# Effects of Seasonality and Water Quality on Salinity Gradients in the High Plains Aquifer


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## Sub-objective 3

Improve the understanding of hydrological and climatic factors that affects water use and economic profitability, and provide estimates of the climatic, hydrologic, cropping, and profitability conditions that are likely to occur on the southern High Plains over the next 50 years.


## Abstract

The Ogallala Aquifer is among the largest freshwater aquifers in the world and it is being depleted at a rapid rate. The High Plains Water District (HPWD) set restrictions that attempt to preserve 50% of the remaining saturated thickness of the Ogallala Aquifer over the next 50 years. This goal does not address the quality of the remaining water. Generally, groundwater quality will vary over time as the Ogallala aquifer is depleted. Groundwater quality may also vary with depth within a well due to the influence of geological factors and varying strata within the Ogallala formation. The vertical profile of water quality may also be influenced by the upward migration of water from underlying formations, such as the Dockum formation. In addition, pumping will alter these gradients and as such vertical profiles of water quality will likely exhibit a strong seasonal trend. The goal of this study is to evaluate changes in groundwater quality with changes of saturated thickness with special emphasis on periods before and after the growing season.


## Project Narrative

A: **Objective**

The goal of the proposed study is to examine vertical gradients of groundwater quality within irrigation wells and determine how the salinity profile is changed by pumping during the growing season. This study will improve our understanding of hydrological and geological factors that influence current groundwater quality as well as vertical variations of water quality within a typical well.

B: **Rationale**

The Ogallala Aquifer extends across a large portion of the Great Plains of North America, spanning eight states from Texas to Nebraska. Overall, the aquifer underlies a land area of approximately 450,000 $km^2$ and is among the largest aquifers in the world (Opie, 2000). Groundwater resources of the Ogallala have been studied since the late 19th century and early 20th century, when development of groundwater on a limited scale first began (Hill, 1892; Darton, 1898; Baker, 1915;). More significant groundwater development began in the 1940s, primarily for irrigated agriculture

(Moore *et al.*, 1940; Meinzer and Wenzel, 1941). Development continued and intensified rapidly through the 1950s, and groundwater is now used to sustain large regions of irrigated agriculture (Cronin, 1960).

Changes in the saturated thickness of an aquifer respond to changes in the balance between recharge and discharge. On the high plains of the Llano Estacado, the only significant external source of recharge is precipitation, however, hydrogeological studies have shown that groundwater withdrawals exceed the amount of recharge by a large margin (Cronin, 1969). Thus, despite its critical importance to irrigated agriculture, the Ogallala Aquifer is being depleted at a rapid rate (Custodio, 2001; Dutton et al., 2001; Whitehead, 2007; McGuire, 2014). Depth-to-water measurements obtained each year by the High Plains Underground Water Conservation District indicate that the saturated thickness of the aquifer has dropped at an average rate of 0.3 m per year since 1985 (HPWD, 2014; McCain, 1996). During drought conditions, the depletion of the aquifer can accelerate to nearly twice this long-term rate (Mullican, 2013).

While it is important to conserve the quantity of groundwater, it is also important to preserve the quality of the remaining groundwater (Chaudhuri and Ale, 2014; Ledbetter, 2014). It has been suggested that the impact of increased salinization of freshwater is the largest threat to global water resources(Williams 2001). Aqueous salinity is a measure of the dissolved mineral content of water and is reported mg/L TDS (total dissolved salts). The quality of water produced from the Ogallala Aquifer generally falls into the category of brackish (1,000-10,000 mg/L TDS)(Hanor 1994). The Dockum Aquifer is a second aquifer that underlies Ogallala Aquifer is categorized as saline with TDS values exceeding 10,000 mg/L(Hanor 1994). In general, water quality decreases in the lower sections of the saturated thickness of an aquifer. It is this phenomena that causes the increased salinization of aquifers over time. In areas such as those overlying the Ogallala Aquifer, pumping of the available groundwater for irrigation creates a situation where a common mechanism for groundwater salinization to occur(Druhan, Hogan et al. 2008). Generally, there would be a diffuse mixing layer of variable thickness that would separate areas of higher and lower salinity. Pumping of groundwater induces the migration of poorer quality water (such as that in the Dockum) and if pumping rates are high enough the saline water can enter the well's capture zone resulting in increasing salinity of water applied to overlaying fields(Kreitler 1993). Once pumping has ceased the cone of depression will begin to fill in, and in the well the water will setup vertically to resemble the water present in the adjacent horizontal strata. Comparing the water quality profiles of wells with depth prior to the growing season (full cone of depression) to after the season ends should allow us to determine vertical changes in water quality of the adjacent geological strata and at what depth the water quality will be sufficient for agricultural irrigation. Additionally, the extent of mixing or migration of low quality water into the wells capture zone can be determined.

C: **Methods**

Wells will be selected based on the saturated thickness of the underlying aquifer as water quality tends to decrease with decreasing saturated thickness unless there is sufficient mixing (McMohan et al., 2004). The saturated thickness will be set into 3 groups: 0-50 feet, 50-100 feet and 100-150 feet. Three to five wells will be used as sampling sites for each of these three groups. At each well, a Solnist (TLC Model 107) Temperature, Level, Conductivity meter will be used to determine the conductivity profile with depth. Conductivity measurements will be taken at 10 cm intervals from the top of the water column to the bottom of the well for each well. These measurements will be obtained before the start of irrigation in April, soon after irrigation is ceased (September) as well as two more times (November and February) to observe the changes in water quality profile as the cone of depression fills in. In addition to these measurements samples will be collected from the wells to observe water quality changes. Other hydrogeological data such as aquifer geology, hydrogeological characteristics such as storage and transmissivity and historical water level measurements will be compiled to provide context to the measurements made in this study and interpret the results.

D: **Expected Outcome**

The results from this study will provide data regarding water quality changes across the Southern High Plains portion of the Ogallala Aquifer. This research effort addresses **sub-objective 3**. Results will provide an estimate of the amount of time that the water being extracted from the aquifer will continue to be useful for irrigation. The results will also provide a hydrologic profile of the aquifer surrounding the wells in the different study areas. This information will be combined to develop a publication on the effects of irrigation on salinity gradients.

## Relevant Papers

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