APPENDIX C

SUBIRRIGATION AND ITS ASSESSMENT

Introduction

The identification of subirrigated areas (fig. C-1) is important in identifying alluvial valley floors, since alluvial valley floors include areas where water is "sufficient for subirrigation * * * agricultural activities." This appendix is intended to provide the user with an understanding of what subirrigation is, how it can be identified, how it can be mapped, and what references are available on the topic.

General Definitions

Subirrigation, in terms of the alluvial valley floor regulatory program, is "the supplying of water to plants from underneath or from a semi-saturated or saturated zone where water is available for use by vegetation" (30 CFR 701.5). The U.S. Soil Conservation Service (SCS) definition of a naturally subirrigated area is land "with an effective subsurface ground-water table and water rarely over the surface during the growing season" (Zacek and others, undated). Implicit in the SCS definition is that ground water is useable for the entire growing season, or a sizeable portion of it.

When considering subirrigation, biologists are more inclined to consider the plants and plant communities growing in a particular area ground water accessible to them during the entire growing season. These plants experience limited moisture stress, and their life cycles tend to be longer than those of upland plants.

In other areas plants may benefit only a little from subirrigation because available water is only accessible for a short time. In terms of the alluvial valley floor regulatory program, subirrigation occurs if enough water is available for a long enough time to have a recognizable effect on the species type and the productivity of a plant community. Agricultural crops or rangeland must receive enough subirrigation that the community is notably more productive or more agriculturally useful when compared to dryland areas.

Various problems have been encountered in the past by regulatory and industry personnel in defining subirrigated and non-subirrigated areas. These difficulties, some of which are described below, have been experienced because the regulatory process requires that areas of marginal or occasional subirrigation must be classified as either subirrigated or not subirrigated. The regulatory process necessitates a definite delineation of subirrigation and non-subirrigation areas, when, in fact, such arbitrary delineation of these areas is not definitively accurate.

Water supplied by subirrigation is recharged by ground water and not by local infiltration of precipitation, surface runoff, or snowmelt. Areas which are naturally wet because of poor drainage

> Of special importance in the arid and semiarid coal mining areas are alluvial valley floors which are the productive lands that form the backbone of the agricultural and cattle ranching economy of these areas. For instance, in the Powder River Basin of eastern Montana and Wyoming, agricultural and ranching operations which form the basis of the existing economic system of the region could not survive without hay production from the naturally subirrigated and flood irrigated meadows located on the alluvial valley floors. (U.S. House of Representatives, Committee on Interior and Insular Affairs, 1976).

The understanding of an alluvial valley floor is well described in this statement and has been consistently understood in the subsequent passage and implementation of the SMCRA.

The two major aspects of an alluvial valley floor--geology and water resources--are discussed more extensively in the following sections.

A. Geology. As already noted, one of the two fundamental aspects of an alluvial valley floor is its geologic character. Regulations, judicial review, and administrative decisions have expanded and clarified the statutory definition. The geologic criteria of an alluvial valley floor are understood to be:

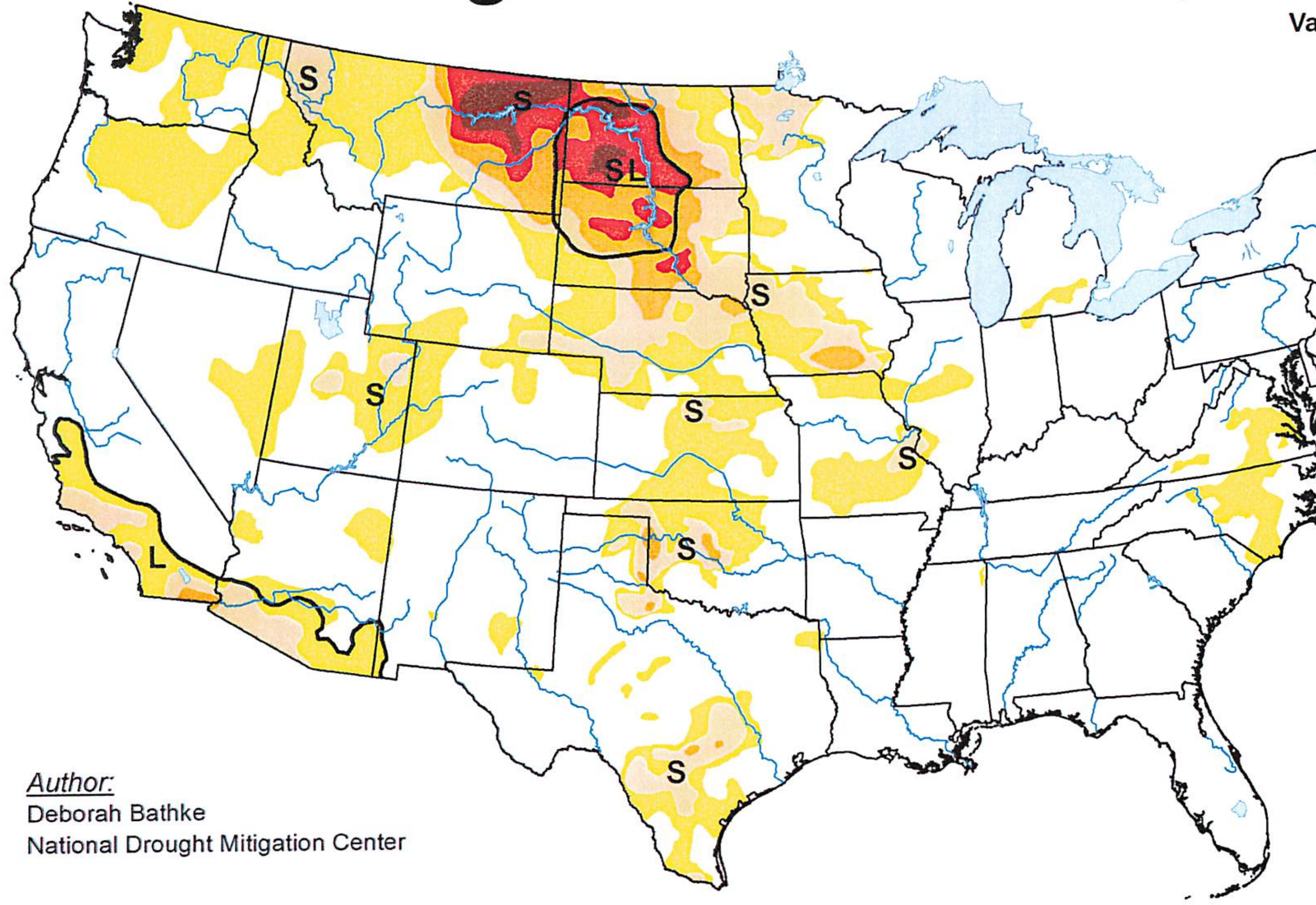
> (a) A TOPOGRAPHIC VALLEY WITH A CONTINUOUS PERENNIAL, INTERMITTENT, OR EPHEMERAL STREAM CHANNEL RUNNING THROUGH IT; AND


06/12/2014


06/12/2014

U.S. Drought Monitor

August 1, 2017
(Released Thursday, Aug. 3, 2017)
Valid 8 a.m. EDT



Author:
Deborah Bathke
National Drought Mitigation Center

Drought Impact Types:

~ Delineates dominant impacts

S = Short-Term, typically less than 6 months (e.g. agriculture, grasslands)

L = Long-Term, typically greater than 6 months (e.g. hydrology, ecology)

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

USDA NDMC

http://droughtmonitor.unl.edu/


06/27/2017


06/27/2017


06/27/2017


06/30/2017

http://www.ext.nodak.edu/extnews/spouts/

water spouts

No. 228 MAY 2007

Upcoming NDSU Field Days and Other Crop-related Events

Streeter Central Grasslands Research Extension Center	June 27	(701) 424-3606
Minot – Canola Day North Central Research Extension Center	June 27	(701) 857-7677
Williston – Pulse Crops Day Research Extension Center	June 29	(701) 774-4315
Minot – Pulse Crops Day North Central Research Extension Center	July 10	(701) 857-7677
Hettinger Research Extension Center	July 10	(701) 567-4323
Dickinson Research Extension Center	July 11	(701) 483-2348
Williston Research Extension Center	July 12	(701) 774-4315
Carrington Research Extension Center	July 17	(701) 652-2951
Minot North Central Research Extension Center	July 18	(701) 857-7677
Sidney, Mont. USDA/ARS Northern Plains Ag Research Lab	July 18	(406) 482-2208
Langdon Research Extension Center	July 19	(701) 256-2582
Mandan USDA/ARS Northern Great Plains Research Lab	July 19	(701) 663-6445
Kidder County and Oakes area *Tour of commercial onion production and processing*	Aug. 28	(701) 223-8332

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Understanding Crop Water Availability

Knowing the average seasonal water use for a crop is important for both irrigated and dryland production. With water resources becoming more expensive to obtain and pump, water management becomes an important issue. Predicting when and how much precipitation will fall during a growing season can be difficult. With irrigation, you have the capability to supply the difference between what the crop needs and what precipitation will supply.

When considering crop water use, root depth is an important factor. Generally, during the fast-growing vegetative stage, the root depth for most annual crops will be approximately the same distance below the soil surface as the crop is above the soil surface. By the time the crop has reached full height, the roots will not develop downward but will continue to produce fine roots in the interval between the surface and the depth of maximum root penetration.

Figure 1 shows the final average effective root depth for each crop (assuming the soil profile will allow full root penetration). The majority of the moisture is obtained from the top half of the root zone, with decreasing extraction by deeper roots. This is because more root mass generally is at the top of the root zone and the root mass tapers off with depth.

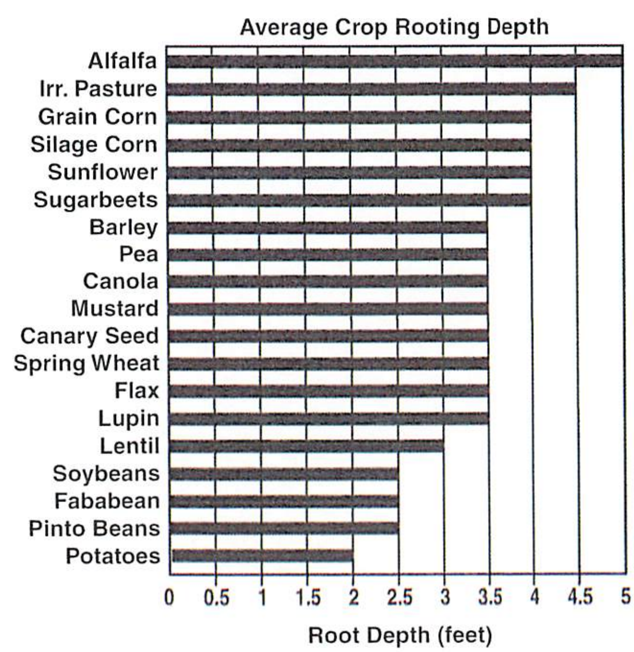

Figure 1. Average root depth for various crops.

Figure 2 shows the average crop total seasonal water needs (precipitation + irrigation + beginning soil water content). Usually full-season crops, such as alfalfa and corn, need more water than short-season or cool-season crops, such as wheat and legumes. Figure 2 gives irrigators an idea of how much irrigation water they need if they know the average rainfall and beginning soil water content.

For irrigation scheduling and allocations of limited water supplies, knowing the crop growth periods that are most sensitive to water stress is an important factor. Figure 3 shows the approximate time frame for North Dakota and growth stage in which moisture stress probably will reduce yield potential. Usually the short-season crops or cool-season legumes will not tolerate stress early in the season, compared with full-season crops that need adequate moisture later in the season.

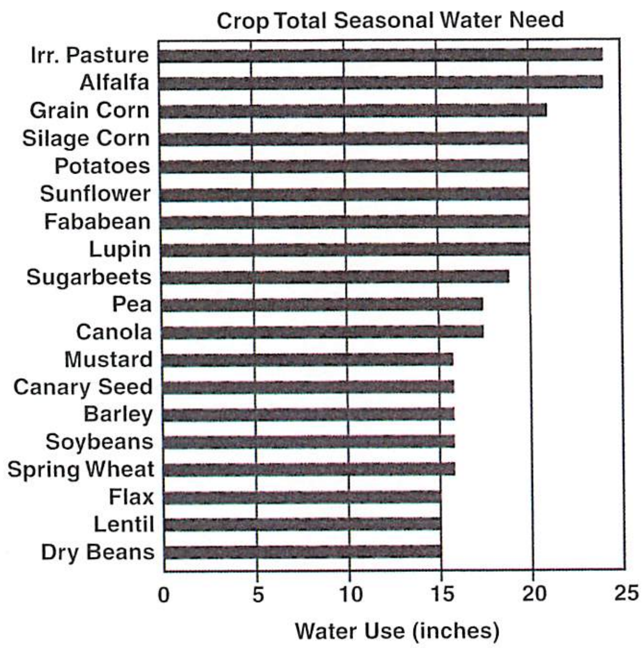

Figure 2. Total seasonal water use for various crops.

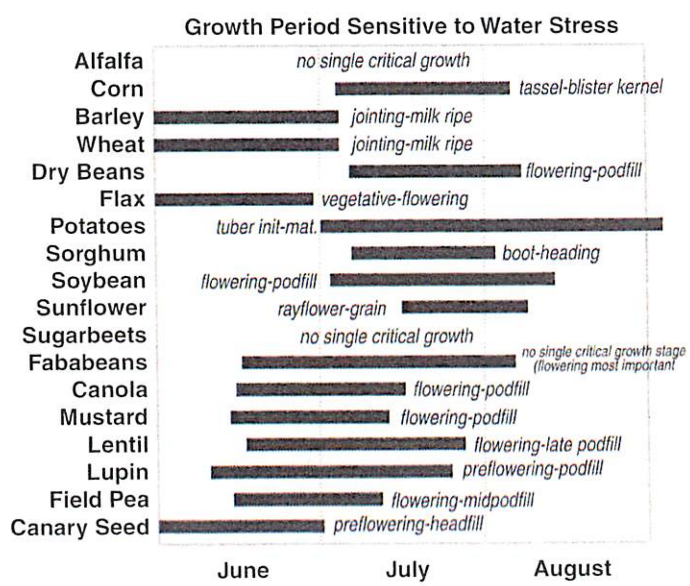

Figure 3. Growth period when crops are sensitive to water stress.

This information is to be used only as a general guideline or comparison among the different crops. More detailed crop water curves and irrigation scheduling criteria have been developed for many of these crops. Irrigation scheduling information is available in Extension publication AE-792, "Irrigation Scheduling by the Checkbook Method," or by accessing the North Dakota Agricultural Weather Network (NDAWN) Web site *(http://ndawn.ndsu.nodak.edu/)* to find estimated daily crop water use values for each weather station on the network.

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Rewritten from a Water Spouts article by David Klinkebiel in 1994

Irrigation System Maintenance and Recordkeeping

Irrigation equipment is no different than other crop production equipment. If not properly cared for, it may fail at the time it is most needed. Fixing small problems is less expensive than fixing a major breakdown during July or August. Repairs should be made early in the season when the crop water demands are low (before June 15). If maintenance was performed on the irrigation system last fall, then early season maintenance should require only checking to see that no damage occurred during the winter.

Spring maintenance should include checking the operation of your well (if you have one), pump, motor, electrical control boxes, piping and distribution system (sprinkler system, gated pipe, etc.) Rodents, dirt and water do the most damage to electrical components. If you don't feel confident performing routine irrigation system maintenance or you don't have the time, most irrigation dealers offer an annual service contract.

Maintaining an efficient well

Most water in the state contains enough iron to provide a source of energy for the growth and development of "iron bacteria." These bacteria are not the cause of high iron concentrations, but grow very well in the constant water temperature in the well. Iron bacteria accumulate on the screen, casing, pump and piping in the form of a slimy, red-brown to pink mass. The accumulation of iron bacteria will plug the open area of the screen and formation, thus reducing the rate at which water can flow into the well. **Chlorination of the well should be done both in the spring and fall; however, if this is not possible, then it should be done in the fall.**

Keeping a well near its original productivity is possible with semiannual chlorination. However, if your well's production last year was low, it may need to be rehabilitated by swabbing and using acid to dissolve encrusted minerals on the screen. Instructions for chlorination and well rehabilitation can be found in NDSU Extension publication AE-97, "Care and Maintenance of Irrigation Wells." If your well needs to be rehabilitated, do it early in the growing season (before the end of June).

Before you turn the pump on for the first time, measure and record the depth to the static water level in the production well and any nearby observation wells. The depth to the static water level and the date of measurement should be recorded in a convenient place, such as the inside of the pump control panel or pivot panel. Compare this year's reading with past readings. This will tell you what is happening in the aquifer.

Check electrical motors, phase converters and control panels

Before starting your irrigation system, check the control panels and equipment condition. To begin, make sure the electrical power to your equipment is **locked in the OFF position** at the main disconnection point. You always should use extreme caution when working around electrical power boxes and machinery. If you are not sure the power is off, use a voltmeter to determine it truly is disconnected.

Electric motors and phase converters are especially susceptible to dust and moisture accumulations, particularly if a severe storm occurred during the winter. High winds can deposit snow and fine dust inside presumably sealed boxes.

If possible, open the motor for better access to the windings. Using compressed air, remove any dirt and dust. While the motor is open, check for rodent entry and damage. If you see evidence of rodent damage, find the entry hole and plug it. Check the motor shaft to see that it turns freely.

Phase converters, especially the static type, should be cleaned thoroughly. If your power supplier furnishes the phase converter, contact the company about servicing it. If you own the phase converter, treat it like other electrical equipment, thoroughly cleaning it with compressed air and cleaning relay contacts with a high-quality electrical contact cleaner.

Open all the electrical panel covers and examine for dirt, rodent damage, leaking door seals, and loose or damaged wires, and ensure that the bare copper grounding wire is properly connected to the panel box and the grounding rod. Examine any relays with exposed contacts. Moisture condensation may have caused corrosion that will make the contacts remain open or be stuck together. Be sure all switches operate freely. If moisture is present, remove it and leave the box open until it dries.

Check the piping and sprinkler systems

Visually inspect the piping between the pump and the distribution system (center pivots, lateral moves, big guns or gated pipe). Check all the air release valves to make sure they are working. Replace broken pressure gauges. Check all valves to make sure they open and close properly.

Check the operators manual for specific maintenance items to look for on your equipment. If for some reason you do not have an operators manual, get one from a dealer or the manufacturer. If the sprinkler system is relatively new, determine what service is required to keep the warranty in effect. Also, determine any other service the manufacturer suggests before the system is put into operation each year.

Repair or replace damaged electrical cables and controls, tighten nuts and bolts. inspect welds and stress points for cracks, and inspect tires and makes sure they are properly inflated. On center pivots, check gearbox lubricant levels, drain off moisture and refill with approved lubricant or change the lubricant if discolored. Inspect seals and gearbox for cracks. Lubricate all fittings, joints, bearings and the pivot point.

The sprinkler system should be checked thoroughly for vandalism and any other winter damage. Many machine manufacturers require that the grease in all gearboxes be drained and replaced. If this is not the case, check all gearboxes for moisture accumulation from condensation. Drain off any moisture and check that the proper amount of grease is in each. All fittings should be greased to replace grease that may have hardened during the winter. Check inflation pressure on all tires. Improper inflation can cause tire breakdown and also may place stress on the drive system. Finally, remove the end cap from the sprinkler boom and leave off until the system has been flushed.

For electric and oil drive center pivots and lateral moves, start the machine and run dry. Listen to each gearbox and motor for abnormal noise, and inspect and repair or replace as needed. On pivots, open the collector ring cover and inspect the brushes and contacts. For the individual tower boxes, do the following:

a) Using compressed air or a good-quality electrical contact cleaner, clean all of the contacts in each box. Do a visual check and clean any corrosion with high-quality sandpaper or emery cloth and apply cleaner.
b) Freeze/thaw cycles cause electrical contacts to loosen. Check and tighten all connection screws. Repair or replace any damaged or broken wires.

Now that you have completed the dry walk-through of the irrigation system, start the pump and put some water through the system. **However, don't stand in front of the main electrical panel when starting the system for the first time. Stand to the side of the panel.**

Check the pump and well performance

Assuming you have performed a "dry walk-through" of the irrigation system, turn on the pump. Listen for any unusual sounds. When the system comes up to pressure, if your flowmeter works, record the flow rate. Compare this with the pump design rate and past recordings. If the flow rate and pressure are the same as in previous years, you can assume the pump and well are in good condition.

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Flush out the piping system. On pivots and lateral moves, flush out the main line by removing the end cap or emptying the sand trap. Replace the end cap. When the system is filled with water, check the sprinklers to see if any are plugged or not operating properly.

After irrigating for a day, if you have a well, record the pumping water level. You can calculate the drawdown by subtracting the static water level from the pumping water level. Record this reading with the flow rate measurement. This will help determine if your well screen is starting to plug. Use a steel tape or electric sounder for measurement readings. Compare these readings to previous years' readings. Divide the flow rate (GPM) by the drawdown to determine the specific capacity of the well (GPM/ft drawdown). If the specific capacity has dropped to 80 percent of original, the well should be acidized. A well should be acidized in the off-season; during the fall is best. If the specific capacity of a well drops to less than 70 percent of its original value, restoring it to the original value is practically impossible.

If the flow rate is less than last year's recorded flow rate, but the drawdown is about the same or less, you may have a problem with the pump. Submersible pumps cannot be adjusted and, if the flow rate has dropped significantly, the pump needs to be pulled and inspected.

Deep-well turbine pumps have an adjustment nut on top of the motor or right-angle gear drive that is used to adjust impeller clearance. Frequently going through this adjustment procedure can improve the flow rate and pressure. Unless you are familiar with making pump adjustments, contact the pump supplier or a well driller for help in determining the problem and making adjustments. A publication on pump adjustment is available from the NDSU Extension Service.

If the flow rate is less than past recordings and the drawdown is more than in the past, the problem is in the well. This indicates water cannot move through the screen into the well as it did in previous years. The cause may be iron bacteria or mineral incrustation plugging the screen openings. Acidizing is needed to remove mineral incrustation. Either one or both processes may be needed to restore a well to its original productivity. Chlorination should precede acidizing. Acidizing is a corrective measure and should be undertaken only after consultation with your well driller to determine its effect on screen and gravel pack.

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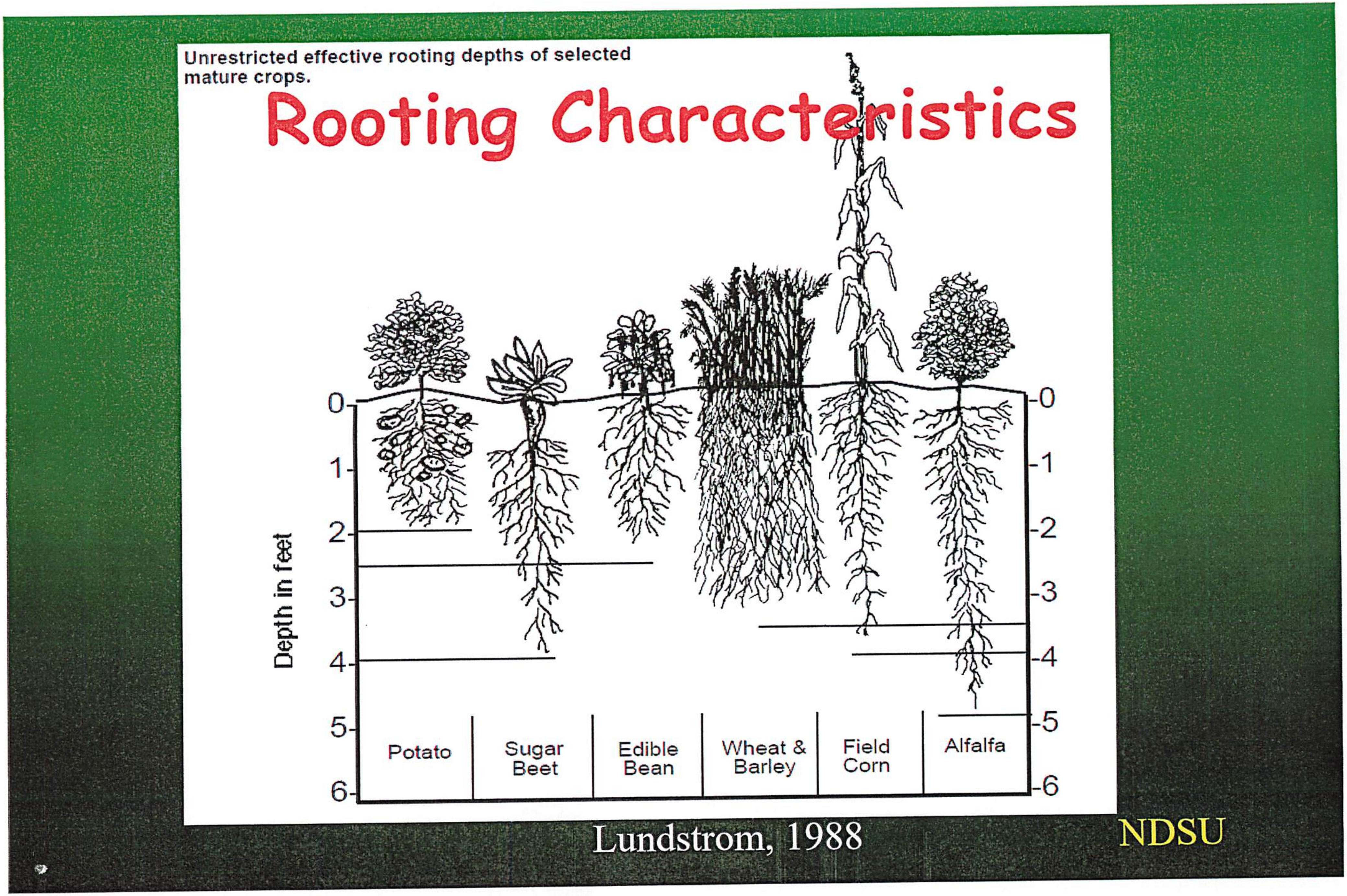
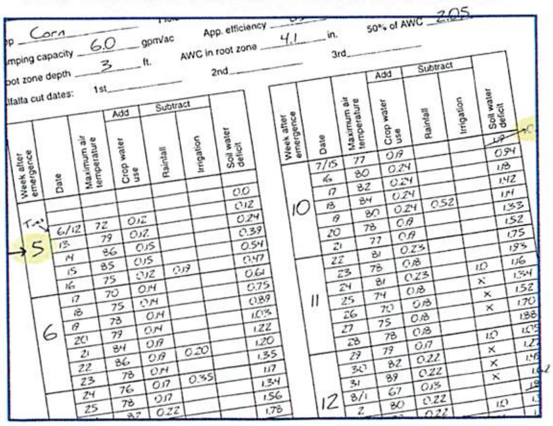
Crop Water Use & Rooting Depth - Crop Rotation for a Dry Cycle

Joel Ransom

NDSU Extension Agronomist

NDSU EXTENSION SERVICE


Unrestricted effective rooting depths of selected mature crops.
Rooting Characteristics
Depth in feet
0
1
2
3
4
5
6
Potato
Sugar Beet
Edible Bean
Wheat & Barley
Field Corn
Alfalfa
Lundstrom, 1988
NDSU



Irrigation Scheduling by the Checkbook Method

Revised by

Thomas F. Scherer
Extension Agricultural Engineer

Dean D. Steele
Associate Professor of Agricultural Engineering

With variable rain events and a mixture of soil types, determining when to irrigate and how much water to apply during the growing season can be a challenge. With too little water, the crop is stressed, while with too much water, crops are stunted and fertilizer is leached below the root zone, and pumping costs are increased. Either way, the crop suffers and reduces the yield.

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North Dakota State University
Fargo, North Dakota

Revised February 2019

Definitions

(Adapted from American Society of Agricultural and Biological Engineers (ASABE) Standard S526.4, used with permission)

Available soil water, more commonly called available water capacity (AWC): The portion of soil water that plant roots of most crops can absorb readily; expressed in millimeters (mm) of water per mm of soil (inches per inch, inches per foot or total inches) for a specific soil depth. It is the amount of water stored in the soil between field capacity (FC) and permanent wilting point (WP). It typically is adjusted for salinity (electrical conductivity) and rock fragment content. In some texts it also is called available water-holding capacity (AWHC).

Crop evapotranspiration (ETc): The amount of water used by the crop in transpiration and building of plant tissue, and that evaporated from adjacent soil or was intercepted by plant foliage. It is expressed as depth in mm (inches, or as the volume-depth ratio of acre-inches per acre) and can refer to daily, peak, design, monthly or seasonal quantities. Sometimes referred to as consumptive use (CU).

Crop water use: Calculated or measured water used by plants; expressed in mm per day (inches per day). Same as ETc except it is expressed as daily use only.

Deficit irrigation: An irrigation water management alternative where the soil in the plant root zone is not refilled to field capacity in all or part of the field.

Field capacity (FC): Amount of water remaining in a soil when the downward water flow due to gravity becomes negligible. An estimate of field capacity ranges between soil water contents at matric potentials of minus 10 to minus 33 kilopascal (kPa) (minus 0.1 to minus 0.33 bar).

Irrigation scheduling: The process of determining when to irrigate and how much water to apply based upon measurements or estimates of soil moisture or water used by the plant.

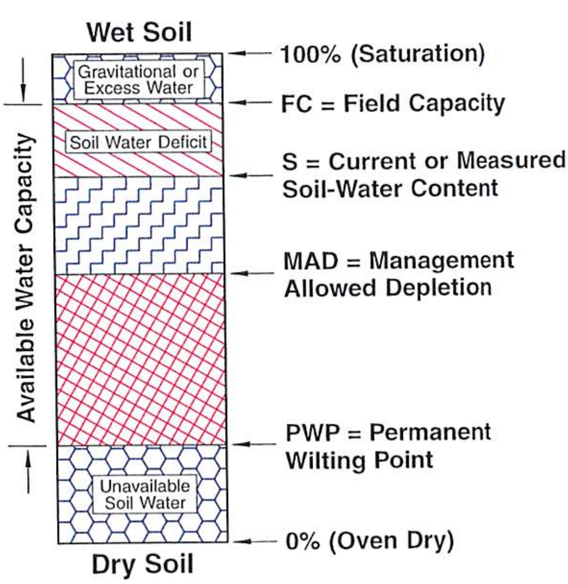
Management-allowed depletion (MAD): The desired soil-water deficit at the time of irrigation.

Permanent wilting point (PWP): Soil water content below which plants cannot readily obtain water and permanently wilt. Sometimes called "permanent wilting percentage," or WP. Often estimated as the water content corresponding to a matric potential of minus 1.5 megapascal (MPa) (minus 15 bar).

Soil-water deficit: Amount of water required to raise the soil-water content of the crop root zone to field capacity. It is measured in mm (inches) of water. Also called soil-water depletion.

Water application efficiency: Ratio of the average depth of water infiltrated and stored in the root zone to the average depth of water applied.

Water-holding capacity (WHC): Total amount of water held in a freely drained soil per increment of depth. It is the amount of water held between field capacity and the oven-dry moisture level; expressed in centimeters/centimeters (cm/cm) (inches/inch), centimeters/meter (cm/m) (inches/foot) or total centimeters (inches) for a specific soil depth. Sometimes called total water-holding capacity.



Adapted from Steele et.al. 2010, Applied Engineering in Agriculture with permission from ASABE

A system for scheduling irrigation using the "checkbook" method is outlined in this publication. It's called the checkbook method because it operates just like a bank checking account. Rain and irrigation are deposits to the soil and the crop withdraws water from the root zone.

During the critical growth periods, the checkbook requires almost daily updates by the irrigator and, if used properly, it is a proven tool for irrigation scheduling.

Quick Start to Using the Checkbook

To use the checkbook method, the irrigation manager needs to obtain the maximum daily air temperature and have at least one and preferably two accurate rain gauges in or near the field being irrigated. Using the maximum daily air temperature, crop water use can be estimated from tables in this publication. The daily water use is entered into a soil water balance sheet to determine the amount of soil water removed from the root zone and the soil water deficit.

Crop water use increases the deficit, but rain and irrigation reduce the deficit. When a predetermined soil water deficit is reached, irrigation should be started.

To start, study the example soil water balance sheet and then begin your own checkbook using the blank copies at the end of this publication.

Soil Water-holding Capacity

The checkbook method is a root-zone soil-water accounting method. The amount of water plant roots can extract is a soil's available water capacity. This is the difference in water content between a wet soil at field capacity and a dry soil at the permanent wilting point.

Soil texture is the major factor affecting soil water-holding capacity. Texture refers to the relative amounts of sand, silt and clay particles in the soil. The available water-holding capacity of the soil must be determined prior to the start of irrigation scheduling.

The available water capacity of soils in the field can be estimated using the values shown in Table 1. If more than one soil type is present in the field, the soil with the lowest water-holding capacity should be used for scheduling irrigations. However, if that soil type covers a relatively small area, the soil type covering the largest area should be used.

More accurate estimates for field soils can be found in the county soil survey books or on the Natural Resources Conservation Service (NRCS) Web Soil Survey website: https://websoilsurvey.sc.egov.usda.gov.

Table 1. Range of plant-available water for different soil textures.

Soil Texture	Inches of Water per Inch of Soil	Inches of Water per Foot of Soil
Coarse sand and gravel	0.02 to 0.06	0.2 to 0.7
Sands	0.04 to 0.09	0.5 to 1.1
Loamy sands	0.06 to 0.12	0.7 to 1.4
Sandy loams	0.11 to 0.15	1.3 to 1.8
Fine sandy loams	0.14 to 0.18	1.7 to 2.2
Loams and silt loams	0.17 to 0.23	2.0 to 2.8
Clay loams and silty clay loams	0.14 to 0.21	1.7 to 2.5
Silty clays and clays	0.13 to 0.18	1.6 to 2.2

The Root Zone

Assuming no subsurface restrictions, at maturity, each crop has a typical fully developed root zone depth. The root zone determines to what depth the plant can extract water from the soil.

The root zone of annual crops may not fully develop until eight weeks after the crop emerges. However, established perennials such as alfalfa and forage grasses will start with deeper roots.

Plant roots extract the greatest amount of soil water from the upper part of the root zone, and each crop is different. Generally, for all the crops shown in Figure 1, more than 90 percent of the water extracted from the root zone during the growing season will come from the depth shown as shaded.

Therefore, a depth less than a fully developed root zone can be used for irrigation management purposes. Fully developed root zone depths, along with irrigation management depths, are shown in Table 2.

At the beginning of crop emergence and growth, having the soil water-holding capacity in the total root zone at or near field capacity is important. Moist soil is necessary for germination and proper root development.

However, low previous autumn rainfall, no winter snow accumulations and less spring rain may result in dry subsoil below about 2 feet. Under these conditions, irrigating prior to or after planting to store water in the lower part of the root zone may be necessary.

Roots will not grow through or into a dry layer of soil, and a reduced root depth will result. Thus, checking the soil moisture to at least the 3-foot depth prior to or at planting time is important.

Table 2. Typical range of crop root depths in deep soils, along with the recommended irrigation water management depth.

Crop	Depth of Fully Developed Root Zone (inches)	Depth of Root Zone for Irrigation Water Management (inches)
Potatoes	24 to 30	18
Soybeans, dry edible beans	30 to 36	24
Wheat, barley, oats	42 to 48	36
Corn, sugar beets, sunflowers	48 to 54	36
Established alfalfa and forage grasses	60 to 72	48

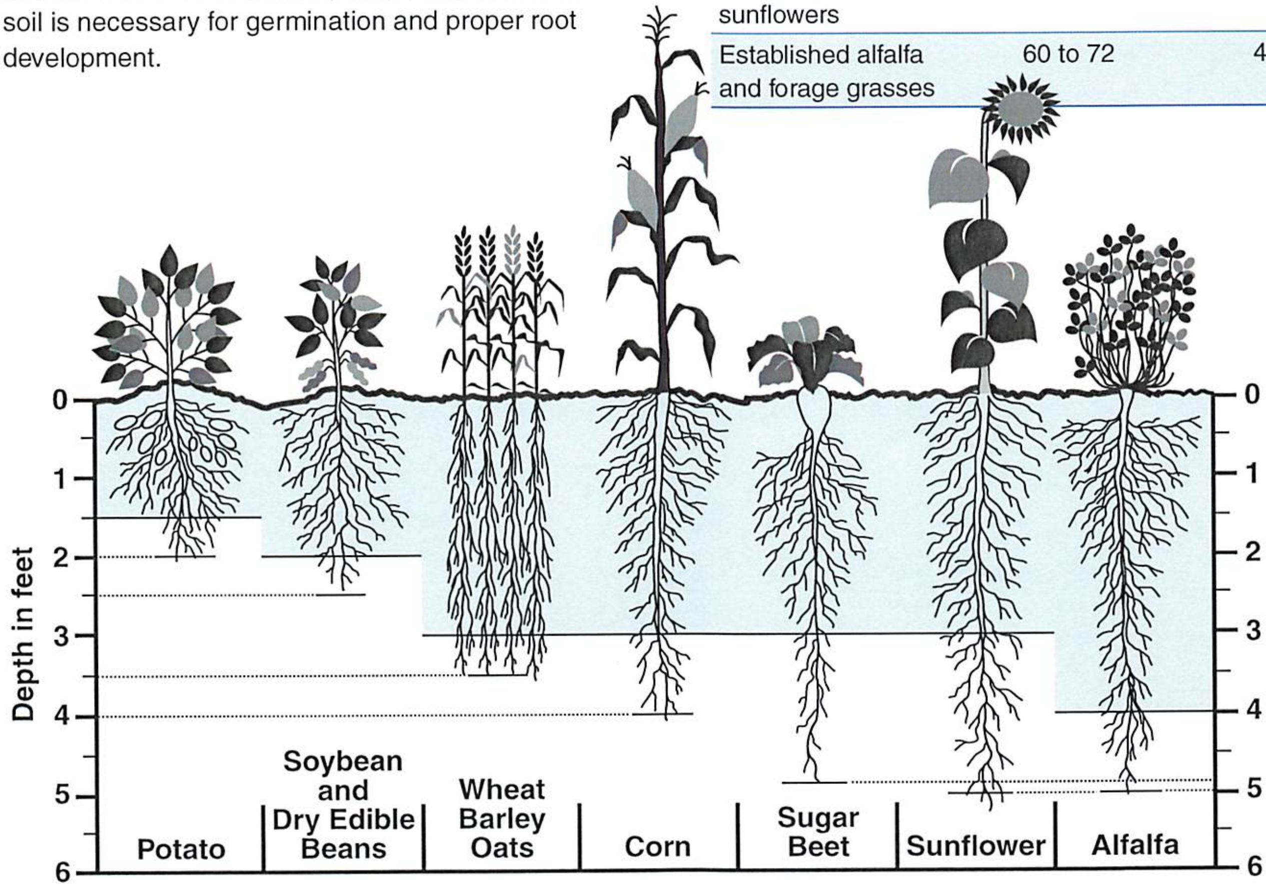


Figure 1. Typical fully developed root zone depths for the commonly irrigated crops in North Dakota. The shaded area is the irrigation water management depth.

NACC-1302 Coyote Creek alluvial water level analysis

Well ID	Location	Location Comment	Date of Reading	MP Elevation	Measured level	Water Elevation	Change since mining began (feet)	Coyote Creek Elev.
CM12-08B	Sec. 31 NE1/4	east side of Voigt's north alfalfa field	3/28/2016	1903.32 ft.	11.40 ft.	**1891.92 ft.**	Pre-mining	
CM12-08B	Sec. 31 NE1/4	east side of Voigt's north alfalfa field	3/19/2019	1903.32 ft.	10.89 ft.	1892.43	+.51	
CM12-08B	Sec 31 NE1/4	east side of Voigt's north alfalfa field	6/25/2019	1903.32 ft.	12.05 ft.	1891.27	-.65	
CM12-08B	Sec. 31 NE1/4	east side of Voigt's north alfalfa field	9/11/2019	1903.32 ft.	11.94 ft.	1891.38	-.54	
CM12-08B	Sec 31 NE1/4	east side of Voigt's north alfalfa field	9/24/2019	1903.32	11.35 ft.	1891.97	+.05	1891.6

From baseline (8/12/2012) to before start of mining (mid-April 2016) water elevations ranged from a low of 1892.26 to a high of 1894.64 (range of 2.38 ft.)
From baseline (8/12/2012) to before start of mining (1st Quarter 2016 measurement) the water level of CM12-08B dropped by .62 ft.
2017 was a significant drought year. From 4th Qtr 2017 to 1st Qtr 2018 the water level of monitoring well CM12-08B increased from 1891.92 to 1893.61 (total of 1.69 ft.)
The 3/27/2018 water level of 1893.61 for monitoring well CM12-08B, after two years of coal removal, represents the 3rd highest water level from this well since 2012 (8 years/30 records)
2014 precipitation was recorded at 26.2 inches. The 2nd and 3rd Quarters of 2014 registered the two highest water level elevations of CM12-08B since 2012 (8 years/30 records)

Well ID	Location	Location Comment	Date of Reading	MP Elevation	Measured level	Water Elevation	Change since mining began (feet)	Coyote Creek Elev.
CM12-20B	Sec. 31 SE1/4	west side of Voigt's south alfalfa field	3/28/2016	1923.31 ft.	12.68 ft.	**1910.63**	Pre-mining	
CM12-20B	Sec. 31 SE1/4	west side of Voigt's south alfalfa field	3/19/2019	1923.31 ft.	12.55 ft.	1910.76	+.13	
CM12-20B	Sec. 31 SE1/4	west side of Voigt's south alfalfa field	6/13/2019	1923.31 ft.	13.12 ft.	1910.19	-.44	
CM12-20B	Sec. 31 SE1/4	west side of Voigt's south alfalfa field	9/11/2019	1923.31 ft.	12.96 ft.	1910.35	-.28	
CM12-20B	Sec. 31 SE1/4	west side of Voigt's south alfalfa field	9/24/2019	1923.31 ft.	12.1 ft.	1911.21	+.58	1911.2

From baseline (8/12/2012) to before start of mining (mid-April 2016) water elevations ranged from a low of 1910.87 to a high of 1913.84 (range of 2.97 ft.)
From baseline (8/12/2012) to before start of mining (1st. Quarter 2016 measurement) the water level of CM12-20B dropped by 1.93 ft.
2017 was a significant drought year. From 4th Qtr 2017 to 1st Qtr 2018 the water level of monitoring well CM12-20B increased from 1910.21 to 1912.35 (total of 2.14 ft.)
2014 precipitation was recorded at 26.2 inches. The 2nd and 3rd Quarters of 2014 registered the highest and 5th highest water level elevations of CM12-208 sinces 2012 (8 years/30 records)

Coyote Creek Mine Precipitation - CoCoRaHS (Data Station ND-MR-7) used from January - April and November - December. May - October data from recording rain gauges at the mine
Beulah Historic Average = 16.59 inches

Year	Inches	
2014	26.2	
2015	12.58	
2016	21.4	
2017	9.55	
2018	15	
2019	17.75	Through the end of 3rd qtr 2019

Table

cc.recgis.cc_gw_levels_2018

objectid *	Well_ID *	Elev_Casing_Top	Date	Depth_to_Water	Water_Elevation	Comments
262	CM12-08B	1903.32	8/12/2012	10.78	1892.54	<Null>
263	CM12-08B	1903.32	11/7/2012	10.69	1892.63	<Null>
264	CM12-08B	1903.32	12/4/2012	10.83	1892.49	<Null>
265	CM12-08B	1903.32	1/16/2013	10.84	1892.48	<Null>
266	CM12-08B	1903.32	3/21/2013	10.07	1893.25	<Null>
267	CM12-08B	1903.32	5/28/2013	9.93	1893.39	<Null>
268	CM12-08B	1903.32	9/13/2013	10.04	1893.28	<Null>
269	CM12-08B	1903.32	3/24/2014	10.12	1893.2	<Null>
270	CM12-08B	1903.32	6/30/2014	9.7	1893.62	<Null>
271	CM12-08B	1903.32	9/15/2014	8.68	1894.64	<Null>
272	CM12-08B	1903.32	11/8/2014	9.78	1893.54	<Null>
273	CM12-08B	1903.32	3/20/2015	9.86	1893.46	<Null>
274	CM12-08B	1903.32	6/30/2015	9.75	1893.57	<Null>
275	CM12-08B	1903.32	9/10/2015	11.06	1892.26	<Null>
276	CM12-08B	1903.32	12/6/2015	10.89	1892.43	<Null>
1127	CM12-08B	1903.32	3/28/2016	11.4	1891.92	<Null>
1205	CM12-08B	1903.32	6/27/2016	11.51	1891.81	<Null>
1283	CM12-08B	1903.32	9/28/2016	11.57	1891.75	<Null>
1361	CM12-08B	1903.32	11/13/2016	11.42	1891.9	<Null>
1437	CM12-08B	1903.32	3/25/2017	10.5	1892.82	<Null>
1513	CM12-08B	1903.32	6/25/2017	11.75	1891.57	<Null>
1589	CM12-08B	1903.32	9/28/2017	11.36	1891.96	<Null>
1665	CM12-08B	1903.32	10/23/2017	11.4	1891.92	<Null>
1786	CM12-08B	1903.32	3/27/2018	9.71	1893.61	<Null>
1787	CM12-08B	1903.32	6/29/2018	11.7	1891.62	<Null>
1788	CM12-08B	1903.32	9/10/2018	11.88	1891.44	<Null>
1789	CM12-08B	1903.32	10/4/2018	11.74	1891.58	<Null>
2030	CM12-08B	1903.32	3/19/2019	10.89	1892.43	<Null>
2031	CM12-08B	1903.32	6/25/2019	12.05	1891.27	<Null>
2032	CM12-08B	1903.32	9/11/2019	11.94	1891.38	PSC measurement
2431	CM12-08B	1903.32	9/24/2019	11.35	1891.97	PSC measurement

Table

cc.recgis.cc_gw_levels_2018

objectid *	Well_ID *	Elev_Casing_Top	Date	Depth_to_Water	Water_Elevation	Comments
939	CM12-20B	1923.31	8/12/2012	10.75	1912.56	<Null>
940	CM12-20B	1923.31	11/5/2012	10.74	1912.57	<Null>
941	CM12-20B	1923.31	12/4/2012	10.74	1912.57	<Null>
942	CM12-20B	1923.31	3/21/2013	9.74	1913.57	<Null>
943	CM12-20B	1923.31	5/28/2013	9.67	1913.64	<Null>
944	CM12-20B	1923.31	9/13/2013	10.38	1912.93	<Null>
945	CM12-20B	1923.31	3/24/2014	10.25	1913.06	<Null>
946	CM12-20B	1923.31	6/22/2014	9.47	1913.84	<Null>
947	CM12-20B	1923.31	9/12/2014	10.27	1913.04	<Null>
948	CM12-20B	1923.31	11/7/2014	11.51	1911.8	<Null>
949	CM12-20B	1923.31	3/20/2015	11.34	1911.97	<Null>
950	CM12-20B	1923.31	6/20/2015	10.49	1912.82	<Null>
951	CM12-20B	1923.31	9/10/2015	12.44	1910.87	<Null>
952	CM12-20B	1923.31	10/21/2015	12.39	1910.92	<Null>
1174	CM12-20B	1923.31	3/28/2016	12.68	1910.63	<Null>
1252	CM12-20B	1923.31	6/27/2016	13.02	1910.29	<Null>
1330	CM12-20B	1923.31	9/28/2016	12.97	1910.34	<Null>
1408	CM12-20B	1923.31	11/13/2016	12.92	1910.39	<Null>
1484	CM12-20B	1923.31	3/25/2017	11.93	1911.38	<Null>
1560	CM12-20B	1923.31	6/25/2017	13.18	1910.13	<Null>
1636	CM12-20B	1923.31	9/28/2017	13.06	1910.25	<Null>
1712	CM12-20B	1923.31	10/24/2017	13.1	1910.21	<Null>
1974	CM12-20B	1923.31	3/27/2018	10.96	1912.35	<Null>
1975	CM12-20B	1923.31	6/29/2018	12.78	1910.53	<Null>
1976	CM12-20B	1923.31	9/10/2018	13.34	1909.97	<Null>
1977	CM12-20B	1923.31	10/5/2018	13.17	1910.14	<Null>
2033	CM12-20B	1923.31	3/19/2019	12.55	1910.76	<Null>
2034	CM12-20B	1923.31	6/25/2019	13.12	1910.19	<Null>
2035	CM12-20B	1923.31	9/11/2019	12.96	1910.35	PSC measurement
2432	CM12-20B	1923.31	9/24/2019	12.1	1911.21	PSC measurement