

# Groundwater and Its Effect on Crop Production

## Background:

Groundwater is characterized as subsurface water and the water-table is the upper surface of the groundwater. Water-table also marks the boundary between the saturated and unsaturated zones. A saturated zone is the zone below the ground where the pore space and cracks in sediments and rocks are completely filled with groundwater, whereas, the unsaturated zone is above the saturated zone, where the pore space is filled with air, water, plant material and soil organisms. Not to be confused with the term aquifers, in this publication the term groundwater is used only in reference to the zone of soil or sediments saturated with water closest to the soil surface.

Good quality groundwater can be an excellent source of water for crops if the water-table is at an optimal depth of about 3 feet and there are drier topsoil conditions.

The quality of groundwater not only affects soil health but poor quality groundwater can severely limit crop yields. Poor quality groundwater is usually the result of high salts or sodium in the water. In addition, water-table at too shallow a depth leads to the depletion of oxygen around plant roots and poses even greater risk of soluble salts and sodium near the soil surface (figure 1).



**Figure 1. Photo of a low-lying area with a very shallow water-table depth along state Highway 1 near Langdon, N.D.**



## Salt Carrier:

The main source of soil salinity and sodicity in North Dakota is the parent material of soils and the underlying sodium-rich shale bedrock below the soil sediments (figure 2). The main carrier for bringing excessive salts/sodium

close to the soil surface is the groundwater.

Glaciation east of the Missouri River mixed and moved these sediments together from the bedrock and the Canadian Shield rock formations resulting in the formation of many closed basins, poorly drained landscapes where high salt/sodium concentrations remain to this day. The high salt concentrations found west of the Missouri River are a result of the high residual salt accumulation from ancient sea water inundation (intrusion) before the glacial periods (Maianu, 2010. Natural Conditions of Salt Accumulations in North Dakota).

When groundwater moves towards the soil surface, through capillary action or shallower water-table depth due to the higher than historically normal rainfall/precipitation, it also brings excessive salts with it. As the water approaches the soil surface, the water evaporates, leaving behind the salts.



**Figure 2. A subsurface soil high in salts, near Forman, N.D.**

There are different methods to test the groundwater quality for different purposes. For crops, soil electrical conductivity is used to estimate the quantity of salts in the water. To test for excessive sodium, ratios of sodium to calcium and magnesium soil ions are analyzed and the ratios are calculated using the formula for exchangeable sodium percentage (ESP) or sodium adsorption ratio (SAR).

The soil pH is also a good measurement to check east of the Missouri River to confirm potential sodium problems. Be advised that in the far west of the state, pH of 5.00 or below can be associated with soils high in sodium.

Groundwater can also be analyzed for Total Soluble Salts (TSS). Groundwater having a Total Soluble Salt level of under 500 ppm will be considered non-saline (figure 3).

Irrigation Water Quality	Electrical Conductivity (dS/m)	Total Soluble Salts (mg/liter)
Non-saline	Less than 0.7	Less than 500
Slightly saline	0.7 to 3.0	500 to 2000
Medium saline	3.0 to 6.0	2000 to 4000
Highly saline	More than 6.0	More than 4000
Very saline	More than 14.0	More than 9000
Brine	More than 42.0	More than 30000

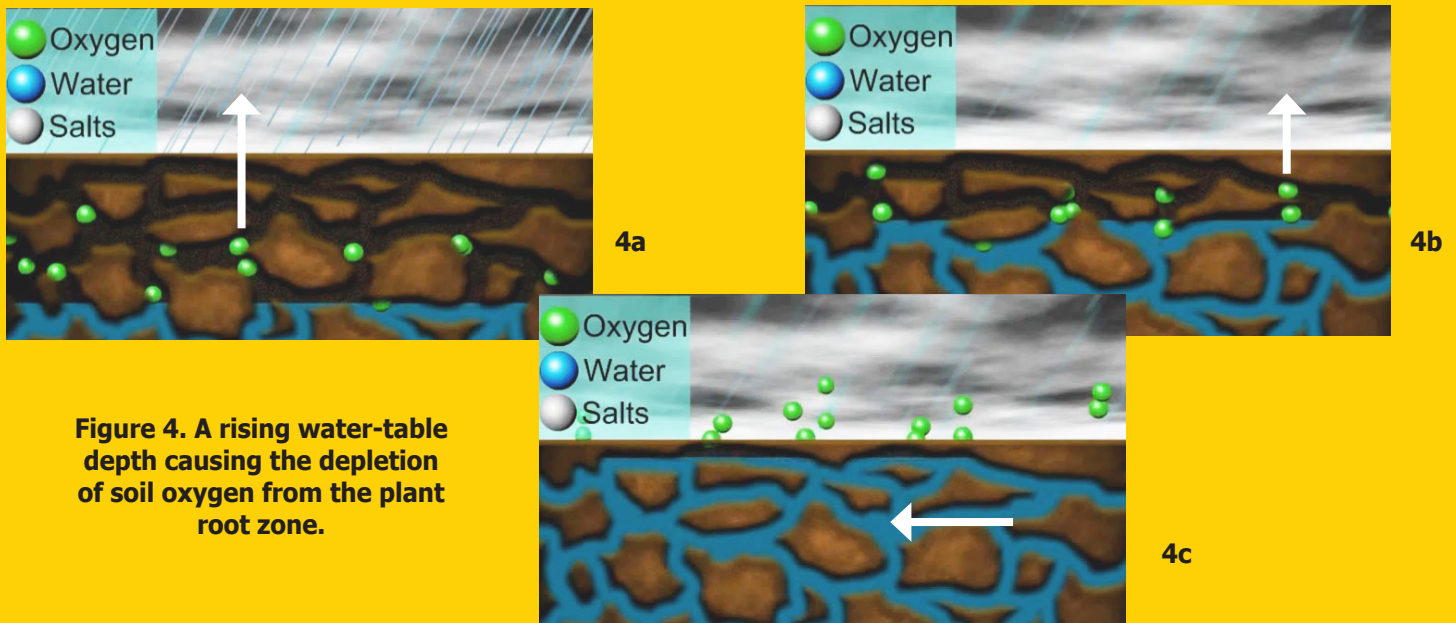
**Figure 3. Levels of Electrical Conductivity and Total Soluble Salts to assess the groundwater quality.**

## Impact on Soil Health:

Groundwater quality and water-table depth have a direct impact on soil health and subsequently crop yields. Good quality groundwater at an optimum water-table depth can increase crop yields by providing the much needed water to the plant roots in the absence of irrigation or rainfall.

Poor quality groundwater will decrease soil health and plant growth when it is shallow enough to be drawn into the rooting zone of crops.

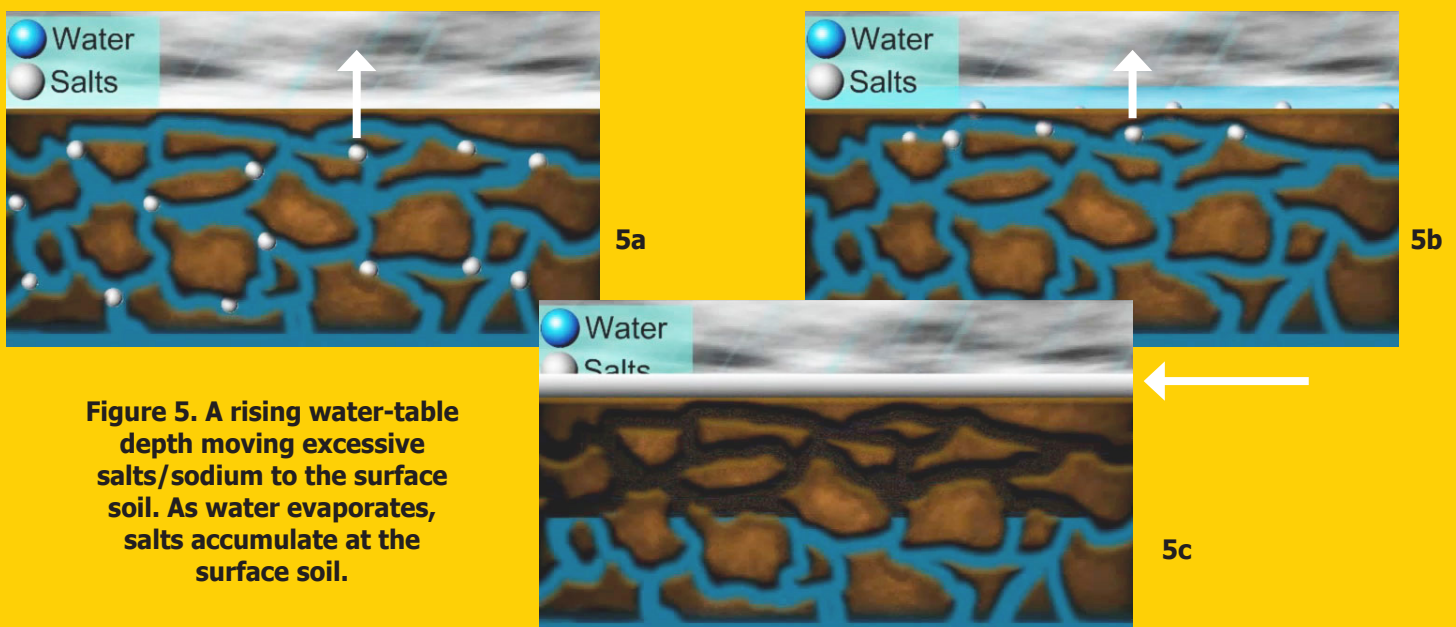
Irrespective of the groundwater quality, if water-table depth rises close to the surface more soil pores will be filled with soil water which depletes oxygen within the plant root zone (figure 4a, 4b and 4c).



**Figure 4. A rising water-table depth causing the depletion of soil oxygen from the plant root zone.**

Plant roots need oxygen to survive and grow. A lack of oxygen results in shallow root systems and poor plant growth. Roots of all North Dakota crops cannot grow in saturated soils.

A shallow water-table depth with poor quality groundwater brings excessive salts and sodium to the soil surface, thus increasing the severity and acreage of saline, sodic or saline-sodic conditions (figure 5a, 5b and 5c).

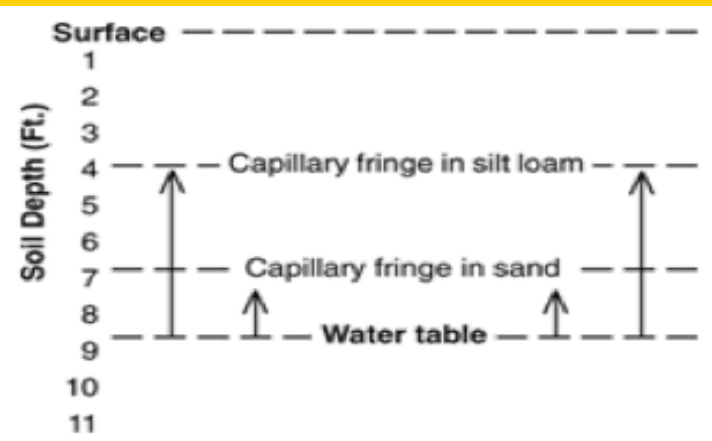


**Figure 5. A rising water-table depth moving excessive salts/sodium to the surface soil. As water evaporates, salts accumulate at the surface soil.**



## Factors Controlling Water-Table Depth:

Water-table depth is affected by the rainfall/precipitation amounts and by irrigation additions. Under wet conditions



**Figure 6. Capillary rise of soil water for different soil textural types (figure courtesy of Dr. Dave Franzen, NDSU Fargo).**

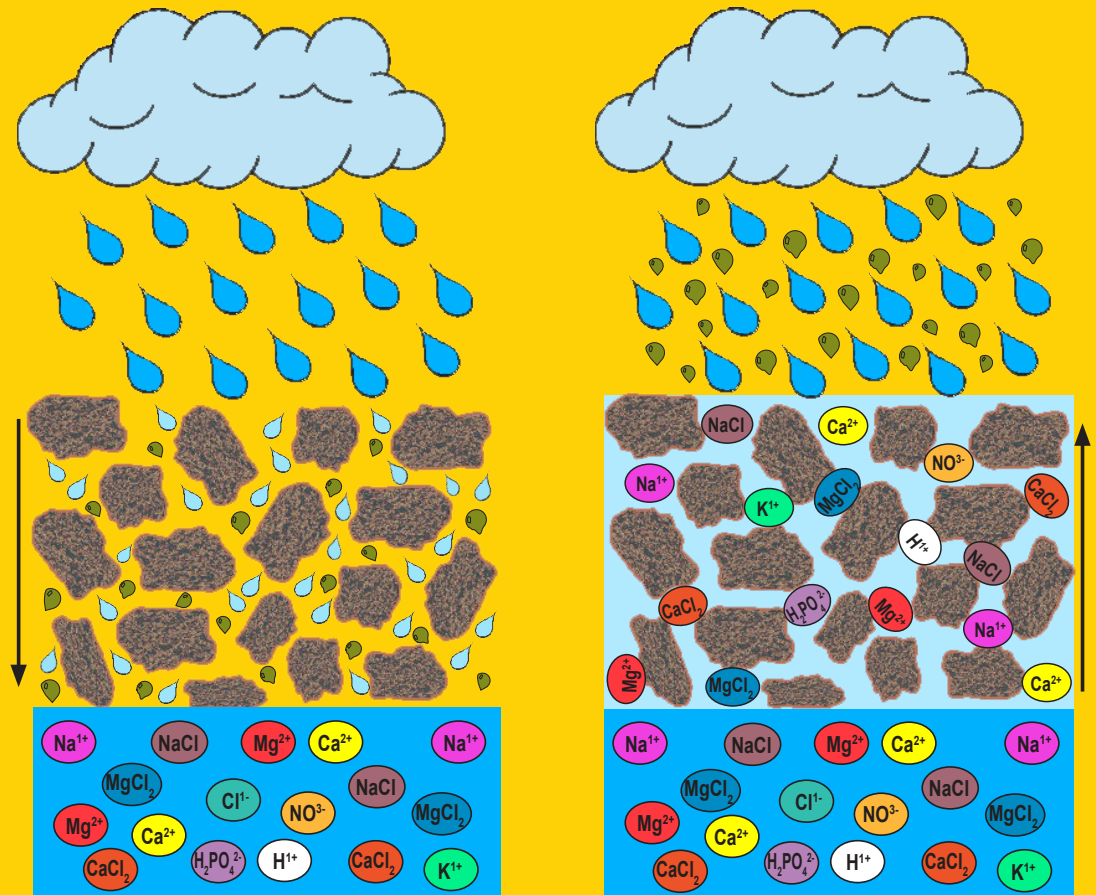
a very shallow water-table depth depletes the oxygen within the root zone for both plant roots and soil microorganisms. Under drier conditions, good quality groundwater can result in high crop yields despite low growing season rainfall, as deeper subsoil water rises to the surface through capillary flow. Subsoil water can move upward through capillary rise as much as 8 feet in finer textured soils, but as little as 2 feet in coarse sandy soils (figure 6).

Capillary rise is maximized in North Dakota in very fine sandy loams, silt loams and some silty clay loams. Our native smectitic clays tend to shrink and crack when dry, preventing very high clay soils such as Fargo and Hegne soil series from achieving their laboratory potential capillary rise.

## Managing Water-Table Depth:

Maintaining water-table levels at an optimum depth to provide the best combination of crop water supply and aeration within the plant root zone, as well as limiting salt accumulation near the soil surface should be a goal of any crop production strategy. By maintaining an optimum water-table depth soils will function optimally and produce economically sustainable yields (figure 7).

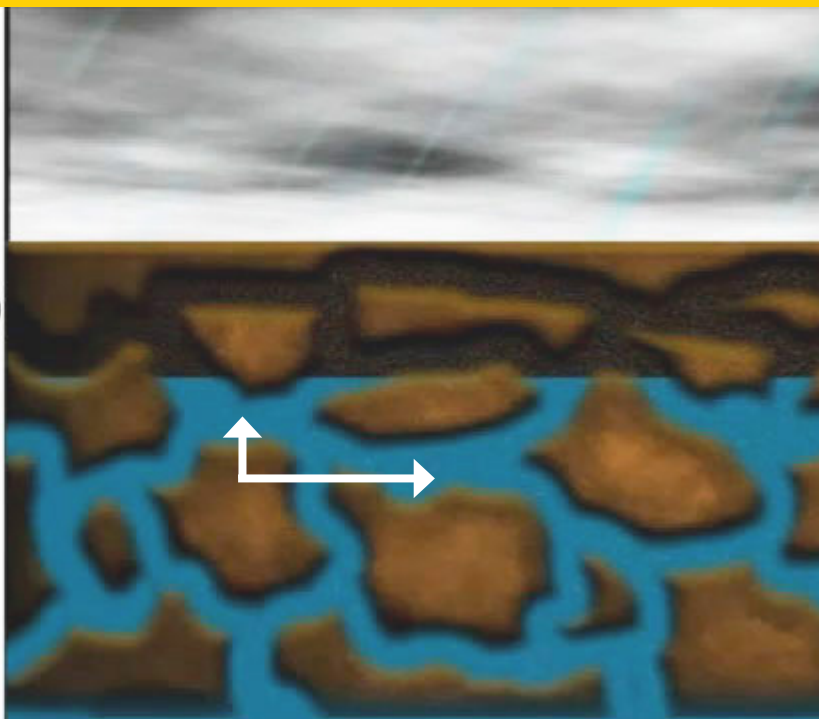
An optimum water-table depth should begin the season at a deep enough depth to allow early seed germination and minimal surface salt accumulation. During the growing season, the groundwater depth should ideally recede to allow the maximum possible rooting depth for the crops (Follett et al., 1978). Optimum water-table depths for corn were found 2 to 3 feet deep, 1.5 to 2 feet for soybeans and about 2 feet deep for alfalfa (figure 8).



**Figure 7. A well-drained soil with low water-table depth on the left versus a saturated soil with a very shallow water-table depth on the right.**



Soybeans (1.5 - 2 feet)  
Alfalfa (2 feet)  
Corn (2-3 feet)



**Figure 8.** Optimum water-table depths for corn, soybean (0.76 to 0.86 meters and 0.46 to 0.61 meters by Williamson and van Schilfgaarde, 1965) and alfalfa (0.61 meter by Tovey, 1963).

### **Saline Seep Management:**

To best manage saline seeps, intercept water above the seep before it exits the hillside of the footslope. This can be achieved without tiling by growing high water using crops such as alfalfa above the seep.

### **Ditch-bank related salinity management:**

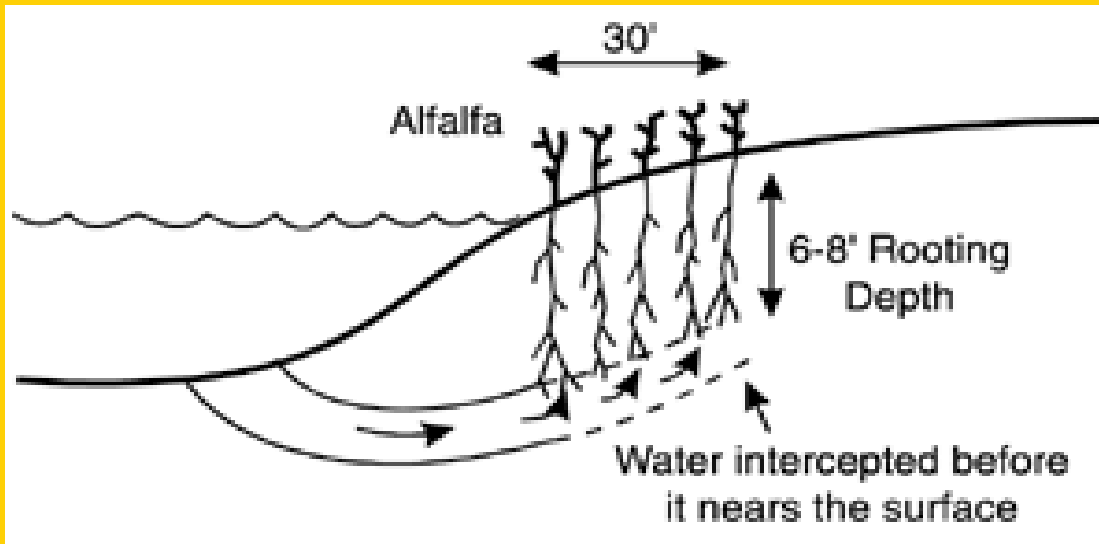
Creating ditches along natural drains in fields is another water-table management strategy. Salinity develops 30-100 feet within the field along a field ditch due to the ditch acting as a shallow pond at some time during the growing season (figure 9).



**Figure 9.** A field ditch, acting as a shallow pond during the growing season along state Highway 17 near Edmore, N.D.



These areas can be minimized by careful planning of ditch water movement towards a natural stream or outlet. Also, a strip of alfalfa planted about 30 feet wide along the ditch has been shown to intercept excessive water from the subsoil movement of ditch water into the field and prevent or alleviate ditch associated salinity (figure 10).



**Figure 10. Alfalfa planted in 30 feet wide strip along a ditch to intercept the excessive movement of subsoil water (figure courtesy of Dr. Dave Franzen, NDSU Fargo).**

To manage moderately shallow water-table depth, deep-rooted late-maturing and high water-using crops, like alfalfa, sunflower and in some cases sugarbeets, are likely rotational choices. If there is time during the growing season either before planting or after harvest, cover crops may be useful in depleting the excessive subsoil water and lowering the water-table to an optimum depth. Selection of crops that have some tolerance to salinity in already affected fields is also important. In the example of growing soybeans, if soil electrical conductivity range from 2.00 to 5.00 dS/m in a field it will result in not only very poor soybean yield, but very low water use, resulting in a greater salinity challenge the following year and a likely increase in the acreage affected by salinity in the field.

For very shallow water-table depth, installation of a subsurface drainage system like tile drainage may become necessary (figure 11).



**Figure 11. Installation of tile drainage in progress in Ramsey County along state Highway 17 near Edmore, N.D. (Photo courtesy of Ronald Beneda, NDSU Cavalier County Extension agent).**



## **Tile Drainage Management:**

In order to get the maximum output out of the drainage system, soils should be thoroughly checked for their sodium and soluble salts content. Tiles installed below or within the sodic or saline-sodic sub-soils may function properly initially, but may lose efficiency due to the leaching of calcium and magnesium based salts and the dominance of sodium causing soil dispersion. This results in the sealing of the soil layers above or around the tiles. Considering the important relationship between gradual drops in the water-table depth during the growing season and high crop yields, a tile drainage system combined with a control drainage structure may be a very good investment as it provides the flexibility of controlling the water-table depth during wet and drier seasons.

To prevent the capillary rise of poor quality groundwater in drier weather, use systems that preserve the surface soil moisture as long as possible. This can be achieved by planting cover crops, mulching of surface soil with plant residues or manure and by not exposing the surface soil to direct sunlight such as conditions achieved under no-till or strip-till. If any of these systems are not possible or unacceptable to the grower, then shallow tillage is at least helpful. Deep tillage or ripping should be avoided to preserve any soil moisture present and to prevent physical movement of salty soil to the surface (figure 12a, 12b, 12c and 12d).



**12a**



**12b**



**12c**



**12d**

**Figure 12. Different ways to minimize the capillary rise of the subsoil water includes planting cover crops (12a), adding manure (12b), mulching the surface soil with plant residues (12c) or by avoiding deep tillage (12d).**

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