
1956	266	71200	--	64700	41	6500	336	70100
1955	212	34247	--	32030	--	2317	--	32797
1954	--	24680	--	23758	--	922	--	23580
1952	--	13000	--	--	--	--	--	--
1950	53	11500	--	--	--	--	--	--

Source: Mapp, 1980.

The primary sources of irrigation water in the Oklahoma Panhandle is the Ogallala Aquifer, a major underground aquifer supporting irrigation water throughout much of the Great Plains. Continued overdraft of the Ogallala Formation and water level declines of two to three feet per year in many areas, make physical exhaustion of the aquifer a major concern. The characteristics of the aquifer make physical exhaustion a very real possibility – one that has already occurred for some irrigators in parts of the Oklahoma Panhandle.

The rapid development of irrigated crop production has resulted in overdraft of the aquifer, with withdrawals greatly exceeding natural recharge and return percolation of irrigation water. The result has been a gradual decline in the water table within the aquifer. The declining water table interacts with rapidly increasing costs of energy inputs, particularly natural gas being utilized by most irrigation systems in the Oklahoma Panhandle and, other things being equal, reduces the profitability of irrigated crop production. Continued declines in the water level within the aquifer threaten the capital-intensive irrigated agricultural economy of the area.

Several factors are interacting to reduce the economic life of the aquifer. One, rapid water withdrawals lower the water table and increase the vertical lift of the water to the surface. And two, declines in saturated thickness of the aquifer reduces the well yield, measured in gallons per minute, which increases the time required to apply a specified quantity of water onto the crops. Reduced well yield and increased feet of lift interact with the cost of pumping irrigation water and reduce the profitability of irrigated crop production.

In a study conducted over the period 1978-80 by Oklahoma State University and the Oklahoma Water Resources Institute, the economic life of the underground water supply in the Oklahoma Panhandle was analyzed. Economic exhaustion is said to occur when net returns from the production of the best dry-land crop alternative exceeds the net returns of the most profitable irrigated crop activity. The study predicts that the decline in the underground water supply and conversion from irrigated to dry-land production would be a part of the future of the Oklahoma Panhandle. The study did not answer the question of exactly when this conversion will occur and which crops will remain under irrigated production until the economic life of the aquifer is exhausted for agricultural purposes. However, the study concluded on the note that the eventual economic exhaustion of the aquifer appears inevitable unless dramatic and unforeseeable output price increases or institutional or technological changes occur.[19]

An example of the aquifer's water depletion in the Oklahoma Panhandle area is in Texas County. Texas County consumes almost all of its water from the Ogallala Aquifer flowing some 200 feet beneath the Panhandle. In 1990, approximately 363 million gallons per day of groundwater were pumped from the High Plains Aquifer. Throughout the High Plains, the water table dropped 9.9 feet from predevelopment times to 1980, and then dropped another 3.05 feet from 1980 through 1995. Irrigation methods became increasingly efficient with fully automatic center-pivot drop sprinklers. But as efficiency rose, crop acreage rose as well. While there were approximately 54,400 acres in irrigated corn in 1991, there were approximately 90,000 acres in irrigated corn in 1998.[20]

Texas County has more than 380,000 head of feedlot cattle, a ready market for the corn. While corn is a particularly thirsty crop unable to grow without irrigation in Texas County, it yields up to 200 bushels per acre with 22 inches of irrigated water. With an estimated 90,000 acres of corn in 1998 and each acre using approximately two-acre feet per year,[21] Texas County uses approximately 58,653,180,000 gallons of irrigated water a year on corn alone. Corn is fed to both cattle and hogs, and uses some of the nutrients in the hog manure. While livestock water usage is 3% directly, livestock feed requires all that irrigated fields can produce, accounting for 92% of water withdrawal from the High

Plains Aquifer in Texas County.[22] While hogs are not the sole cause of water depletion as well as water quality deterioration in the Panhandle, the large hog operations increase pressure on an already stressed ecosystem. The growth of intensive hog operations contributed to a 66% increase in livestock water use between 1990 and 1995.[23]

3.1.1. Water Quality in the Oklahoma Panhandle

In the Panhandle of Oklahoma, the environmental capital can be easily overlooked with its treeless plains being open and wide as the horizon. But this wide open space is a premier cattle raising and dryland farming area as well as a cornucopia of irrigated corn thanks to the underlying Ogallala Aquifer.

The increased use of confined animal feeding operations for cattle, poultry, and hogs has raised concerns regarding the possibility of groundwater pollution. Full-grown hogs, grown under confined conditions, produce 15 pounds of waste per day. Since hog manure is disposed of as highly-liquid slurry in confinement operations, the cost to transport it are prohibitive. Therefore, it has to be used in the local area. Although there are many systems to handle hog waste, lagoons are the cheapest and least efficient. The current regulations allow lagoons to be constructed to hold the waste and to seep at roughly one-quarter inch per day. The Oklahoma Department of Environmental Quality translates that into a total of more than 500 gallons per acre per day.[24]

Thus more area is put into irrigated corn which is a high user of nitrogen – a key component in manure. Irrigated corn, in the course of consuming enormous amounts of water, produces nutrient runoff particularly high in phosphorous because of the use of animal manure as a source of nitrogen. Sunflower, milo, and native grass also have effluent spread on them. There is no procedure in Oklahoma to monitor how much and where nutrients are spread on the various crops and grasses grown in the Panhandle. And one does not need to speculate about where this runoff finally travels, i.e., into the Ogallala Aquifer.[25]

3.2. Case of the Texas Panhandle

The period of rapid growth in irrigation in the High Plains of Texas started after World War II and lasted about 20 years. This development triggered a rapid increase in population, employment, farm product sales, and total area income. By the mid-1960's, irrigation development started to taper off mainly due to a decrease in the water table level. The Ogallala Aquifer, which is the source of water for irrigation in this area, was being pumped down faster than it was recharged. And with the decrease in the rate of irrigation development came a decrease in the rate of growth of the area's general economy.

A study conducted by the United States Department of Agriculture's Economic Research Service branch in 1988, found that in the 1940's and following World War II, economic development took sharply different paths in the two study areas. The economy of the dry-land farming area continued to stagnate and periodically worsen, because of inadequate moisture for crops. The area is subject to erratic rainfall, where adverse weather cycles may last several years, and lacks sufficient water for irrigation. In contrast, the irrigated counties, which were fortunate enough to be located in the Ogallala Aquifer basin, experienced rapid economic growth and development throughout most of this period.[26]

This study found that economic growth in the irrigated area appears to be closely linked to developments in the local agricultural economy, which has passed through three distinctive phases: (1) introduction of irrigation, (2) intensive use of irrigation, and (3) declining water resources. And as the water level in the aquifer declines, the farmers are being increasingly faced with some rather severe decisions: to be more efficient in the use of water, change cropping practices to raise plants that need less water, or revert to a dry-land economy.[27]

The USDA study about the Texas Panhandle concluded on a note similar to that in Mapp's study[28] on the Oklahoma Panhandle area: At some point dry-land agriculture will be the more efficient production method. How soon the transition will be made, says the report, will depend somewhat on the farmers' willingness to change their irrigation practices. Some irrigation will probably continue for a number of years. Development of new technology in irrigation and more drought tolerant plants may delay the absolute end of irrigation. Whatever the time, adjustments must be made so as to be ready if the wells do indeed run dry.

Water is the limiting factor in farming on the Texas High Plains, with most of it coming from the Ogallala Aquifer. Agriculture accounts for approximately 70% of the water use, while municipal uses account for approximately 20%. Land use and watershed management have the most significant impact on aquifer depletion. Most observers agree that in an area with 17 inches of rain yearly, high-water-use crops like corn cannot be produced with any sustainability. The irony of the situation is that vast amounts of this finite resource is used to grow crops that only provide farmers a marginal financial return in some years and is simply enough to service debt and meet fixed overhead costs.[29] It is also significant to note that in this situation of extreme distress, an oilman and other wealthy ranchers are buying up water rights in the rural areas of the Texas Panhandle, and are selling them to large Texas cities.[30]

3.2.1. Water Quality in Texas Panhandle

The Texas Panhandle region suffers significant water pollution from confined animal feeding operations. Cattle feedlots and pig farms are frequently located near the numerous "playa" lakes that dot the High Plains. Playa lakes are large, circular, natural depressions where water collects and seeps slowly down into the Ogallala Aquifer, the major source of both drinking and irrigation waters for the region.[31]

The land throughout the Panhandle is also perforated with incompletely plugged wells, test holes, oil and gas wells, and other borings. During rainstorms or when playa lakes or lagoons overflow, water will drain directly through these holes into the Ogallala Aquifer, carrying any polluted animal waste along with it. Residents throughout the Panhandle believe a significant threat to the aquifer is posed by these man-made holes in combination with seepage from the playa lakes, which can act like giant puddles to receive polluted wastewater from overflowing manure lagoons and feedlots.

For years, farmers in the region used playa lakes as retention ponds for wastewater runoff. The state still allows farmers to use the playa lakes for this purpose if they started doing this prior to September 1, 1993.[32] Of particular concern to local residents in the Texas Panhandle, are the state's design standards for CAFO (Confined Animal Feeding Operations) lagoons allowing clay liners, which can crack after long droughts, and the lack of leak detection and ground water monitoring.

Efforts are now being made in this region to reduce irrigation farming practices. According to the High Plains Underground Water Conservation Service, several factors have contributed to the reduction of pumping of groundwater. Everyone knows that they need to improve water-use efficiency, and as the technology became available, farmers have begun to implement it.

Average water-use efficiency improved in the Water District service area from about 50% in mid 1970s to approximately 75% in 1990. Current state-of-the-art low-pressure, full dropline center pivot systems are about 95% efficient; while buried drip lines approach 100% efficiency. Producers are now irrigating fewer acres. In 1979, 3.95 million acres on the Texas High Plains were irrigated, but by 1989, only 1.39 million acres were irrigated. Land enrolled in the Conservation Reserve Program (CRP), rising energy costs, and declines in well yields and low farm prices also account for part of this reduction.[33]

The Texas portion of the Ogallala Aquifer contained approximately 450 million acre-feet of water in 1990. The Texas Water Development Board in Austin estimated that the net depletion rate of the Ogallala Aquifer is predicted to average about 3.62 million acre-feet per year from 1990 to 2000 as more efficient water-use equipment and practices are being put into place.[34]

Section 4: Sustainable Development - A Possible Solution

This section explores the possibility of adopting sustainable development practices to curb the increasing aquifer water depletion and deterioration. The importance of implementing sustainable agriculture in place of the existing irrigation practices, which require immense water resources, is emphasized.

4.1. What is Sustainable Development?

Sustainable development is commonly defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The practice of sustainable development may date back to the ancient Greeks, whose laws avoided exploitation of resources and sought environmental balance. The modern discussion started in 1972 when the United Nations Environment Program stressed the importance for Third World nations to build a balance between natural resources and economic development. This emphasis on the maintenance of essential ecological processes continued to receive fresh momentum with the publication in 1987 of *Our Common Future* by the World Commission on Environment and Development. [35]

Sustainable development is extremely important in the context of High Plains farming where the Ogallala water levels have been rapidly declining due to uncontrolled irrigation practices. Not only are the water levels in these regions declining at ten times the rate of recharge, they are also losing topsoil each year. Cattle feedlots that run tens of thousands of cattle through their pens every year demand a minimum of eight to ten gallons of water per head per day. Today the plains are locked into high water consumption to grow the wheat and water the beef.[36]

According to MacNeil[37] (1989), one objective of sustainable development is to track soil and water consumption as real environmental costs, as compared to the historic treatment of natural resources as a free commons. A second priority is to produce more wheat (and alternative crops) using less water, chemicals, soil, fuel, and capital. Third, sustainable development does not support fixing resources in place as an extreme environmental paradigm might. Instead it argues for a shift that would still allow humanity to live comfortably, but within the world's ecological means. And lastly, sustainable development seeks to integrate the rival interests of the environment and economics.

4.2. Availability of Viable Alternatives to Current Practices

Do our methods of farming conserve water and avoid surface and groundwater pollution? Excessive or improper use of herbicides, other pesticides, and fertilizers, including manure, leads to water pollution. Many of the herbicides, other pesticides, and fertilizers polluting groundwater can be reduced or replaced by skillful management practices without a significant loss in production. A switch to strategies that reduce purchased inputs has the added benefit of reducing costs, increasing profits, and protecting natural resources.

Crops can be grown under both dry-land conditions or under irrigated conditions. In either case adequate soil moisture is necessary for optimal growth[38], as water can be detrimental to crops if the soil becomes saturated and literally suffocates roots by decreasing the oxygen in the soil. It is therefore in the best interest of the farmer to keep the right amount of water available to his plants. One way to do this is by increasing the organic matter in order to make the soil more spongy and able to absorb water. Conservation tillage and green manures also improve soil structure, and cover crops slow down water movement. Retiring highly erodible land also conserves water quality by conserving soil.[39]

Some classic soil conservation/water quality preservation measures include contour farming (which is farming with row patterns nearly level around the hill, not up and down the hill) and strip cropping (which is planting strips of corn or soybeans alternated with strips of oats, grass, or legume). Contour strip cropping[40], planting fiber strips (which are strips of grass trees or shrubs that filter run off and remove contaminants before they reach the water), and established grass waterways (which prevent gullies from forming in the way of natural drainage), are other soil conservation/water quality preservation techniques. Most of these strategies are intended to slow water or trap sediment and chemicals before they reach bodies of water or wells. In effect, they act as filters to the farm waters. When these filter strips are planted in permanent vegetation they fall under the rubric of “conservation buffers” and “buffer strips.”[41]

Besides the time tested conservation techniques, new strategies such as integrated pest management (IPM) practices can help protect water supplies. IPM is a planned program that coordinates economically- and environmentally-acceptable methods of pest control with judicious and minimal use of toxic pesticides. IPM programs assess local conditions, including climate, crop characteristics, the biology of the pest species, and soil quality, to determine the best method of pest control. Tactics employed include better tillage to prevent soil erosion and introduction of beneficial insects that eat harmful species.[42]

Adopting the above practices can make a real difference. These practices have been tried out effectively at the Kerr Center in Poteau, Oklahoma, to protect water quality. First, attempts were made to keep the soil in place with heavy vegetation. Since just a few small plots of vegetables and fruits are raised there at the Horticulture Farm, no problems such as those faced by farmers who grow crops like wheat and corn season to season, were encountered. But even on a cattle ranch, there are areas around water sources that are trampled by cattle. Efforts were taken to keep the areas especially favored by the cattle seeded and covered with grasses and clovers. Grazing pastures in rotation allows the pastures to "rest" for periods of time and plants to grow densely. Installation of water tanks and the fencing out of ponds keeps cattle away from them. This strategy was found to be an effective one because cows normally trample tender vegetation around water and can also erode the banks of waters, stir up the muddy bottom, and burden the water with wastes.[43]

Conservation is urgently needed. According to many scientists, 70% of the water used never reaches the crops. Conventionally used sprinkler irrigation has been found to allow too much water to escape during evaporation. Techniques such as drip irrigation have been implemented at the Kerr Center to conserve water and to apply water where it is needed. This reduces the evaporation rate and places the water next to the plant root zone.[44]

4.3. Barriers to Adoption of More Sustainable Practices

It is widely prophesied that sustainable agriculture would result in a heavy financial loss. This is however a misconception. Sustainable agriculture need not be less profitable than conventional agriculture. The farms using alternative-methods had lower yields initially, but this was offset by lower costs for fertilizers and pesticides. Even when increased labor costs were included there was still little difference. In a drier region like the High Plains, sustainably- or organically- farmed soils offer the advantage of greater water-holding capacity than conventionally farmed soils.[45] And even though water may be essentially a free good, a farmer would still need to invest his money in machinery to irrigate his fields.

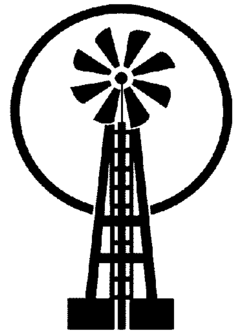
Farmers also worry that sustainable farming will mean a return to hard labor. Sustainable agriculture needs to be seen more clearly not as a throwback to hundred-year-old agricultural practices. Instead, it requires the farmer to be more knowledgeable about his farm's ecosystem and recognize its place in his life and society's. In most cases, sustainable agriculture simply implies diversification rather than specialization. The objective is long-term self-sufficiency to sustain the farm environment and to reduce economic as well as environmental costs.

Many farmers do acknowledge that access to Ogallala water will gradually become too expensive as water levels decline and pumping costs increase. In the case of the Ogallala Aquifer, the immediate need is physical sustainability, i.e., implementation of practices such as planting more wheat or other alternative crops using less water, chemicals, soil, fuel, and capital.

Low-input sustainable agriculture is hampered by federal programs that do not recognize it – for example, the rotational system used by alternative-method farmers, who end up sacrificing income support payments available to conventional farmers. For decades conventional farmers have received federal economic incentives that distort their profit picture. What they need instead are economic incentives to change their current unsustainable practices.[46]

It is worth noting at this point that low-input sustainable agriculture (LISA) became a small part of the farm policy with the passage of the 1985 farm bill, significantly entitled the Food Security Act. LISA was later expanded and renamed SARE (Sustainable Agriculture Research and Education Program). It evolved mainly as a reaction to two factors:

1. Modern industrial agriculture has not protected the environment well, and
2. Economic failure continues to bedevil most independent farmers who practice conventional agriculture.



Section 5: Conclusion

> *"A Faustian bargain with the water is now coming due; it created a prosperous irrigation economy based on levels declining ten times faster than any recharge. But we have no historical experience from which to predict the future of high-production industrial agriculture or the small-time farmer on the High Plains without the continuous massive infusions of groundwater. Nor have pragmatic alternatives been devised, much less tested. Pumping the Ogallala remains a one-time experiment."*[47]

There is justifiable cause for concern over the adequacy of our water supplies. We have limited control over the resource, most opportunities for increasing supplies are financially and environmentally not cost effective, and current uses are depleting or contaminating some valued supplies. While demands for the many services provided by water are growing, institutions have been slow to adapt to the challenges of growing scarcity, supply vulnerability, and rising instream values.

Concerns regarding the safety of drinking water are also rapidly growing. Legislative reforms are needed that would:

(1) allow local communities to target their resources to the most pressing problems;

(2) require the Water Resources Boards in the concerned states to assign more value and to focus more on the contaminants that pose the greatest health risks; and

(3) give greater emphasis to protecting drinking water supplies from contamination in the first place.

The various societal and individual responses to growing water scarcity suggest that farming regions may adapt well to a slowly changing climate. Still, despite the positive changes that have occurred in this region, one should not be overly optimistic. Groundwater depletion continues in much of the aquifer, even though at reduced rates in some regions, and many farmers face a reduction in future farm income as they decrease their water use.

Without irrigation, the High Plains region would have remained a hostile and unproductive frontier environment. Even today dry-land farming remains high-risk farming about which the producers in the region have doubts. But while the Dust Bowl label is appropriate, the High Plains has become one of the most productive farming regions of the world. However, now as groundwater levels decline, workable alternatives for sustainable development have to be further explored.

While past changes were gradual, spontaneous, and largely unconscious, changes now will have to be specific, and carefully planned. The abuse of the Ogallala Aquifer for the last thirty years together with the wasteful depletion of soil symbolized by the Dust Bowl, matched by the decline of America's historic independent farmer, signals that today's conventional farming cannot continue indefinitely into the future. The need of the hour is to identify a workable farm model or paradigm that avoids both environmental and human (social, economic, political) pitfalls, such as the ones American farming has already fallen into.

The following are some recommendations that policy makers need to urgently adhere to and implement to ensure the future availability of the Ogallala waters:

- Support to make small, as well as moderate-size farms economically viable, because they can ensure social, economic, and environmental diversity (for example, the family farm);
- Ensure rural community and institutional viability because it provides a working social "surround" of goods and services as well as an extended lifestyle;
- Implement policies that provide incentives to farmers to adopt sustainable practices;
- Promote long-term environmental integrity together with long-term productivity by supporting policies for conserving soil and water, and reducing dependence on capital intensive equipment and chemicals;
- Introduce new crops more suited to the soil conditions, and encourage diversity of crops as good environmental stewardship is based on locally specific knowledge;
- Promote individualized on-site response to climate and geography;
- Ensure that trade and agriculture policy take into account total-cost accounting.

Notes

1. N. H. Darton is credited with naming the aquifer in 1899 after the town of Ogallala, Nebraska.

2. *Aquifer Close Up.* Published by Center for Biological Computing**,** Indiana State University, Department of Life Sciences. [http://mama.indstate.edu/users/johannes/aquifer/htm].

3. Precipitation is the principal sources of natural groundwater recharge in the High Plains. Recharge from precipitation is quite variable in the High Plains, both in time and in space. Factors that affect this variability include the precipitation regime, evapo-transpiration, soils, vegetation, and land-use practices, and the characteristics of the unsaturated zone between the soil zone and water table. In a few areas, however, natural recharge can result from seepage losses from streams and lakes. This recharge is particularly important along parts of the Platte River system in Colorado, Nebraska, and Wyoming, where substantial seepage losses of stream flow originating outside the High Plains result in recharge to the High Plains Aquifer. (*High Plains Aquifer Background Information*. http://www-ne.cr.usgs.gov/highplains/bckgrnd.html).

4. Cunningham, W.P., & B.W. Saigo. *Environmental Science: A Global Concern*. William C. Brown publication. Dubuque, Iowa. 1990.

5. *The Ogallala Aquifer.* High Plains Underground Water Conservation District No.1. [http://www.hub.ofthe.net/hpwd/ogallala.html].

6. Glantz, M. *The Ogallala Aquifer Depletion*. 1989.

7. See Note 3.

8. USGS. *Characteristics of the High Plains Aquifer.* [http://www-ne.cr.usgs.gov/highplains/hpchar.html].

9. *Id.*

10. The aquifer is porous and filled with water; lying between a water table and a bedrock bottom.

11. The aquifer is replaced by precipitation and surface streams. It is recharged primarily by direct infiltration of precipitation falling on the overlying soils. When the amount of water withdrawn from the aquifer continually exceeds the recharge, a mining situation results.

12. Opie, J. *OGALLALA: Water for a Dry Land.* University of Nebraska Press. 1993, p. 294.

13. It has in fact been known to cause the “blue baby syndrome.” Nitrates can be changed to nitrites by bacteria in our bodies and reduce the oxygen carrying ability of blood especially in babies and young children. Also, nutrients can not only form nitrosamines that are suspected of causing stomach cancer, but can cause excessive algae

growth in lakes and estuaries.

14. Non-point refers to sources of pollution that are scattered, with no specific place or point where they discharge into a body of water. This makes them more difficult to identify, monitor, and regulate. Such sources include run off from farm fields, golf courses, lawns, roads, parking lots, etc. Point sources, on the other hand, are specific locations such as drainpipes, or sewers. (USGS. *High Plains Regional Ground Water (HPGW) Study*. National Water-Quality Assessment (NAWQA) Program. [http://webserver.cr.usgs.gov/nawqa/hpgw/HPGW_home.html]).

15. *Id.*

16. Cash, D. *Assessing and Addressing Cross-Scale Environmental Risks: Information and Decision Systems for the Management of the high Plains Aquifer*. GEA Discussion Paper E-98-17.

17. See Note 13.

18. *Id.*

19. Mapp. H.P. Jr. *Impact of Availability of Water and Cost of Energy Inputs on Agricultural Production in the Oklahoma Panhandle*. Oklahoma Water Resources Research Institute. 1980.

20. Oklahoma Agricultural Statistics Services, Oklahoma Department of Agriculture. [http://www.usda.gov/nass/].

21. One acre foot equals 325,851 gallons.

22. *Bringing Home the Bacon: The myth of the role of corporate hog farming in rural communities*. Research provided by The North Central Regional Center for Rural Development. Sponsored by The Kerr Center. 1999. p. 37.

23. *Id*. p.38

24. Schepers, J.S., D.D. Francis, and M.F. Vigil. *Nutrient management and utilization from manures*. pp. 686-88. Proceedings of “Agricultural Research to Protect Water Quality “ Conference. Held in Minneapolis, MN on February 21-24, 1993.

25. *Id.*

26. Holmes, W., and M. Petrulis. *Groundwater Irrigation: Declining Water Levels in the Texas High Plains Translate to Declining Economic Performance*. USDA/ ERS. Agriculture and Rural Economy Division. August 1988.

27. *Id.* p. 3.

28. See Note 15.

29. *Agriculture Policy Project.* By Henry A. Wallace Center for Agricultural and Environmental Policy and Winrock International. [http://www.hawiaa.org/wagpoldocs/tx.html].

30. *Pickens buying water rights.* Edited by Max Albright. Web posted Tuesday, January 25, 2000. [Available at http://www.amarillonet.com/stories/012500/new_touts.shtml/news/].

31. J.M. Sweeten, "Groundwater Quality Near Two Cattle Feedlots in Texas High Plain: A Case Study," *ASAE*, Vol. 11, No. 6 (November 1995), p. 845.

32. America's Animal Factories: How States Fail to Prevent Pollution from Livestock Waste. Natural Resources Defense Council, Inc. 1998.

33. High Plains Underground Water Conservation District No.1, 1997-98. *The Ogallala Aquifer.* [http://www.hub.ofthe.net/hpwd/ogallala.html].

34. *Id.*

35. World Commission on Environment and Development, Our Common Future. New York: Oxford University Press, 1987).

36. *Id.*

37. MacNeill, J. Strategies for Sustainable Economic Development. *Scientific American,* Volume 261, no. 3 (September 1989): 158-59, 163-64.

38. There is a strong link between high levels of photosynthesis and high transpiration rates.

39. See Note 4.

40. Contour strip cropping is a combination of contour farming and strip cropping.

41. Horne, J. *Ecological Approach: Our Approach*. The Kerr Center for Sustainable Agriculture, Inc. 1993.

42. The Concise Columbia Electronic Encyclopedia. Third Edition. Copyright © 1994, Columbia University Press. [Available at: http://www.encyclopedia.com/articles/06407.html].

43. Horne, J., & M. McDermott. *The Next Green Revolution: Essential Steps to a Healthy, Enduring Agriculture*. Manuscript version. To be published by Haworth Press, Binghamton, NY. Jan. 2001.

44. See Note 39.

45. Opie, 1990, p. 11

46. Schroeder, L. Low-input agriculture: Overcoming the impediments. *Journal of Soil and Water Conservation*. Volume 45, no.1. (January/February 1990). P. 40.

47. Opie (1993), p. 286.