GeoSystems Analysis, Inc.
Innovative Solutions

TECHNICAL MEMORANDUM

September 19, 2018

TO: Matthew McMillan, SWCA Environmental Consultants

FROM: Todd Caplan & William Widener

RE: Soil sampling and piezometer installation at Candelaria Farms

The purpose of this technical memo is to report methods, results and locations of soil assessments and groundwater monitoring well installations as part of the Candelaria Farms Nature Preserve development project (SWCA Project No. 42157.02).

Soil Assessment

GeoSystems Analysis, Inc. (GSA) assessed soil conditions at the Candelaria Farms project area on July 20, 2018. Bore hole locations (**Figure 1**) were guided by soil map units previously delineated by the Natural Resources Conservation Service (NRCS) and published online https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx. **Appendix A** contains a table with detailed technical descriptions of each NRCS soil map unit.

A hand-held soil auger was used to bore 10 holes to a depth of eight feet or to the water table, which ever was encountered first. Soils extracted from each bore hole were placed on a tarp in approximately 12-inch segments in order from ground surface to bottom of bore hole. Soil texture was recorded for each depth increment where there was a distinct color break and/or textural change. Textures were estimated in the field using the "texture by feel" procedure (Thien 1979[1]). Results from the field texture assessment are presented in **Table 1**.

Ten soil samples from different bore holes were sent to Green Analytical Laboratory (Durango, CO) for chemical analysis. Analyses included salinity (electrical conductivity of a saturated paste extract – ECe), particle size distribution (6-hour hydrometer, modified Bouyoucos) and sodium adsorption ratio (SAR). Laboratory results are presented in **Table 2**.

[1] S.J. Thien. 1979. A flow diagram for teaching texture by feel analysis. Journal of Agronomic Education, 8:54-55.

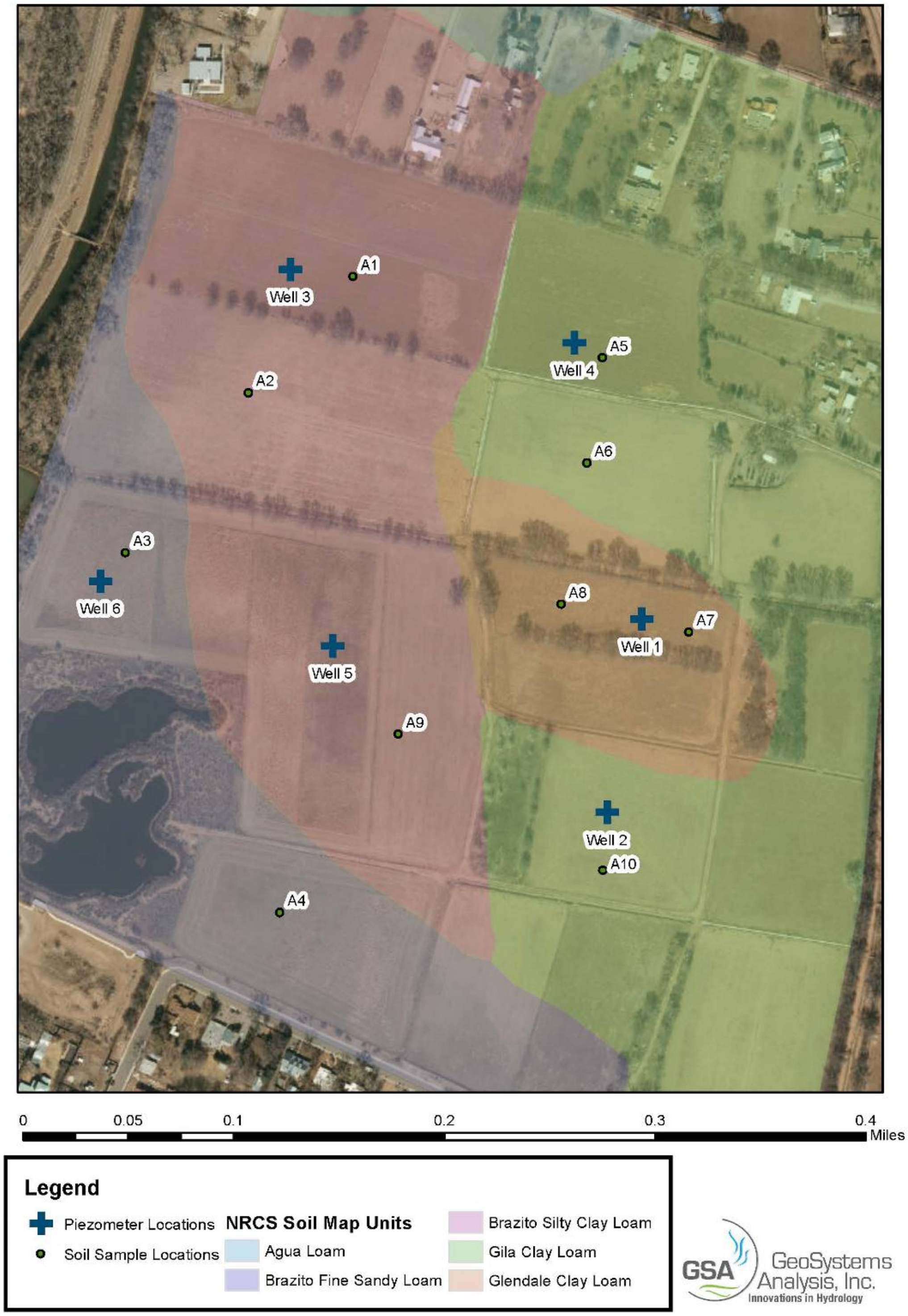

Figure 1. Map showing NRCS soil map units and locations of GSA soil bore holes and piezometer installations.

Table 1. Soil bore hole texture log.

Bore Hole #	Depth Increment (inches)	Field Texture	Notes
A1	**0-12***	Clay	Moist
	12-15	Sandy Clay Loam	Moist
	16-22	Loam	Moist; Distinct mottles
	22-34	Sand	Moist; Distinct mottles, root staining
	34-60	Coarse sand	Moist
	60-68	Coarse sand w/gravel & cobble	Moist
	68-96	Gravelly sand w/cobble	Very moist; **Water table at 94"**
A2	0-10	Loam	Very slightly moist
	10-30	Fine sand	Very slightly moist
	30-46	Sand	Slightly moist; Few mottles
	46-60	Coarse sand w/gravel	Moist
	60-80	Coarse sand w/gravel and cobble	Very moist; **Water table at 80"**
A3	0-10	Loam	Very slightly moist
	10-15*	Clay loam	Slightly moist
	15-33*	Sand	Moist
	33-46	Coarse sand w/gravel	Moist
	46-66	Coarse sand w/gravel and cobble	Very moist; **Hole collapses and prevents boring deeper**
A4	0-12	Silt loam	Slightly moist
	12-30	Sand	Slightly moist; Distinct mottles/common;
	30-66	Coarse sand	Moist; Diffuse mottle/many
	66-72	Coarse sand	Very moist
	72-96	Coarse sand w/gravel & cobble	Very moist; **Water table not reached**
A5	0-17*	Clay	Slightly moist
	17-19	Sandy loam	Slightly moist
	19-26	Silty clay	Slightly moist
	26-38*	Loam	Slightly moist
	38-45	Silty clay loam	Slightly moist
	45-63	Sand	Moist
	63-70	Coarse sand	Moist; Distinct mottles/common
	70-96	Coarse sand w/gravel	Very moist; **Water table not reached**
A6	**0-12***	Clay	Slightly moist
	12-24	Silty clay	Slightly moist
	24-36*	Clay	Slightly moist
	36-70	Fine sand	Slightly moist; diffuse mottles/few
	70-84	Coarse sand	Moist; Diffuse mottles/few
	84-96	Coarse sand w/gravel and cobble	Very moist; **Water table not reached**
A7	0-12	Silty clay	
	12-24*	Clay	
	24-40	Loamy sand	Slightly moist
	40-55	Sand	Slightly moist; Distinct mottles/few but increase with depth
	55-96	Coarse Sand	Very moist; **Water table not reached**
A8	0-15	Silty clay	Slightly moist
	15-24	Loam	Slightly moist
	24-27	Sandy loam	Slightly moist
	27-32	Fine sand	Slightly moist
	32-60	Sand	Slightly moist
	60-66	Sand w/gravel	Moist
	66-96	Coarse sand w/gravel and cobble	Very moist; **Water table not reached**

Bore Hole #	Depth Increment (inches)	Texture	Notes
A9	0-6	Loam	
	6-12*	Sandy Clay loam	
	12-24	Fine sand	
	24-36	Sand	Slightly moist; Distinct mottles/few
	36-65	Sand	Moist
	65-88	Coarse sand w/gravel and cobble	Very moist; **Water table at 88”**
A10	**0-12***	Clay loam	
	12-28	Loamy sand	Very slightly moist
	28-32	Fine sand	Slightly moist
	32-44	Loamy sand	Distinct mottles/few; slightly moist
	44-56	Sand	Diffuse mottles/few; moist
	56-86	Coarse sand w/gravel	Very moist; **Water table at 86”**

*samples collected for laboratory analysis

Table 2. Laboratory Analytical Results Summary

Sample Name; Depth	% Sand	%Silt	%Clay	Conductivity (mmhos/cm)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	SAR
A1; 0-12 in.	21.3	37.5	41.3	0.97	174	19.5	39.7	0.76
A3; 10-15 in.	42.5	26.3	31.3	0.54	72	11.2	31.3	0.91
A3; 15-33 in.	95	5	0	0.31	39.9	5.1	20.6	0.82
A5; 0-17 in.	12.5	38.8	48.8	0.79	131	15.7	37	0.81
A5; 26-38 in.	36.3	45	18.8	0.59	85.7	9.03	33.4	0.92
A6; 0-12 in.	7.5	36.3	56.3	0.91	145	17.3	46.9	0.98
A6; 24-36 in.	3.8	38.8	57.5	0.68	93.3	10.7	45.1	1.18
A7; 12-24 in.	3.8	38.8	57.5	0.59	80.2	10.5	35.5	0.99
A9; 6-12 in.	55	20	25	0.58	80.6	11.6	28.1	0.77
A10; 0-12 in	45	22.5	32.5	0.60	80.2	11.9	29.5	0.81

Lab Data Application:

Soil Sodicity: The accumulation of sodium in fine-grained soils can result in sodicity. Sodic soils are defined as having a sodium adsorption ratio (SAR) values greater than or equal to 13. Sodicity negatively affect riparian species due to toxic effects of sodium and typically-associated high pH values; plant nutrient deficiencies due to imbalances in soil cations; and negative impacts on germination, growth, and survival from changes in soil structure. Sodic soils are typically rich in clay and contain high amounts of sodium ($Na^{+)}$ and low amounts of calcium (Ca^{2+}) and magnesium (Mg^{2+}). As shown in **Table 2** (far right column), all the samples had very low SAR levels, with the highest being only 1.18 (i.e., these soils are not sodic).

Soil salinity: Electrical conductivity is used to measure salt concentration in the soil. High sodium salt concentration results in high osmotic potential of the soil solution, so the plant has to use more energy to absorb water. Under different salinity conditions, certain plants are unable to absorb water and will wilt, even when the surrounding soil is saturated. Riparian plants like cottonwood and willow have a low tolerance for soil salinity, and these species will suffer from reduced growth or death at relatively low concentrations. Soil salinity units are typically expressed as mmhos/cm. Published literature reports that cottonwood and willow suffer when salinity levels exceed approximately 4 mmhos/cm. The laboratory data found that salinity levels are all below 1 mmhos/cm (i.e., salinity is not currently a limiting factor for salt sensitive plant species).

The field texture assessment and the lab data indicate that the NRCS soil mapping (**Figure 1**; **Appendix A**) is reasonably accurate in predicting spatial distribution of sandy vs. clayey soils. The NRCS soil map unit boundaries used in combination with our soil laboratory results should serve as a reasonable guide when prescribing different plant communities for future revegetation treatments at Candelaria Farms.

Piezometer Installation

Six shallow groundwater monitoring wells (piezometers) were installed on September 5 and 6, 2018. Wells were distributed across the different NRCS soil map units (**Figure 1**). Each piezometer was constructed using one 2-inch diameter, 6-foot long stainless-steel screen (0.012 mm) with a welded drive point. Each stainless-steel screen was manually connected in the field to two five-foot long galvanized steel pipes using 2-inch threaded galvanized steel couplings. Total external length of each piezometer was approximately 16-feet (**Figure 2**).

Pre-determined installation locations were navigated to using a hand-held GPS unit. Bore holes were opened to a depth of eight-feet using a hand-held soil auger. A piezometer was placed in each bore hole and a 40-lb fence-post driver was used to drive each piezometer into the groundwater table until only approximately 28-36 inches remained above the ground surface (**Figure 2**). The sand excavated from the bore hole was used to fill the space between the pipe and the hole perimeter using a rebar to pack the sand tightly. Bentonite clay pellets or natural clay extracted from the bore hole was added to the upper three inches and packed firmly to form a seal near the ground surface.

Once installation of each well was completed, we measured and recorded the internal length of each piezometer, recorded the depth to groundwater using an electronic water sounder, and measured the length of pipe exposed above ground ("top of casing height"; **Table 3**). A locking well cap was then placed to cover the exposed pipe opening (Note: we did not install padlocks). Lastly, a 4-foot rebar was installed approximately 2-feet into the ground next to each piezometer and a 10-foot long PVC pipe was placed over the rebar. The PVC was marked with pink spray-paint and yellow tape flagging to improve visibility for farm tractor operators and for those responsible for future groundwater monitoring.

Table 3. Piezometer installation specifications. Depth to groundwater measurements recorded on September 6, 2018.

Piezometer ID	**UTM Coordinates Northing**	**Easting**	**Inside Length (ft)**	**Top of Casing (TOC) (ft.)**	**DTW (ft.) (measured from TOC)**	**DTW (ft. below ground surface)**
Well 1	35.1315	-106.6768	16.29	2.29	13.01	10.72
Well 2	35.1302	-106.6771	16.1875	2.75	12.65	9.90
Well 3	35.1339	-106.6798	16.0	2.58	9.92	7.34
Well 4	35.1334	-106.6774	16.33	2.77	12.89	10.12
Well 5	35.1313	-106.6794	16.25	2.68	10.02	7.34
Well 6	35.1318	-106.6814	15.75*	2.82	9.15	6.33

*Internal pipe length was less than 16' due to sediment seeping through screen during installation. Internal lengths should be measured periodically to track sedimentation.

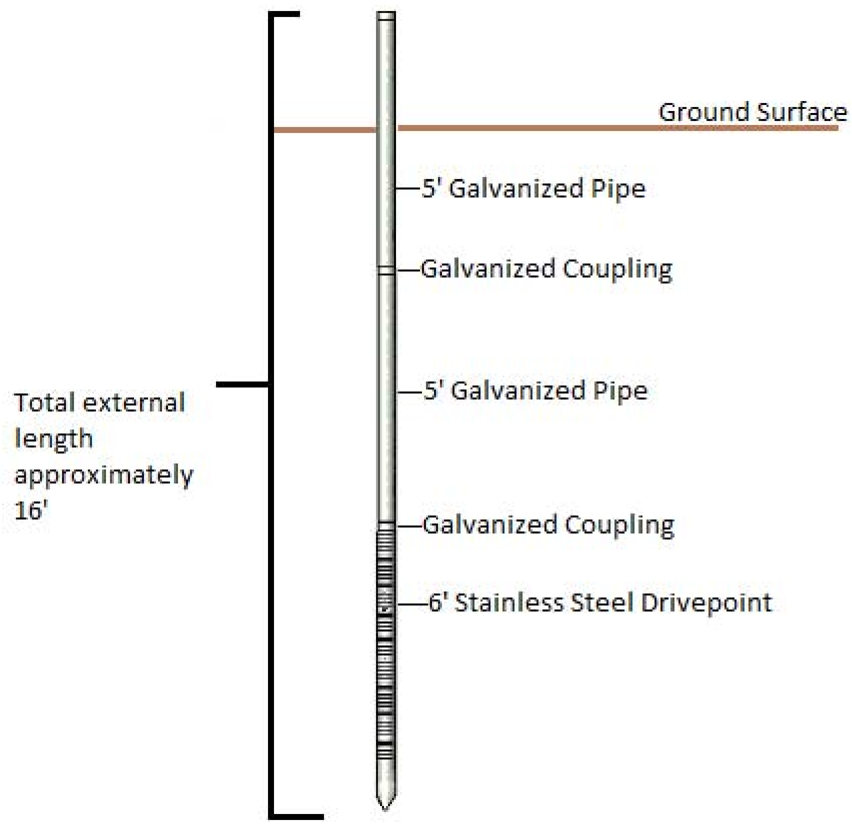

Figure 2. Schematic of piezometer construction specifications.

APPENDIX A. NRCS Soil Map Units for Candelaria Farms.

Map symbol and soil name	Depth	Sand	Silt	Clay	Moist bulk density	Saturated hydraulic conductivity	Available water capacity	Linear extensibility	Organic matter	Erosion factors			Wind erodibility group	Wind erodibility index
										Kw	Kf	T		
	In	Pct	Pct	Pct	g/cc	micro m/sec	In/In	Pct	Pct					
Af—Agua loam MLRA 42														
Agua	0-10	-42-	-38-	15-20- 25	1.40-1.50-1.55	4.23-9.17-14.11	0.18-0.19-0.20	0.0- 1.5- 2.9	0.5- 0.8-1.0	0.37	0.37	3	6	48
	10-24	-45-	-41-	10-14-18	1.40-1.50-1.55	4.23-9.17-14.11	0.17-0.19-0.20	0.0- 1.5- 2.9	0.3- 0.3-0.5	0.43	0.43			
	24-60	-95-	- 1-	0- 4- 8	1.40-1.50-1.55	42.34-91.74-141.14	0.03-0.05-0.06	0.0- 1.5- 2.9	0.1- 0.2-0.3	0.02	0.05			
Br—Brazito fine sandy loam MLRA 42														
Brazito	0-5	-69-	-22-	5-10-15	1.45-1.50-1.55	14.11-28.23-42.34	0.13-0.14-0.15	0.0- 1.5- 2.9	0.4- 0.5-0.6	0.28	0.28	5	3	86
	5-60	-90-	- 4-	2-6-10	1.40-1.45-1.50	42.34-91.74-141.14	0.05-0.06-0.07	0.0- 1.5- 2.9	0.2- 0.3-0.3	0.05	0.05			
Bs—Brazito silty clay loam MLRA 42														
Brazito	0-12	-18-	-51-	28-32- 35	1.40-1.50-1.55	1.41-2.82-4.23	0.19-0.20-0.21	0.0- 1.5- 2.9	0.3- 0.4-0.5	0.37	0.37	2	6	48
	12-60	-94-	- 1-	0- 5- 10	1.40-1.50-1.55	141.14-141.14-141.14	0.04-0.05-0.06	0.0- 1.5- 2.9	0.2- 0.3-0.5	0.1	0.1			
Ge—Gila clay loam MLRA 42														
Gila	0-7	-35-	-33-	28-32- 35	1.35-1.40-1.45	1.41-2.82-4.23	0.13-0.14-0.15	3.0- 4.5- 5.9	0.5- 0.8-1.0	0.24	0.24	5	6	48
	7-60	-30-	-56-	10-14-18	1.35-1.40-1.45	4.23-9.17-14.11	0.17-0.18-0.19	0.0- 1.5- 2.9	0.3- 0.5-0.6	0.37	0.49			
Gm—Glendale clay loam, 0 to 1 percent slopes MLRA 42.1														
Glendale	0-6	21-26- 50	20-44-53	20-30- 39	1.40-1.44-1.47	1.40-2.70-4.00	0.17-0.19-0.21	2.2- 4.2- 6.1	0.5- 0.8-1.0	0.43	0.43	4	4L	86
	6-13	5-10-30	40-68-88	5-22-35	1.29-1.37-1.45	4.00-9.00-14.00	0.15-0.18-0.21	0.4- 2.7- 5.1	0.1- 0.3-0.5	0.49	0.49			
	13-16	88-88- 95	0- 7-10	2-5-8	1.55-1.60-1.65	42.00-92.00-141.00	0.05-0.07-0.08	0.1- 0.4- 0.7	0.1- 0.3-0.5	0.1	0.1			
	16-38	2-5-30	41-70-88	5-25-35	1.31-1.38-1.44	4.00-9.00-14.00	0.15-0.18-0.21	0.4- 3.2- 5.1	0.1- 0.3-0.5	0.49	0.49			
	38-46	10-17-45	3-38-70	20-45- 55	1.27-1.36-1.46	0.01-0.22-0.42	0.14-0.15-0.16	2.1- 7.1- 9.6	0.1- 0.3-0.5	0.32	0.32			
	46-60	5-26-30	35-44-72	5-30-35	1.39-1.40-1.42	4.00-9.00-14.00	0.17-0.19-0.21	0.4- 4.1- 5.1	0.1- 0.3-0.5	0.43	0.43			

Physical Soil Properties

This table shows estimates of some physical characteristics and features that affect soil behavior. These estimates are given for the layers of each soil in the survey area. The estimates are based on field observations and on test data for these and similar soils.

Depth to the upper and lower boundaries of each layer is indicated.

Particle size is the effective diameter of a soil particle as measured by sedimentation, sieving, or micrometric methods. Particle sizes are expressed as classes with specific effective diameter class limits. The broad classes are sand, silt, and clay, ranging from the larger to the smaller.

Sand as a soil separate consists of mineral soil particles that are 0.05 millimeter to 2 millimeters in diameter. In this table, the estimated sand content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Silt as a soil separate consists of mineral soil particles that are 0.002 to 0.05 millimeter in diameter. In this table, the estimated silt content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

Clay as a soil separate consists of mineral soil particles that are less than 0.002 millimeter in diameter. In this table, the estimated clay content of each soil layer is given as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter.

The content of sand, silt, and clay affects the physical behavior of a soil. Particle size is important for engineering and agronomic interpretations, for determination of soil hydrologic qualities, and for soil classification.

The amount and kind of clay affect the fertility and physical condition of the soil and the ability of the soil to adsorb cations and to retain moisture. They influence shrink-swell potential, saturated hydraulic conductivity (Ksat), plasticity, the ease of soil dispersion, and other soil properties. The amount and kind of clay in a soil also affect tillage and earthmoving operations.

Moist bulk density is the weight of soil (ovendry) per unit volume. Volume is measured when the soil is at field moisture capacity, that is, the moisture content at 1/3- or 1/10-bar (33kPa or 10kPa) moisture tension. Weight is determined after the soil is dried at 105 degrees C. In the table, the estimated moist bulk density of each soil horizon is expressed in grams per cubic centimeter of soil material that is less than 2 millimeters in diameter. Bulk density data are used to compute linear extensibility, shrink-swell potential, available water capacity, total pore space, and other soil properties. The moist bulk density of a soil indicates the pore space available for water and roots. Depending on soil texture, a bulk density of more than 1.4 can restrict water storage and root penetration. Moist bulk density is influenced by texture, kind of clay, content of organic matter, and soil structure.

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates in the table are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity (Ksat) is considered in the design of soil drainage systems and septic tank absorption fields.

Available water capacity refers to the quantity of water that the soil is capable of storing for use by plants. The capacity for water storage is given in inches of water per inch of soil for each soil layer. The capacity varies, depending on soil properties that affect retention of water. The most important properties are the content of organic matter, soil texture, bulk density, and soil structure. Available water capacity is an important factor in the choice of plants or crops to be grown and in the design and management of irrigation systems. Available water capacity is not an estimate of the quantity of water actually available to plants at any given time.

Linear extensibility refers to the change in length of an unconfined clod as moisture content is decreased from a moist to a dry state. It is an expression of the volume change between the water content of the clod at 1/3- or 1/10-bar tension (33kPa or 10kPa tension) and oven dryness. The volume change is reported in the table as percent change for the whole soil. The amount and type of clay minerals in the soil influence volume change.

Linear extensibility is used to determine the shrink-swell potential of soils. The shrink-swell potential is low if the soil has a linear extensibility of less than 3 percent; moderate if 3 to 6 percent; high if 6 to 9 percent; and very high if more than 9 percent. If the linear extensibility is more than 3, shrinking and swelling can cause damage to buildings, roads, and other structures and to plant roots. Special design commonly is needed.

Organic matter is the plant and animal residue in the soil at various stages of decomposition. In this table, the estimated content of organic matter is expressed as a percentage, by weight, of the soil material that is less than 2 millimeters in diameter. The content of organic matter in a soil can be maintained by returning crop residue to the soil.

Organic matter has a positive effect on available water capacity, water infiltration, soil organism activity, and tilth. It is a source of nitrogen and other nutrients for crops and soil organisms.

Erosion factors are shown in the table as the K factor (Kw and Kf) and the T factor. Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Factor K is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and Ksat. Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value, the more susceptible the soil is to sheet and rill erosion by water.

Erosion factor Kw indicates the erodibility of the whole soil. The estimates are modified by the presence of rock fragments.

Erosion factor Kf indicates the erodibility of the fine-earth fraction, or the material less than 2 millimeters in size.

Erosion factor T is an estimate of the maximum average annual rate of soil erosion by wind and/or water that can occur without affecting crop productivity over a sustained period. The rate is in tons per acre per year.

Wind erodibility groups are made up of soils that have similar properties affecting their susceptibility to wind erosion in cultivated areas. The soils assigned to group 1 are the most susceptible to wind erosion, and those assigned to group 8 are the least susceptible. The groups are described in the "National Soil Survey Handbook."

Wind erodibility index is a numerical value indicating the susceptibility of soil to wind erosion, or the tons per acre per year that can be expected to be lost to wind erosion. There is a close correlation between wind erosion and the texture of the surface layer, the size and durability of surface clods, rock fragments, organic matter, and a calcareous reaction. Soil moisture and frozen soil layers also influence wind erosion.

Reference:

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. (http://soils.usda.gov)