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Soil Hydrodynamic Interpretations for Wetlands

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Cover photo: Endosaturated RIVERINE wetland—Ninnescah River floodplain, Reno County, Kansas, by Richard Weber, NRCS

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Soil Hydrodynamic Interpretations for Wetlands

Scope

This technical note describes the use of the Web Soil Survey as a data source for wetland hydrology information needed to develop wetland restoration plans and is intended for use by those involved in plan development. It describes the use of the soils information available in the Web Soil Survey and/or published soil surveys. This technical note is meant for use in the restoration of natural wetland hydrology functions, and its main focus is on the interaction between soils and wetland hydrology.

There are currently no classification or assessment systems that link soil data interpretations and wetland hydrologic functions. However, the formation of wetland soils and source of the water that forms these soils and maintains wetland hydrology and the depth, duration, and direction of movement of water in a wetland are directly related. Understanding the relationship between wetland soils and wetland hydrology is critical for the success of wetland restoration efforts. However, the information needed varies greatly. Some wetlands types, such as organic flats, are directly related to a broad soil order, Histosols in this case. In other cases, soil taxonomy, Official Soil Series Descriptions (OSD), and water feature information may all be needed to understand how the wetland soil functions with wetland hydrology.

In many cases, the information available in the Web Soil Survey is more than adequate to develop an understanding of how wetland soils and water interact on a specific restoration site. In other cases, soils have not been mapped to a scale small enough to provide the needed information or field investigations are required to supplement the information available in the Web Soil Survey. For this reason, the information presented should always be supplemented with an adequate field investigation to verify or supplement the available information.

The Hydrogeomorphic Wetland Classification System

The Hydrogeomorphic (HGM) Wetland Classification System defines wetlands based on their landscape position, dominant water source, and direction(s) of water movement, or hydrodynamics. Most other classification and assessment systems for wetlands use vegetation and/or wildlife habitat to differentiate between wetlands. Landscape position and the source and movement of water are also the parameters which determine soil formation and hydrologic processes. For these reasons, an understanding of the HGM system is directly related to an understanding of wetland soil morphology and wetland hydrology.

Refer to these documents for a full understanding of the HGM Wetland Classification System:

- Wetlands Research Program Technical Report WRP–DE–4, A Hydrogeomorphic Classification for Wetlands, available at: ftp://ftp-fc.sc.egov.usda.gov/WLI/HGM.pdf
- Wetlands Research Program Technical Report WRP–DE–9, An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices, available at: http://el.erdc.usace.army.mil/wetlands/pdfs/wrpde9.pdf
- Technical Note No. 190–8–76, Hydrogeomorphic Wetland Classification System: An Overview and Modification to Better Meet the Needs of the Natural Resources Conservation Service, available at: ftp://ftp-fc.sc.egov.usda.gov/WLI/HGM.pdf

Hydrodynamics is a term that defines the source and direction of water movement. It is defined with the terms “horizontal” or “vertical,” and “unidirectional” or “bidirectional.”

The seven HGM wetland classes are written in upper case letters in accordance with the HGM taxonomic rules. All natural wetlands can be assigned to one of these classes. Subclasses are written with the first letter uppercase and the remainder of the name lower case. Subclasses are developed for similar wetlands

within a broad HGM class, as needed by functional assessment model developers. Thus, there is no limit to the number of actual HGM subclasses. However, subclasses correspond to the general categories in the following list.

- **RIVERINE**
  —Episaturated
  —Endosaturated
- **SLOPE**
  —Topographic
  —Stratigraphic
- **ESTUARINE FRINGE**
  —Salt marsh
  —Freshwater marsh
- **LACUSTRINE FRINGE**
- **MINERAL SOIL FLATS**
- **ORGANIC SOIL FLATS**
  —Fens
  —Bogs
- **DEPRESSIONAL**
  —Recharge
  —Discharge
  —Flow through

Hydrodynamics

The interactions between the wetland hydrodynamics and the properties of the soils where these interactions occur are profound. With knowledge of soil properties, a detailed understanding of the wetland's hydrodynamics can be interpreted.

An evaluation of wetland hydrology is often performed using a water budget. The sources of water entering and leaving a wetland are included in the water budget. Often, the water budget can be used quantitatively to determine the depth, duration, degree of saturation, and other wetland hydrology parameters. Or, the water budget can be used qualitatively to gain an understanding of how water works with the soil and landscape to create a wetland. Once the water budget parameters are defined, their directions of movement through wetland soils can be addressed.

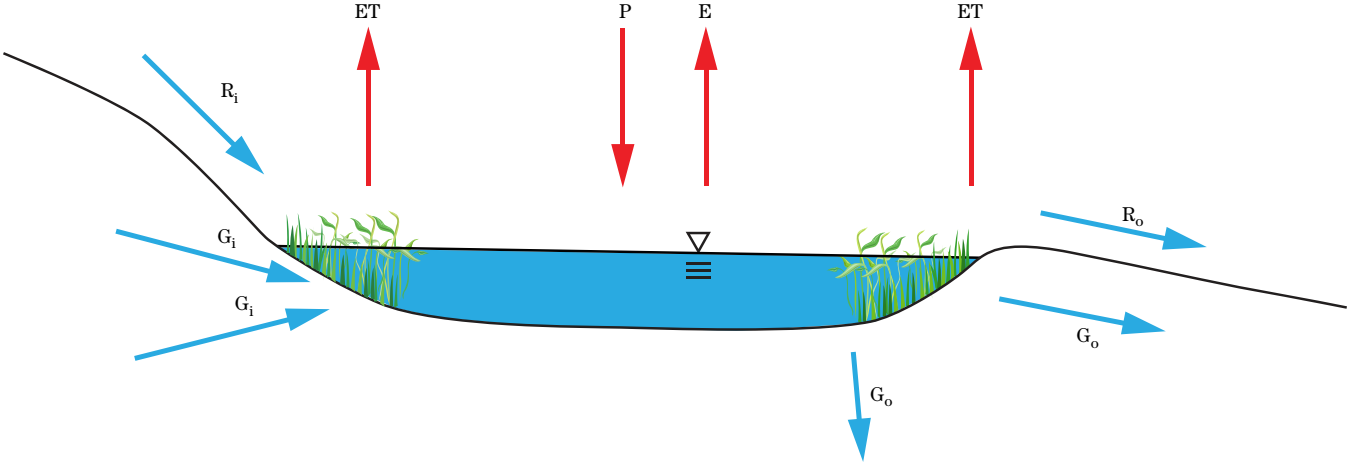
Figure 1 shows a generalized view of the sources and movements of water in wetlands. The concepts illustrated can be applied to all wetland HGM types in a general sense. It is rare for an individual wetland to have all of the illustrated sources as a dominant factor. In some cases, the individual gains and losses can be simplified to one major input and output.

The water budget parameters shown in figure 1 are defined as:

- E—evaporation from a water or bare soil surface
- ET—the combination of evaporation from the soil or water surface and plant leaves and stems. This can be significantly different from E
- R_i—surface runoff into the wetland
- R_o—surface runoff out of the wetland
- G_i—groundwater inflow
- G_o—groundwater outflow
- P—direct precipitation on the wetland

Detailed information about wetland hydrodynamics, data sources, and monitoring schemes are located in the National Engineering Handbook (NEH), Part

Figure 1 Generalized water budget



650 and Engineering Field Handbook (EFH), Part 650, Chapter 13, Wetland Restoration, Creation, and Enhancement.

Soil Taxonomy

The classification system used by the USDA for soils is defined in Soil Taxonomy (USDA 1975, 1998). The six levels of the naming hierarchy are Order, Suborder, Great Group, Subgroup, Family, and Series. A soil's taxonomic name may or may not indicate anything about how it functions in a wetland. However, there are some taxonomic classifications that provide much valuable information about how a wetland soil was formed and how it interacts with water. The 12 soil orders in the soil classification system are:

- Alfisols
- Andisols
- Aridisols
- Entisols
- Gelisols
- Histosols
- Inceptisols
- Mollisols
- Oxisols
- Spodosols
- Ultisols
- Vertisols

Soils of all orders except Aridisols can potentially occur in wetlands. However, some soil order names can provide more wetland interpretative information than others. This document focuses on the seven soil orders that provide information on wetland soils based on their definition.

Soil orders

Alfisols
These soils typically occur in cool, humid forests. The climate provides enough water for clay particles to be transported vertically downward through the soil profile to develop a Bt soil horizon.

Interpretation—Because of the climatic conditions where this soil order occurs, a significant number of wetland soils are contained within this order.

Aridisols
These soils, by definition, form in dry conditions. The presence of water in the soil profile is not a significant factor in the formation of most Aridisols.

Interpretation—Unlikely to be a wetland soil.

Entisols
Entisols are soils that lack distinct soil horizons. Usually, this is because the soil is not old enough for chemical and weathering processes to have created distinct horizons. In some cases, the soil may be only a few years old. In addition, the age of Entisols can potentially be traced to known land use changes in a contributing watershed that has caused increased erosion in recent historic times. These soils are commonly depositional and were placed by the actions of water or wind. Those deposited by flowing water are often wet with the frequency and duration needed for wetland conditions. Entisols deposited by flowing water are typically associated with the RIVERINE HGM wetland type. These RIVERINE landscapes are uniquely capable of supporting wetlands in an environment that is also capable of scouring and depositing soil. The other HGM wetland types do not have the necessary flow energy and hydrodynamics needed to deposit Entisols. Entisols also include soils with little weatherable minerals and may not be associated with fluvial sediments. A common example in the Atlantic Coastal Plain is the Typic Psammaquents, which are found in wet coastal plain flats and depressions, including interdunal swales. Entisols may also be found in relatively young colluvial sediments in toe-of-slope and residual sediments in stream headwater landscape positions that may be associated with SLOPE wetlands.

Interpretation—Probably formed by stream deposition if in a floodplain landscape. The potential exists for the soil to exist in a wetland if the stream provides water at a sufficient duration and frequency. The soil is fairly young. Its presence may be due to anthropogenic activities that occurred in an historic time frame. Look for the presence of buried A soil horizons that may indicate that a lower land surface existed in the recent past that has been covered by deposition.

Gelisols
These soils form and are maintained in a cold climate and by alternate freezing and thawing of surface layers over a layer of permafrost. Permafrost typically maintains liquid or frozen water at or near the surface, creating wetland conditions.

Interpretation—Vast areas of wetlands occur on the tundra landscapes where Gelisols are found.

Histosols

Histosols are unique and highly interpretative for wetland processes. By definition, they are formed and maintained by wetland conditions unless they are Folists. They are formed from organic debris provided by hydrophytic vegetation. Continuous saturation to the surface provides the anaerobic conditions needed to slow the conversion of organic carbon to carbon compounds in gaseous form. Decomposed plant material builds on the surface until the available water no longer has the potential energy to rise higher on the landscape. The potential head of the water and land surface are then in equilibrium until the water head potential increases or decreases due to drainage, change in climate, or some other external cause. If the water head decreases, the surface soil dries out, becomes aerobic, and converts to carbon dioxide and other gaseous compounds in a process called mineralization. If the available water head increases, dead plant material builds up higher on the surface until a new equilibrium point is reached.

Wetlands with Histosols can be broadly divided into Fens and Bogs. Fens are supplied with water from groundwater inflows. The groundwater potential provides the head that reaches equilibrium with the elevation of the wetland surface. This equilibrium is a function of the head and the loss of water from the wetland due to evapotranspiration. Surface runoff may be a significant source of water to the area as well, but the increase in water surface due to these runoff events is not long term. Since these elevation increases are not long term, they do not supply the conditions required for additional organic material to build up.

Bogs are organic soil wetlands that are supplied with water from direct precipitation and limited surface runoff. The important point is that both water sources enter the wetland at the surface. The climatic conditions must be such that the surface inflows minus the losses due to evapotranspiration maintain a near constant equilibrium. These wetlands commonly occur on depressional landscapes with an outflow point and on flats. The elevation of the outflow maintains the water surface at a constant elevation, as long as surface inflows are adequate.

The SLOPE HGM wetlands type that maintains Histosols are usually Fens. These wetlands have groundwater inflows as the dominant water source and exist as either Topographic or Stratigraphic SLOPE wetlands. Both types have the conditions to force groundwater to the land surface, and this flow occurs on a continuous basis. The constant surface saturation creates the anaerobic conditions needed for organic soil buildup to occur.

Bogs are usually associated with ORGANIC SOIL FLAT or shallow DEPRESSIONAL HGM types. Since direct precipitation is the dominant water source, they are nutrient poor.

Interpretation—Histosols or other soil orders that exhibit a surface layer of organic material are direct evidence of near continuous surface saturation. By definition, these are wetland conditions. The HGM wetland type is usually ORGANIC SOIL FLAT or SLOPE.

Spodosols

These soils have a spodic horizon. This is a horizon where amorphous mixtures of organic matter and aluminum, with or without iron, have formed. Spodosols are most extensive in areas of moist, cool, humid, or perhumid climates, but include the warm climate groundwater suborder Aquods in the Southeast, mainly in Florida. Spodosol topography is variable and includes low-lying flats and swales on the coastal plain in the Southeast, flat to depressional outwash plains in the upper Midwest, and uplands and sloping wetlands in the Northeast. Spodosols usually transition to wetter Inceptisols. The Spodosols that occur in wet regions have horizons that developed in a fluctuating water table at some time in normal years. These soils occur mostly in areas of quartz-rich sands that have a fluctuating level of groundwater. In many Spodosols, the silt and sand fractions contain very few weatherable minerals, and the albic horizons tend to be thick.

Interpretation—The Spodosol suborder Aquods are wetter soils characterized by either a shallow fluctuating water table or an extremely humid climate. The soils can be either wetland or nonwetland. The soils are low in silicate clay and occur on coarse-textured acid parent materials on sloping or flat landscapes. The soils profiles usually have a light gray eluvial (E) horizon overlaying the spodic horizon, which is an indication of soil forming processes relating to chelation-induced eluviation and water movement within the soils. Many Aquods have a black surface horizon over a dark reddish brown spodic horizon that is virtually free of iron. There have been problems determining Aquic conditions in some Aquods in wet regions.

On sloping landforms, oxygenated water can be an issue for wetland determination on Aquods, especially in northern climates. On MINERAL FLATS in southeastern coastal plain landscapes, both wetland and nonwetland Aquods occur. Some studies have shown that the iron in the B horizon is so bound that it does not react to normal oxidation/reduction reactions.

Vertisols
Vertisols are soils with a high content of montmorillinitic clay, which gives the soil a high potential for shrinking and swelling. The shrink-swell dynamic creates deep vertical cracks. As surface material falls into these cracks and the soil is rewetted, material is forced to the surface to create chimneys. There are two great groups in the Vertisol order with wetland interpretations, the Epiaquerts and Endoaquerts, although other great groups are found in wetlands, as well. A unique property of these soils is the development of microtopography features on wetland surfaces. In some Vertisols, the dynamic process of shrinking and swelling creates small, shallow depressions which commonly occur in geometric patterns. These depressional features are called gilgai (pronounced gill-guy) and provide high-value hydrologic diversity.

Interpretation—When Vertisols occur in wetlands, their high shrink-swell properties often provide high-value surface microtopography features. Vertisols often form in the MINERAL FLATS or Discharge and Recharge DEPRESSIONAL HGM class, although they can be found in others.

Soil suborders

The 28 formative elements in soil taxonomy names of suborders are used with the 12 formative elements from names of the orders to make the names of 64 suborders. The formative elements with the greatest value for wetland interpretations are described in this technical note. The name of the formative element is followed by the syllable used in the taxonomic naming system.

Albic—Alb
Albic horizons are only recognized with the soil order Mollisols as Albolls. Albolls are formed under fluctuating shallow water table conditions and movement of material in solution from one horizon to another within the soil. Surface saturation exists during the winter months. The soils lose water through vertical downward movement, translocating clays and iron oxides, leaving behind base sands and silts. Thus, the hydrodynamic is unidirectional, vertical downward. There can be Albolls that are not hydric. Redox features must be found within 100 centimeters. Thus, the water table could be deeper than that required for a hydric soil.

HGM types: Usually MINERAL FLATS

Aquic—Aqu
Soils with Aquic conditions are those that form under continuous or periodic saturation and reduction. Some of these soils are found in wetlands. The water may be supplied from precipitation, surface runoff, or groundwater. The Aquic suborder allows saturation to be found to a depth of 40 to 50 centimeters, so some soils with Aquic suborders are not, in fact, hydric. Usually the soils that are not hydric will classify as Aeric at the subgroup level.

HGM types: Common on all HGM types

Argillic—Arg
These soils have an Argillic soil horizon. This is a horizon below the surface A horizon that has more silicate clay content in the Argillic Bt horizon than in the overlying A horizon. The horizon is typically developed by translocation of clay particles vertically downward. There are two important interpretations provided by this designation. First, the movement of water is vertical downward, which is the dynamic required for the clay translocation to occur. Wetland soils that discharge for part of the year and recharge for part of the year can form an Argillic horizon. Secondly, if hydraulic conductivity is low in the Argillic horizon, it may enable the wetland to maintain a water table in a perched condition during some portion of the year.

HGM types: MINERAL FLATS, Recharge DEPRESSIONAL, and other types where dominant direction of water movement is vertical downward

Fibric—Fibr, Hemic—Hem, Sapric—Sapr, or Histic—Hist
All of these elements are associated with the presence of organic material. The Fibric, Hemic, and Sapric suborders are only associated with Histosols as Fibrists, Hemists, and Saprists and denote the state of decomposition of the organic soil, from least to most decomposed. The histic element is only applied to Gelisols to form the suborder Histels. All of these suborders are hydric by definition.

HGM type: ORGANIC FLATS, SLOPE, LACUSTRINE FRINGE, ESTUARINE FRINGE

Fluvic—Fluv
These soils have been formed by the action of flowing water. They are almost always associated with floodplains. The floodplain may be a currently active floodplain or a stream terrace that was formerly the active floodplain. Soils in these suborders are commonly part of a RIVERINE wetland. Soils that are hydric, but classify out as Fluv at the suborder level, may be problematic in terms of hydric soils identification.

HGM type: Usually RIVERINE

Great groups

There are more than 300 great groups. The name of a great group consists of the name of a suborder and a prefix that consists of one or two formative elements suggesting something about the diagnostic properties. These formative elements are similar to the formative elements for the suborders. In addition to the Alb, Aqu, Arg, Fibr, Fluv, Hem, Hist, and Sapr, there are other formative elements with wetland interpretations.

Endosaturated—Endo
Endosaturated soils are those that have a water table that starts near the surface and extends downward to a depth greater than 200 centimeters. It is important to note the water table may actually be perched on a slowly permeable layer at or deeper than 200 centimeters. In other cases, the water table may actually be the local water table. In the latter case, water actually moves horizontally and/or vertically upward into a wetland through endosaturated soils. In the former case, water is supplied from the surface from precipitation, surface flooding from an adjacent stream, or surface runoff from nonwetland watersheds. The Endo formative element is highly interpretative for wetlands supplied with water from groundwater, as long as it is determined that the water table is not actually perched on a layer deeper than 200 centimeters. In RIVERINE wetlands, water may move rapidly from the stream's water surface into the wetland through the soil to support a high water table and then moves back into the stream to support strong baseflow. In SLOPE wetlands, groundwater moving horizontally and upward is the dominant water source. In Discharge DEPRESSIONAL and Flow through systems, groundwater also moves horizontally and vertically upward into these wetlands.

For these reasons, the Endo formative element can be highly interpretive of a wetland of RIVERINE, Discharge DEPRESSIONAL, or SLOPE HGM type, which has a strong groundwater supply. However, the interpreter must be assured that the Endo formative element is not assigned because of a perching layer greater than 200 centimeters deep. These soils act more like those that classify as episaturated, and if the condition is not recognized, can lead to a misleading conclusion. Soils in the endosaturated great groups occur as Endoaqualfs, Endoaquands, Endoaquents, Endoaquepts, Endoaquolls, Endoaquods, and Endoaquults. Note that these great groups are all in the Aquic suborder. Endosaturated great groups are those with groundwater as a dominant water source.

HGM type: RIVERINE, Discharge DEPRESSIONAL, or SLOPE if saturation is caused by vertical, upward, or horizontal groundwater movement. On MINERAL FLATS, they are usually classified in the Endosaturated great group because of saturation below 200 centimeters and are more like an Episaturated soil.

Episaturated—Epi
Episaturated soils are those supplied with water from the surface. Commonly, these soils are capable of maintaining water for long periods in a perched condition. They occur mainly in RIVERINE, MINERAL FLATS, and Recharge DEPRESSIONAL HGM wetland types. These soils in riverine systems are common in floodplain macrotopographic features, where floodwater is ponded after the floodwater has receded, and is perched on a low permeability C horizon, or bedrock. The Recharge DEPRESSIONAL wetland types, known as playas, are good examples where soils of this suborder occur. These soils occur as Epiaqualfs, Epiaquands, Epiaquents, Epiaquepts, Epiaquolls, Epiaquods, and Epiaquults. As with the Endosaturated soil great groups, they occur only in the Aquic suborders. The Episaturated great groups are those where the dominant water source is supplied from the surface from precipitation, stream flooding, or surface runoff.

HGM types: RIVERINE, Recharge DEPRESSIONAL, MINERAL FLATS

Fluvic—Fluv
Similar to the Fluvic suborders, the Fluvic great group soils were formed by the actions of flowing water. These commonly occur in floodplains where RIVERINE HGM wetland types are found. The only Fluvic great group is Fluvaquent, which, appropriately, is in the Aquic suborder and, in some cases, is hydric.

HGM type: Usually RIVERINE

Albic—Alb
The Albic great group soils were formed under fluctuating shallow water table conditions or movement of material in solution from one horizon to another within the soil. The only Albic great group soils are Albaqualfs and Albaquults. Additional information provided by the Albic great group designation is that water has moved vertically downward, creating an eluvial (E) horizon. The clay and iron oxides have been removed from the base sand and silt size particles by the vertical downward movement of water. Thus, an Albic horizon is strong evidence of a unidirectional, vertical hydrodynamic.

HGM type: Usually MINERAL FLATS or Recharge DEPRESSIONAL

Subgroups

There are more than 2,400 subgroups. The name of a subgroup consists of a great group modified by one or more adjectives. The adjective typic is used for the subgroup that is the central concept of the great group or soils that fail to meet the criteria of the other subgroups. Aquic also is used to define subgroups of soils that are not in Aquic suborders, but have shallow groundwater at some period and have redox criteria at a depth generally of more than 50 centimeters. Aquic subgroups are not as wet as Aquic suborders. The formative elements for subgroups with Aquic are usually somewhat poorly to moderately well-drained soils.

Soil horizons

Histic epipedon

An epipedon, if it exists, is a shallow surface horizon. Only a histic epipedon is diagnostic for wetland soils. Histic epipedons are organic and, thus, are indicative of surface saturation for at least part of the year. The soil may not be hydric, but it can be inferred that surface saturation occurs with duration long enough for decayed plant material to be in an anaerobic state for a long enough period for the material to build up. Histic epipedons are found in SLOPE HGM wetland types at the interface between groundwater and the land surface. They are also found in Discharge DEPRESSIONAL HGM types and depressions within a MINERAL FLAT. The hydrodynamic is horizontal, unidirectional, or vertical upward.

HGM types: Found in SLOPE, Discharge DEPRESSIONAL, and depressions within MINERAL FLATS wetlands

Argillic horizon

An argillic horizon is normally a subsurface horizon with a higher percentage of silicate clay than the overlying soil material. It shows evidence of clay illuviation (deposition). The argillic horizon forms below the soil surface, but it may be exposed at the surface later by erosion (USDA 1999).

Because of the clay content of this horizon, it may have a low enough hydraulic conductivity to maintain a groundwater table in a perched condition. This horizon may be the single most important feature that maintains wetland hydrology. These horizons are common on soils in Recharge DEPRESSIONAL, RIVERINE (in depressional floodplain macrotopographic features), and in MINERAL FLATS HGM wetland types. Breaching this horizon can allow the perched water to drain out to higher permeability substrata. The hydrodynamics are vertical downward. These horizons are often found below an albic horizon or an E master horizon.

HGM types: Common in Recharge DEPRESSIONAL, MINERAL FLATS, and RIVERINE where precipitation, surface runoff, or flooding is the dominant water source

Albic horizon

As stated earlier in the suborder and great group sections, albic horizons are eluvial horizons where vertical downward movement has removed clay and iron oxides, leaving behind base sands and silts. The direction of movement is vertical downward.

Calcic horizons

In soils where groundwater near the surface contains appreciable amounts of calcium bicarbonate, capillary rise, evaporation, and transpiration cause precipitation of calcium carbonate. Depending on the depth from the surface to the capillary fringe, the top of the zone of calcium carbonate accumulation may be from the surface to a depth of about 60 centimeters. In such soils, the accumulation of calcium carbonate is comparable to the accumulation of more soluble salts in desert playas. Depending on the position of the water table, these soils may occupy depressions. In ponded conditions, a soil with a Calcic horizon commonly forms a circular outline around the deeper depressions and can also occur on microhighs in the depressions (USDA 1999). In soil profiles where this horizon occurs within the plant root zone, it may be indicative of a wetland hydroperiod where surface and/or groundwater is supplied to a ponded depression and is lost through evaporation and/or evapotranspiration. Soils with Calcic horizons are commonly found adjacent to Discharge DEPRESSIONAL wetlands and in RIVERINE wetland depressions. They may also be found in MINERAL FLATS.

HGM Types: Typical of Discharge DEPRESSIONAL, MINERAL FLATS. Hydrodynamics are vertical upward

Master horizons

The capital letters O, A, E, B, C, and R represent the master horizons and layers of soils (USDA 1993). The O and B horizons may contain features that are particularly interpretative for wetland hydrodynamics.

O horizons

These horizons are dominated by organic material. This horizon is created by surface saturation. This

horizon may not be extensive enough for the soil to be a Histosol, so its presence is not definitive for organic soils. The O designation is used for both anaerobically accumulated OM and aerobically accumulated OM. Most soils in their undisturbed state are going to have an O horizon of some sort. It is usually much thinner under normal conditions in a nonhydric soil. Some O horizons are associated with a Histic epipedon and, as mentioned in that section, are commonly found in SLOPE HGM wetland types. The subordinate distinctions a, e, and i are associated with the O horizon. The "a" designation indicates highly decomposed organic material, "e" indicates intermediated decomposition, and "i" indicates slight decomposition.

B horizons

The B horizon is formed below a horizon, which may be an A, E, or O. Wetland hydrodynamic processes usually occur within this horizon or are caused by B horizon properties. The subordinate distinctions with particular wetland interpretative value are g, k, and t.

A Bt horizon is one that has an accumulation of silicate clay that has translocated vertically downward from an upper horizon, usually an A. This indicates that the hydrodynamic direction of movement is unidirectional and vertically downward. In addition, the low hydraulic conductivity that may occur in this horizon means that a shallow groundwater table can be maintained in a perched condition. This is a common soil horizon in Recharge DEPRESSIONAL, RIVERINE depressions, and MINERAL FLAT HGM wetland types. They are usually not associated with Discharge DEPRESSIONAL or SLOPE wetlands. This horizon is also associated with Argillic suborders and great groups.

A Bk horizon is one with an accumulation of carbonates. In wetlands where surface or groundwater with dissolved calcium enters and is removed through evaporation and/or evapotranspiration, carbonates are left behind in this horizon. This horizon is associated with Calcic suborders and great groups. In addition, it can be found with translocated clays in a horizon designated as Btk. In these cases, it can be interpreted that water with dissolved calcium is perched and removed by evapotranspiration, leaving behind calcium deposits. As with the Bt horizon, Bk and Btk horizons are common in soils in Recharge DEPRESSIONAL, RIVERINE depressions, and MINERAL FLAT HGM wetland types. Calcium carbonate above the B horizon is more indicative of hydric soils than in the B horizon. A moderately well-drained soil may have a Btk horizon.

A Bg horizon is one that has strong gleying. The gleying means that iron has either been reduced or removed during soil formation or that saturation with stagnant water has preserved a reduced state. As with the Btk designation, the layer may be designated as a Btg, where the saturation is maintained by perching on a clay layer. A soil with a Btg horizon may have a water table too deep to be hydric. An Ag or Egs horizon above the Bg or Btg is even more indicative of a hydric soil.

Water features

In the Web Soil Survey, under the Soil Reports tab, the Water Features option provides a report as shown in figure 2. The pertinent categories for wetland interpretations are Depth to Water Table, Flooding Frequency Class, and Ponding Frequency Class; all show ratings by month. The monthly numbers are valuable for a quick determination of the wetland hydroperiod. Only the months that typically have a high water table, ponding, or flooding are shown.

Depth to water table columns show values for the upper limit and lower limit. This water table may be the local water table or the saturation zone above an impermeable layer.

Ponding

Ponding is defined as inundation by standing (stagnant) water. The report provides values for the ponding depth range, as well as ponding duration and frequency. The definitions of the ponding frequency class are:

- none: <1 time in 100 years
- rare: 1 to 5 times in 100 years
- occasional: >5 to 50 times in 100 years
- frequent: >50 times in 100 years

The definitions of the ponding duration class are:

- very brief: <2 days
- brief: 2 to <7 days
- long: 7 to <30 days
- very long: >=30 days

The ponding interpretation should be used with care. The ratings are based on the presence of standing water at any depth, from mere surface saturation to several feet of water. Ponding is the presence of surface water that is not moving. Moving surface water is flooding. All wetland soils can have a ponding rating except those that are in RIVERINE sites that are inundated by dynamic floodwater.

Flooding

Flooding is defined as inundation by flowing water. As such, it is associated with stream floodwater, and the duration of flooding is coincident with the stream flood hydrograph. Generally, sites that flood are restricted to the RIVERINE HGM wetland class. However, ESTUARINE and LACUSTRINE FRINGE wetlands are subject to tidal flooding and lake fluctuations. The report provides ratings for duration and frequency in descriptive terms. In RIVERINE wetlands, the surface can be exposed to both flooding and later ponding after the flood hydrograph recedes. In the report shown in figure 2, the Osage series experiences long-duration ponding with only a brief flooding duration. The flat land surface is capable of ponding water supplied by flooding long after the flood hydrograph has passed.

Official Soil Series Descriptions (OSD)

Each soil series has an OSD. This is a comprehensive description that provides essential information about the soil's properties. While the information varies from series to series, the description always includes the taxonomic name, a full description of the soil horizons, and a statement of the ranges of relevant properties. Also, a narrative description is included that provides soil morphology, landscape, and parent material information.

Series and phases

Soil series are individual soil types that have all or similar properties in the OSD in common. Individual soil series are given distinctive names. Some soil series are subdivided into soil phases. Soil phases are used to differentiate features that are outside the soil pedon, such as slope range or flooding frequency, and to differentiate between map units within the range of the series (i.e., moderately eroded, frequently flooded, physiographical). Often, soil series are given descriptions for phases, which constitute different map units that are interpretative for wetlands. For instance, the same soil series can be given a seldom flooded, occasionally flooded, or frequently flooded phase description. Another example is the use of the phases drained, poorly drained, somewhat poorly drained, etc.

Parts of the country having large areas of drained soils often map drained phases of hydric soils. These may be excellent soils for restoration of wetland hydrology if the drainage can be reversed.

Map units

Soil survey maps delineate soils by map unit. The map unit may have one or more major components. A component is a single soil series or series phase, a miscellaneous land type (e.g., urban lands), or soil classified to a higher level than series (e.g., Fluvaquents). A major component is a component that is dominant in the map unit. The number of major components determines whether a map unit is a consociation, association, complex, or undifferentiated group. Consociations are map units that include a single major component series or phase. Associations, complexes, and undifferentiated groups are combinations

Figure 2 Water features report from the Web Soil Survey, Franklin County, KS

Water Features– Franklin County, Kansas										
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Ponding			Flooding	
				Upper limit	Lower limit	Surface depth	Duration	Frequency	Duration	Frequency
				Ft	*Ft*	*Ft*				
8201—Osage silty clay loam, occasionally flooded										
Osage	D	High	January	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	February	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	March	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	April	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	May	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	June	0.8-1.2	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	July	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	August	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	September	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	October	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	November	0.8-1.2	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	December	0.8-1.2	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional

of two or more soil series. In addition, all these categories will have inclusions (minor components) that are too small to be mapped separately.

Soil map units may be hydric, nonhydric, or partially hydric for this reason; hydric soil maps are only tools to assess the likelihood that a hydric soil exists at that location. Map units where all major components are hydric can have nonhydric inclusions, and the reverse is true, as well. Soil map units shown as partially hydric have soils as major or minor components that are both hydric and nonhydric. The determination of hydric or nonhydric is made at the component level. Generally, a hydric map unit can be assumed to be hydric if the minor components have been populated as such in the database, a nonhydric map unit can be assumed to be nonhydric if the minor components have been populated as such in the database, and a partially hydric map unit may have small or large components that are hydric and others that are nonhydric. In some cases, the soil survey may provide enough information to make a hydric soil decision without field verification. However, soil surveys are not intended to be site specific, and if there is any question, a site visit may be required to make a definitive hydric soil determination.

Consociations
Generally, consociations are map units dominated by a single soil series, series phase, miscellaneous land type, or soil classified to a higher level than series.

Soil complexes, associations, and undifferentiated groups
Complexes and associations consist of two or more dissimilar components that occur in a regularly repeating pattern. The total amount of other dissimilar components is minor in extent. Large RIVERINE wetlands found on floodplains often have complexes and associations because of unique floodplain morphology. For example, the Haverson-Glenberg association saline map unit found in Johnson County, Wyoming, is the saline phase of an association of two soil series typically found together on floodplains. Undifferentiated groups consist of two or more components that are not consistently associated geographically and, therefore, do not always occur together in the same map delineation. These components are included in the same named map unit because their use and management are the same or very similar for common uses.

Hydric soil maps
Hydric soil ratings are determined for each component in a map unit. A national list of hydric soils is maintained by the National Technical Committee for Hydric Soils. It is a compilation of all the hydric soils lists located on the Soil Data Mart. The national list is updated once a year. A local list of map units that contain hydric soils can be obtained by soil survey area from the Soil Data Mart, and a list of map units that contain hydric soils for a specific location of interest can be generated through the Web Soil Survey, along with the interpretive map. Only hydric and partially hydric map units are included in the list unless a site-specific list is generated from the Web Soil Survey. Each map unit shows the component or components that are hydric, and the percentage of area covered by the component in that county. Only the map units that have 100 percent coverage of hydric components are mapped as hydric in the Web Soil Survey hydric soil maps. It is common for extensive wetland areas to exist within map units mapped as partially hydric. These areas must be delineated onsite, using appropriate methods.

Case Studies

The case studies presented in this document are made using information readily available from the Web Soil Survey and Soil Data Mart. The site locations were chosen for illustrative purposes only, and the interpretations taken are solely based on the information available. Furthermore, soils information is based on the hydrologic conditions that existed at the time the soil was formed, not on the current hydrologic conditions.

Case 1

RIVERINE—Episaturated

The site is a floodplain located in Franklin County, Kansas, along Pottawattomie Creek. Figure 3 illustrates the hydric soil map obtained by selecting the Soil Data Explorer tab, the Land Classifications, and Hydric Rating by Map Unit from the drop-down menus. The individual map units are color coded to represent "hydric," "partially hydric," "not hydric," and "unknown hydric." The hydric map units displayed in brown include two map units of the Osage series. Map unit 8201 is Osage Silty Clay Loam, and map unit 8203 is Osage Silty Clay. These are separate phases of the Osage series, differentiated by texture. Both have the "occasionally flooded" description attached. The areas displayed in green are mostly comprised of the Verdigris silt loam with two map units. Map unit 8302 is Verdigris silt loam, occasionally flooded, and map unit 8300 is Verdigris silt loam, channeled. In this case, the Verdigris series is divided into separate phases based on flood frequency and surface topography. The remainder of the map is comprised of upland soils coded with colors that show them to be not hydric and unknown hydric.

At first glance, it is obvious that the partially hydric Verdigris series soils (shown in green) are the ones immediately adjacent to the channel, and the hydric Osage series soils (shown in brown) are farther away from the water source, implying that the soils closest to the stream are drier. Based on the conventions for hydric soil maps, assume that the Verdigris soil map units may have both hydric and nonhydric components. Both of the Verdigris phases are listed as having a hydric rating on the hydric soils list for Franklin County, even though the Verdigris map unit phases do not meet the hydric soil criteria of frequently flooded. This simply means that these map units may have inclusions of hydric soils. Based on this evidence, the majority of the map unit areas are nonhydric. Soils found immediately adjacent to stream channels are commonly higher and drier than those farther away from the channel.

In some cases, streamside soils will actually be nonhydric. This seems to be counterintuitive, but can be explained in terms of the geomorphology of stream-floodplain systems. Streams carry sediment of both coarse- and fine-textured material during flooding, as a primary function. The coarser grained sands and silts will quickly drop out of the water column as floodwater leaves the high-energy environment of the channel and enters the low-energy floodplain. This sediment drops out next to the channel and forms natural levees. These features can be quite distinctive and are often large enough to justify mapping as a separate soil series, as in this case. The partially hydric Verdigris map units are in this landscape position, so inclusions of nonhydric soils can be expected. The Osage series map units are in the backswamp position of the floodplain, where fine-grained clay particles in colloidial suspension can settle out in low-energy slack water areas. Because of this interaction between water, sediment, and morphology, there can be evidence of differences in soil texture and other water interpretations. Figure 4 shows a map of the flooding frequency class. This can be obtained from the same Web Soil Survey page as the hydric soil map by selecting the Soil Properties and Qualities tab, then selecting the Water Features link, and Flooding Frequency Class.

All map units of the Osage and Verdigris series are shown in light and dark blue, indicating a flood frequency rating of occasional and frequent. The channeled phase of the Verdigris series, map unit 8300 shown in dark blue, exists adjacent to side tributaries of the main floodplain and has the frequently flooded rating. Flooding can be defined as the presence of flowing floodwater that exists only for the duration of the flood hydrograph. The map provides a quick reference of the extent of the floodplain in terms of the areas subject to periodic flooding. It does not indicate the duration of inundation from rainfall or upland runoff and gives no indication of any water left behind after the flood hydrograph recedes. Short-term flooding, even with a high frequency of occurrence, may not be adequate to create wetland hydrologic conditions. Figure 5 shows a view of the ponding frequency class, also obtained under the Water Features link.

Here, the areas with a ponding rating of occasional are shown in light blue and are the Osage series soils. The remaining Verdigris soils, along with the adjacent uplands, are rated as none. This is in keeping with the morphology of the system, with the Osage backswamp position remaining inundated with water after the flood hydrograph recedes and the Verdigris natural levee position having no inundation after the flood. From this information, it appears that the soils with any duration of surface water are the Osage series, and the duration is mainly due to ponding. However, this rating refers only to how often ponding occurs, not for how long the condition exists.

Figure 6 shows the depth to water table map from the Water Features link. The colors indicate depth ranges, with the Osage series in red having a range of 0 to 25 centimeters, and the Verdigris series in blue with a range of less than 200 centimeters. The depth to water table report shown in figure 7 provides the information

shown in figure 6, with more specific depth information.

Here, the rating for the Osage series is 15 centimeters. The extreme difference in the water table depths is highly interpretative. It is virtually impossible for two adjacent soils to have a true local water drop this drastic. The only explanation is that the Osage series water table is perched on a shallow subsurface layer, and the Verdigris soil horizons readily allow water to move vertically downward to the deeper (>200 cm) local water table. This is in keeping with the other evidence that the Osage map unit exists in a low permeability backswamp landscape position soil, that it was formed with finer grained clay particles with low permeability, and that it ponds water for some time after the flood event has passed. The coarser grained Verdigris soil next to the channel readily transmits water through its profile and is only wet for the duration of active flooding.

An additional interpretation can be obtained from the Drainage Class link under Soil Qualities and Features map shown in figure 8.

The blue Osage series soils have a poorly drained rating, and the yellow Verdigris series soils have a rating of well drained. The drainage class does not indicate whether the drainage is from surface runoff or vertical downward movement through the soil profile. By selecting the Soil Reports tab and then using the Soil Physical Properties link and the Physical Soil Properties link, information on soil texture and saturated hydraulic conductivity can be obtained. The conductivity of the Osage series is only 0.01 to 0.42 micrometers per millisecond, compared to the Verdigris series rating of 4.23 to 14.11 micrometers per millisecond. Note that these numbers are the same for all soil layers, indicating that there is no specific soil horizon where the properties are controlling the movement of water. Figure 9 shows the water features report available under the Soil Reports tab for the Osage silty clay loam, occasionally flooded map unit, and figure 10 shows the report for the Verdigris silt loam, occasionally flooded map unit.

The data for the other map units of the same series are similar. The information presented here is directly related to the potential wetland hydroperiod and dominant water source. In both cases, the frequency and duration of surface flooding is not significant. However, the Osage series experiences long-duration ponding from occasional and brief flood events. The ponding frequency class map shown earlier only indicated the frequency of ponding. This report provides evidence of the duration.

Included in the appendix is the OSD for Osage soil. Osage is an Epiaquert, which is a Vertisol formed under saturated conditions and subject to inundation from surface water. The Verdigris series is a Hapludoll, which is a Mollisol with minimal horizon development and formed in a humid moisture regime, but with no hydric attributes.

Summary for case 1

Verdigris and Osage series soils are located in a floodplain, subject to infrequent, short-duration flood events. The flood duration, by itself, is not enough to support wetland hydrology. The Osage soil, however, has the landscape position, low permeability, and supply of floodwater to support long-term saturation and ponding, which may occur at any time during the year. The dominant water source is stream floodwater, the direction of movement is vertical downward, the slow vertical movement of water causes a saturated zone condition, and the water table is not part of the deeper local water table. The Osage soil is hydric and Verdigris is not. The Verdigris soil is in a natural levee landscape position, and the Osage is in the backswamp. Its dominant water source is stream flooding, the direction of water movement is horizontal, unidirectional (flooding which remains as ponding), and vertical downward (slow percolation through the soil profile). The area can be drained by levees, which prevent floodwater from entering, and surface ditches which remove surface water and prevent ponding. Wetland restoration and enhancement efforts should focus on ditch plugging, restoring and/or creating floodplain microtopographic and macrotopographic features, and levee removal. There is little danger of damaging any shallow subsurface perching soil layer, as the entire soil profile is relatively homogeneous and with low permeability.

Figure 3 Hydric rating by map units, Franklin County, KS

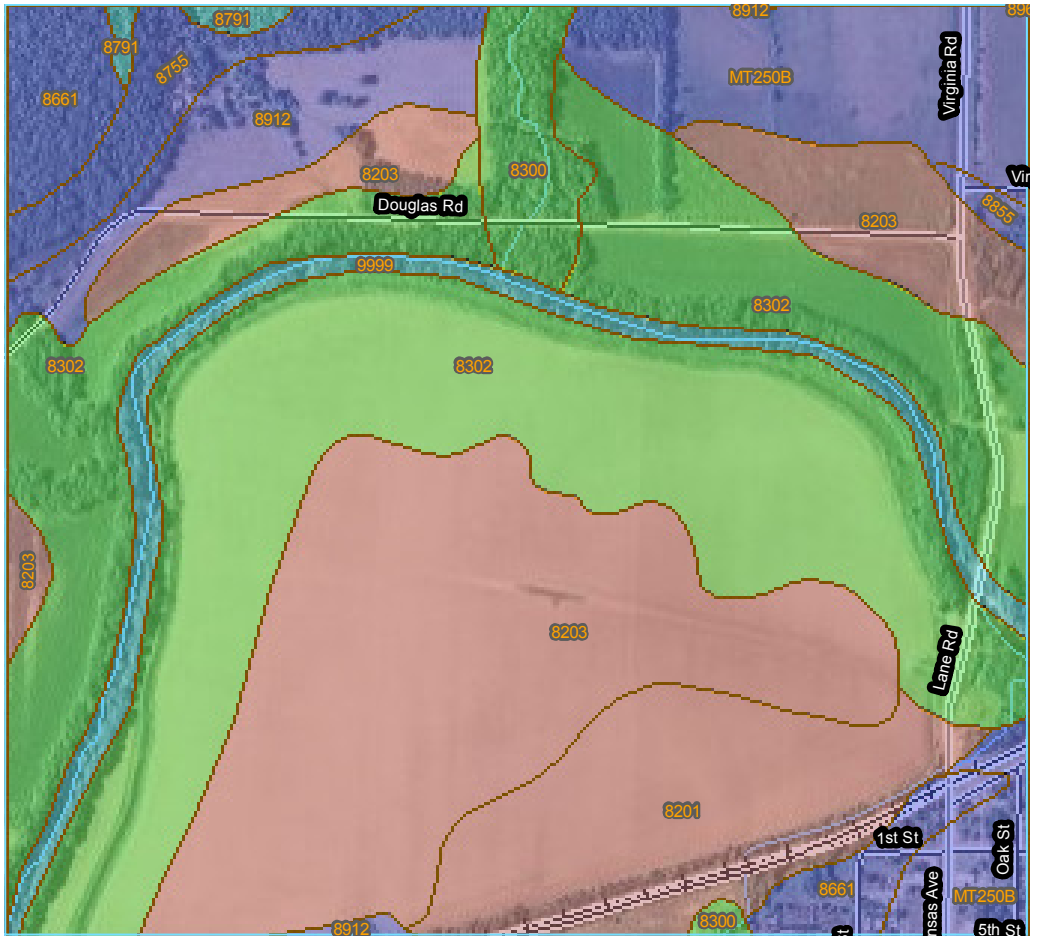


Figure 4 Flooding frequency class, Franklin County, KS

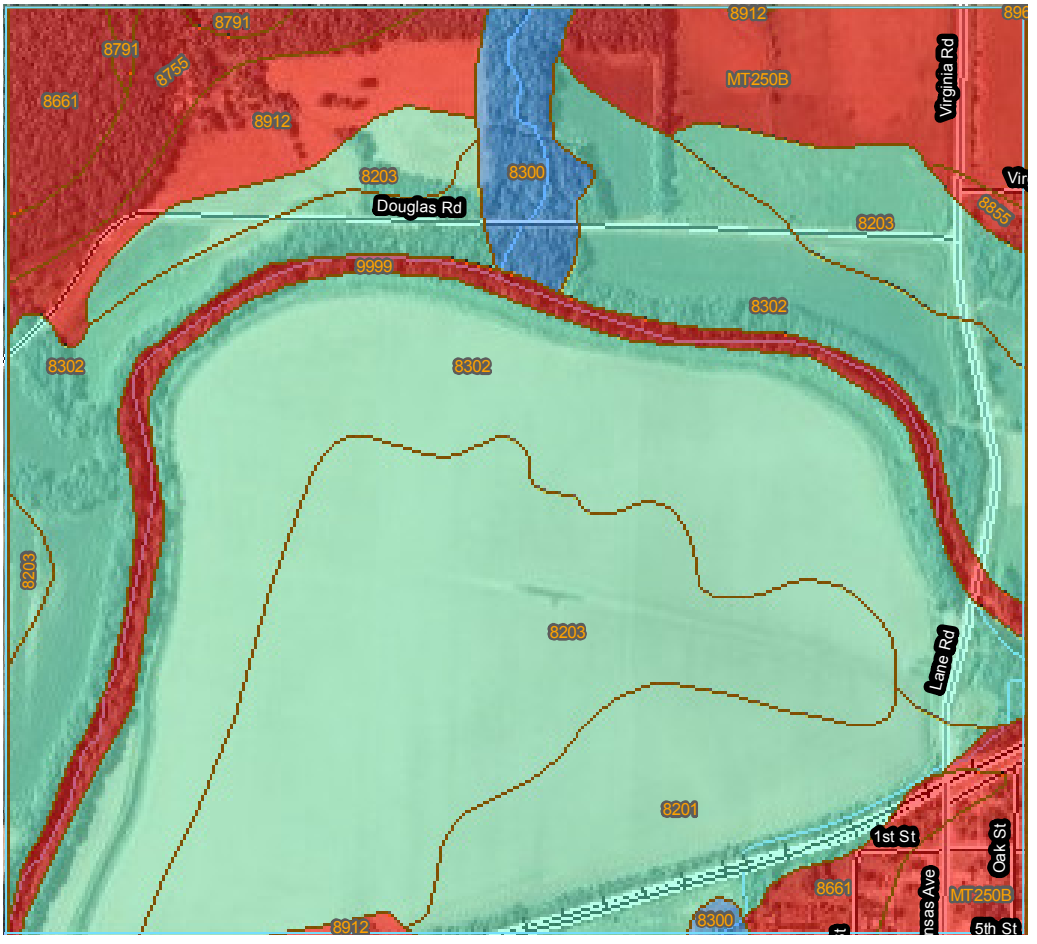


Figure 5 Ponding frequency class, Franklin County, KS

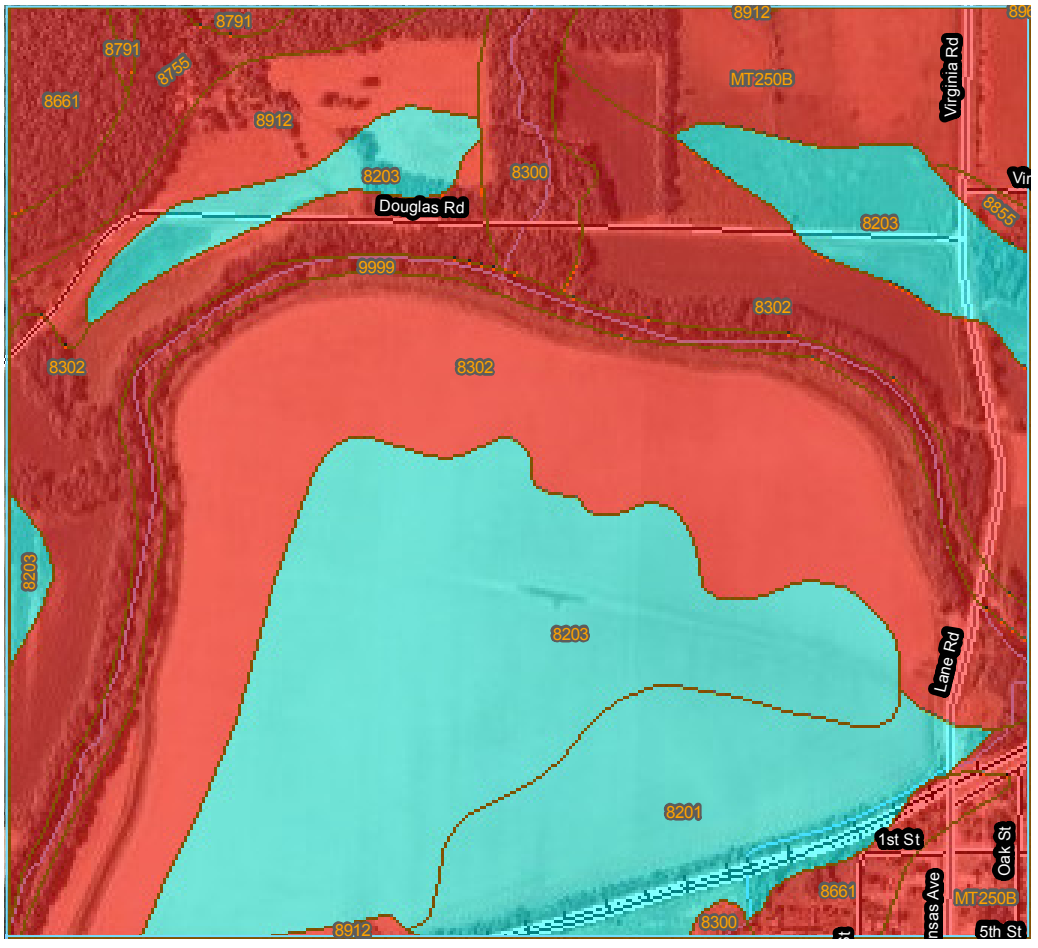


Figure 6 Depth to water table, Franklin County, KS

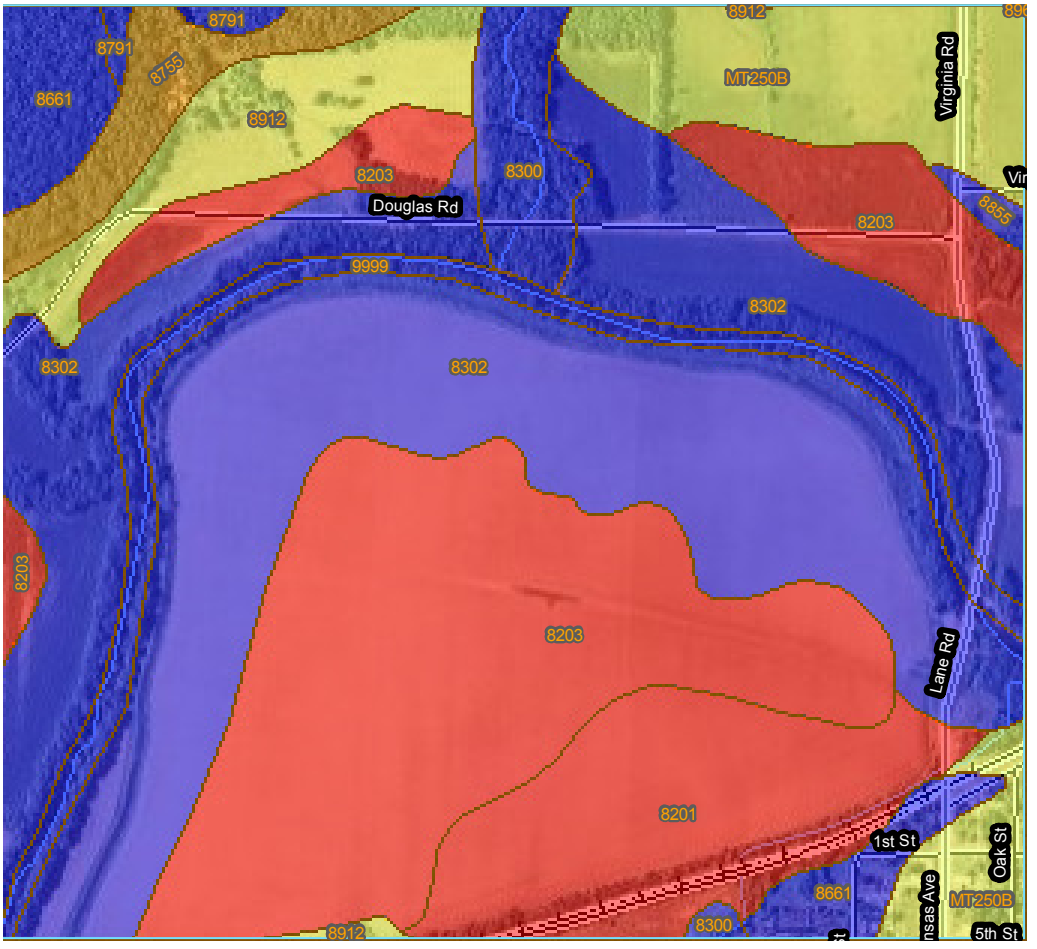


Figure 7 Depth to water table report, Franklin County, KS

Depth to Water Table— Summary by Map Unit — Franklin County, Kansas (KS059)				
Map unit symbol	**Map unit name**	**Rating (centimeters)**	**Acres in AOI**	**Percent of AOI**
8201	Osage silty clay loam, occasionally flooded	15	38.8	9.2%
8203	Osage silty clay, occasionally flooded	15	110.5	26.2%
8300	Verdigris silt loam, channeled	>200	11.2	2.7%
8302	Verdigris silt loam, occasionally flooded	>200	159.2	37.7%
8661	Clareson-Eram silty clay loams, 3 to 15 percent slopes	>200	15.2	3.6%
8755	Eram-Lebo silty clay loams, 5 to 20 percent slopes	36	11.4	2.7%
8791	Lebo-Rock outcrop complex, 20 to 40 percent slopes	>200	1.7	0.4%
8855	Olpe-Kenoma complex, 1 to 3 percent slopes	>200	1.5	0.4%
8912	Summit silty clay loam, 3 to 7 percent slopes	61	19.4	4.6%
8962	Woodson silt loam, 1 to 3 percent slopes	36	0.0	0.0%
9999	Water	>200	17.1	4.1%
MT250B	Aliceville silty clay loam, 1 to 3 percent slopes	75	35.7	8.5%
Totals for Area of Interest			**421.8**	**100.0%**

Figure 8 Drainage class, Franklin County, KS

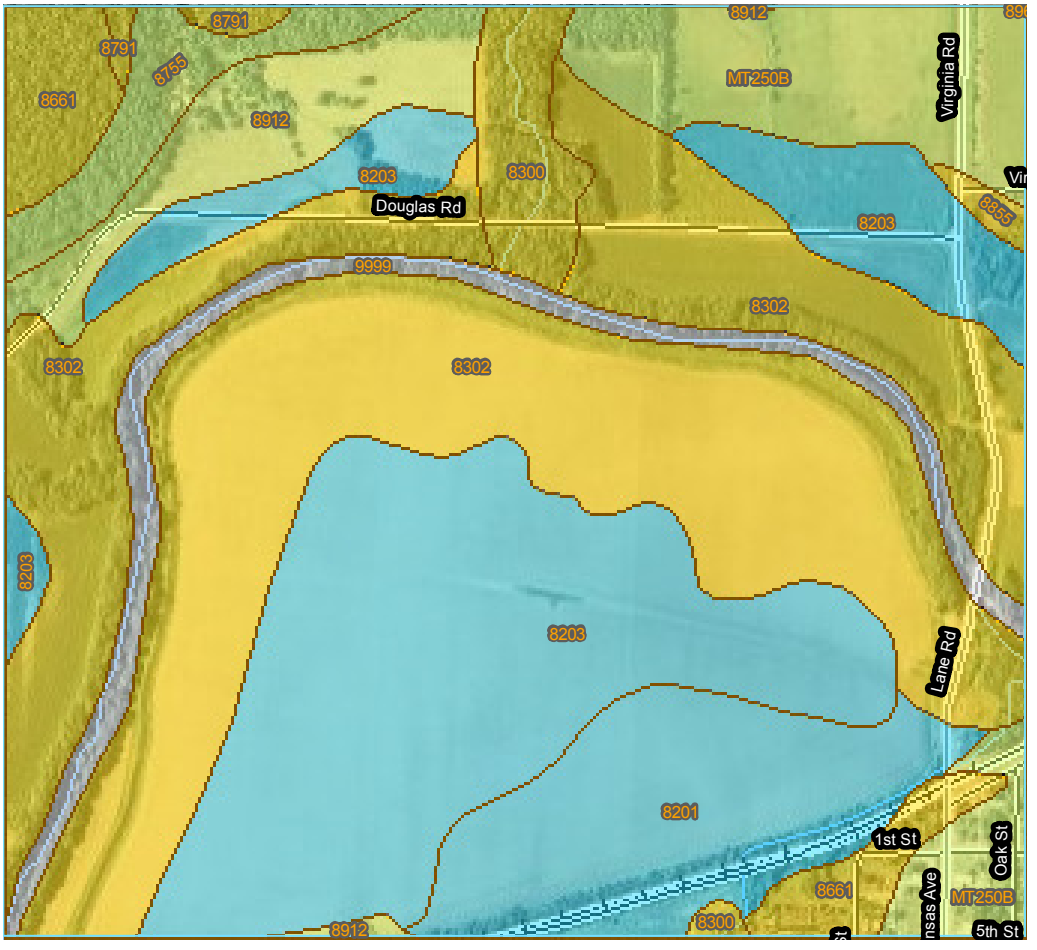


Figure 9 Water features report for Osage silty clay loam map unit, Franklin County, KS

Water Features– Franklin County, Kansas										
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Ponding			Flooding	
				Upper limit	Lower limit	Surface depth	Duration	Frequency	Duration	Frequency
				Ft	*Ft*	*Ft*				
8201—Osage silty clay loam, occasionally flooded										
Osage	D	High	January	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	February	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	March	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	April	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	May	0.2-0.8	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	June	0.8-1.2	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	July	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	August	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	September	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	October	—	—	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	November	0.8-1.2	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional
	D	High	December	0.8-1.2	>6.0	0.0-0.5	Long	Occasional	Very brief	Occasional

Figure 10 Water features report for Verdigris silt loam map unit, Franklin County, KS

Water Features– Franklin County, Kansas										
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Ponding			Flooding	
				Upper limit	Lower limit	Surface depth	Duration	Frequency	Duration	Frequency
				Ft	*Ft*	*Ft*				
8300—Verdigris silt loam, channeled										
Verdigris	B	Low	January	—	—	—	—	None	Very brief	Frequent
	B	Low	February	—	—	—	—	None	Very brief	Frequent
	B	Low	March	—	—	—	—	None	Very brief	Frequent
	B	Low	April	—	—	—	—	None	Very brief	Frequent
	B	Low	May	—	—	—	—	None	Very brief	Frequent
	B	Low	June	—	—	—	—	None	Very brief	Frequent
	B	Low	July	—	—	—	—	None	Very brief	Frequent
	B	Low	August	—	—	—	—	None	Very brief	Frequent
	B	Low	September	—	—	—	—	None	Very brief	Frequent
	B	Low	October	—	—	—	—	None	Very brief	Frequent
	B	Low	November	—	—	—	—	None	Very brief	Frequent
	B	Low	December	—	—	—	—	None	Very brief	Frequent

Case 2

RIVERINE—Endosaturated

The site is located adjacent to the Weber River in Summit County, Utah. Figure 11 shows the site with the hydric soil map.

Map unit 179, which is adjacent to the Weber River throughout the reach shown, is the Wanship-Kovich association, and the green color denotes it as partially hydric, along with map unit 127, which is Echocreek-Kovich association. As in the previous example, the term partially means that the map unit contains soil components that are both hydric and nonhydric. The OSD names for the typical pedon for all three series are Wanship loam, Kovich loam, and Echocreek loam, respectively. The taxonomic name for Wanship loam is Haploxeroll, for Kovich is Endoaquolls, and for Echocreek is Haploxeroll. The Kovich series is in the aquic suborder and is hydric. The other series do not have a hydric taxonomy. We can now assume that map unit 179 and map unit 127 are listed as partially hydric because of the presence of the Kovich series in the association.

The endo great group designation for the Kovich soil means that the soil is hydric because the depth of saturation is greater than 200 centimeters. This saturation may be provided by water moving into the profile through lateral and/or upward movement from an adjacent source. Episaturation is defined as saturation with water supplied from the surface, usually stream flooding and/or direct precipitation, and the depth of saturation is less than 0 centimeters. It is possible for a soil with an endo great group designation to actually be saturated from surface water perched on a deep, low permeability layer. This is an important distinction, as the endosaturated and episaturated soils have different dominant water sources, water budgets, and hydrodynamics. For this reason, the terms endosaturated and episaturated in soil taxonomy may have a different meaning in terms of soil hydrodynamics.

If the Kovich loam is hydrodynamically endosaturated, it can be assumed that the dominant water source is the groundwater moving laterally from the stream water surface into the Kovich soils in the floodplain. It can also be assumed that surface flooding is not required to maintain the high groundwater table, as long as the channel maintains a long-term high water surface. The first step is to rule out the possibility that the Kovich loam is hydrodynamically episaturated. For a hydric soil in a floodplain to be episaturated, it must receive water fairly frequently from stream flooding and pond water on the surface for a significant duration. Figure 12 shows the flooding frequency class for the site. The yellow color shown on map unit 179 indicates a flood frequency rating of rare, and the red color for map unit 127 indicates a rating of none.

Figure 13 shows the ponding frequency class for the site. The red color for the entire area indicates a ponding frequency rating of none.

The flooding and ponding frequency ratings both indicate that surface flooding is infrequent, and the soils are incapable of perching surface water even when it is provided. The evidence indicates that the soil is truly endosaturated.

Figure 14 shows the depth to water table map of the site, with map unit 179 shown in yellow. The yellow color indicates a representative value of 67 centimeters, and the remainder of the site in blue has a representative value of greater than 200 centimeters.

Finally, the water features report, shown in figure 15, shows the Kovich series portion of map unit 179 with the ratings for water table depth, ponding, flooding frequency, and duration. The Kovich loam parts of the map unit have a water table within 1.0 to 2.0 feet of the surface during the months of April, May, and June.

Typically, soils in floodplains that are hydrodynamically endosaturated have a relatively high rate of saturated hydraulic conductivity (Ksat), which allows changes in stream water surface to be rapidly reflected in the floodplain groundwater level.

Figure 16 shows a map of the Ksat ratings for the site. The map unit 179 area, colored in blue, has a representative value of 28.23 micrometers per second, which is the highest value of any of the areas on the site.

Finally, the physical soil properties shown in figure 17 show the soil textures by layer and Ksat in units of micrometers per millisecond. The sand percentage starts at 39 percent at the surface, remains fairly steady, and rapidly increases at 44 inches of depth. The Ksat's are also quite high at the surface and again starting at 44 inches. This is in keeping with a soil that readily transmits water from an adjacent stream with a lateral and/or upward direction of movement.

Summary for case 2

The Kovich map unit component exhibits high groundwater conditions in a RIVERINE wetland that floods infrequently and is incapable of perching water in a ponded condition. The maintenance of a high water table is dependent upon a stream hydrograph that maintains a high water surface profile for long durations. There are two general cases for watersheds capable of supplying such hydrographs. The first is a watershed dominated by sandy soils with very high infiltration

rates. A high percentage of the precipitation enters the soil surface and is converted to groundwater, with a correspondingly low surface runoff potential. Without a large runoff component, flood hydrograph peaks are drastically reduced. Watersheds in the Nebraska Sandhills region are typical for these conditions. The high groundwater supply provides a correspondingly high-stream baseflow. The other case is streams that receive the majority of their annual flow volume from snowmelt. Snowmelt hydrographs are typically long duration and have peak discharges controlled by the melt rate instead of the occurrence of high-intensity rainfall. Both landscapes also typically create floodplains dominated by soils with sandy, gravelly textures, and high hydraulic conductivity rates. The Weber River is a system where the snowmelt-dominated hydrograph provides the high-flow stage duration needed. The high sediment supply of coarse-grained material from the Wasatch and Uinta Mountains provides the high conductivity sands and gravels that exist in the floodplain. This period of high flows occurs in April, May, and June, which coincides with the peak snowmelt runoff period. The wetland hydroperiod for this site is directly coincident with this peak of the stream hydrograph. The Kovich loam component is part of two adjacent soil associations in a floodplain landscape. The Kovich loam component is the only soil that is hydric. In addition, wetland conditions are less likely to exist in the map unit 129 Echocanyon-Kovich association, based on the flood frequency rating, and its higher landscape position. Wetland conditions will exist mostly in floodplain macrotopographic features such as oxbow cutoffs and scour channels, which are the lowest landscape positions on the site. Figure 18 shows a typical floodplain macrotopographic feature on an endosaturated soil.

Figure 11 Hydric soil map, Summit area, Salt Lake and Wasatch Counties, UT

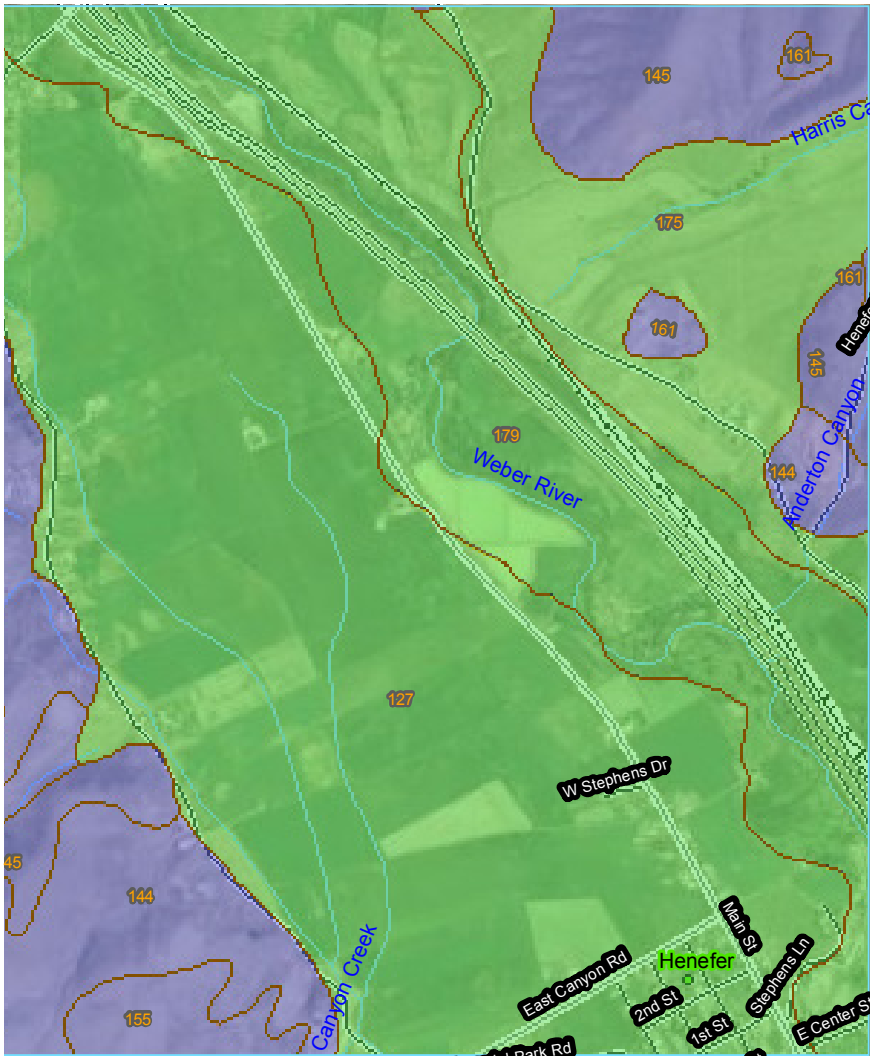


Figure 12 Flooding frequency class, parts of Summit, Salt Lake, and Wasatch Counties, UT

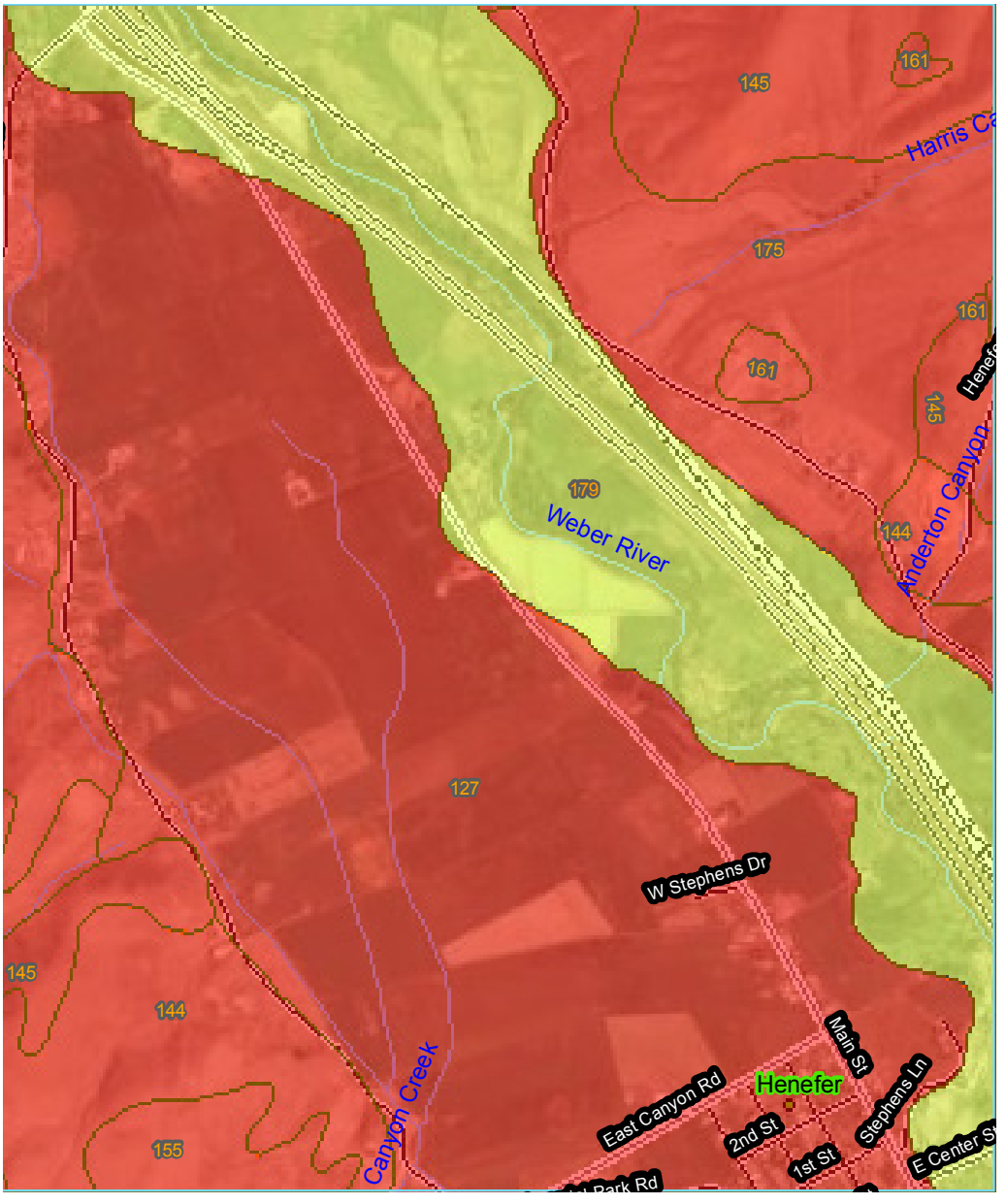


Figure 13 Ponding frequency class, parts of Summit, Salt Lake, and Wasatch Counties, UT

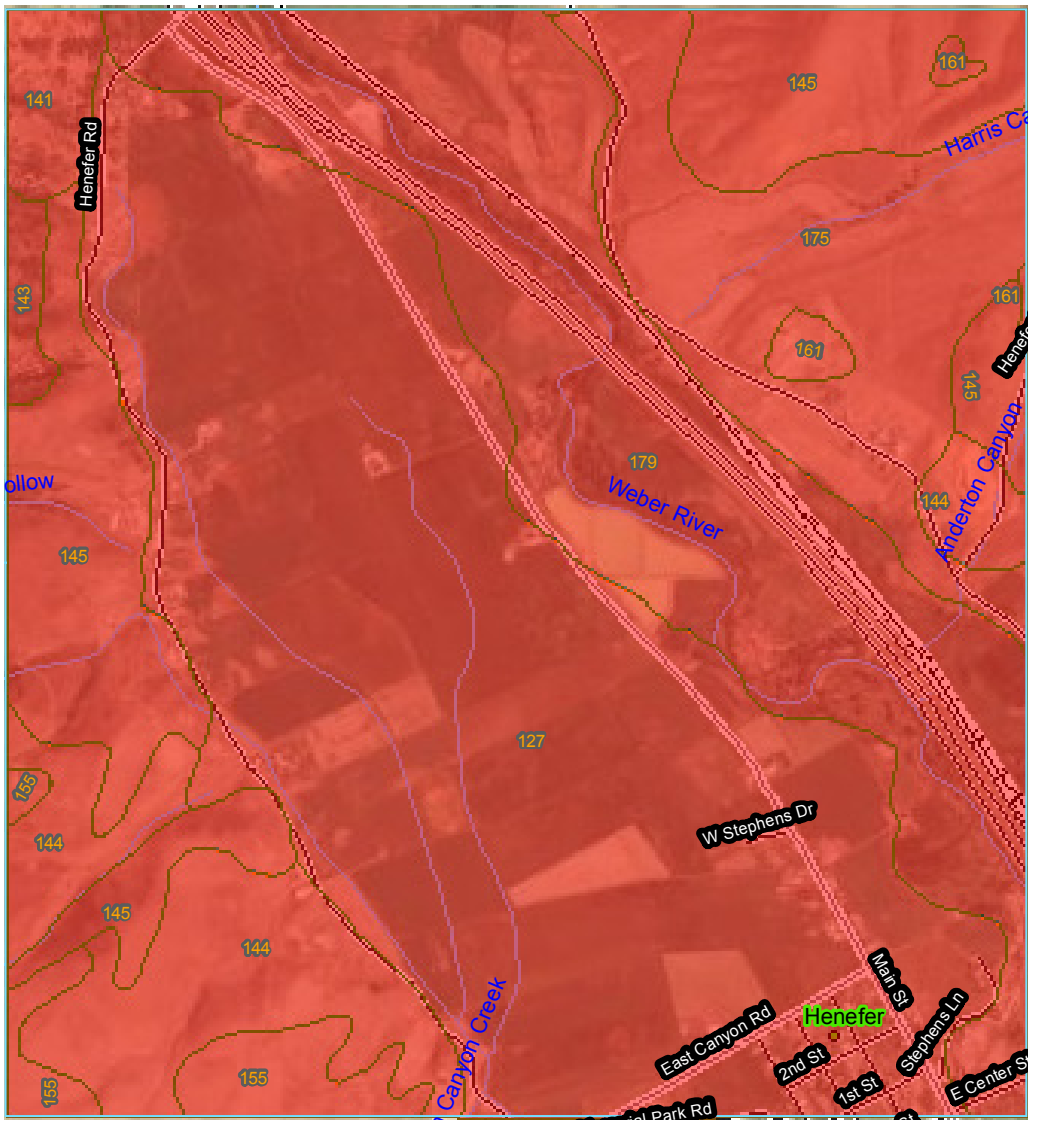


Figure 14 Depth to water table, parts of Summit, Salt Lake, and Wasatch Counties, UT

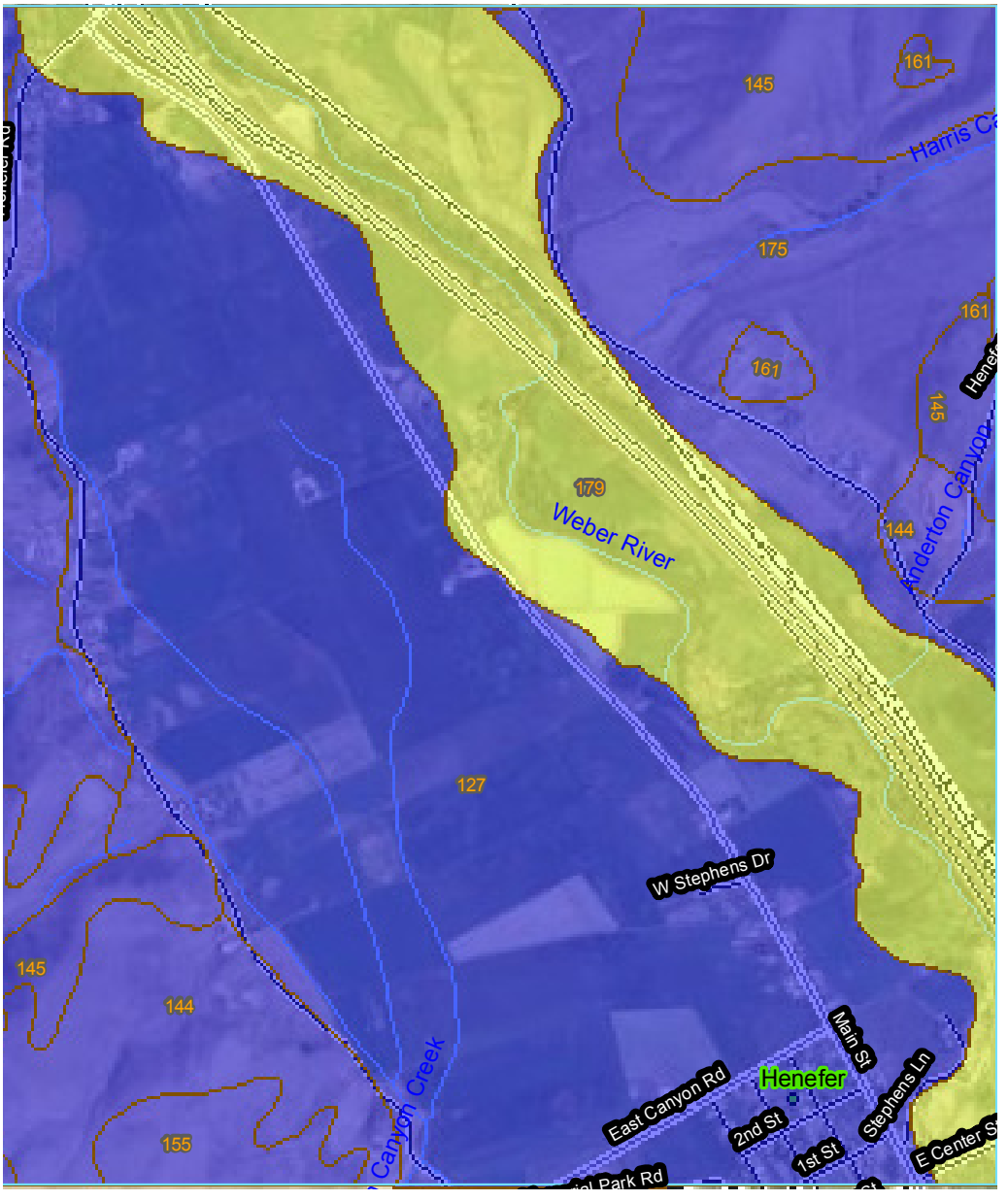


Figure 15 Water features report, parts of Summit, Salt Lake, and Wasatch Counties, UT

Water Features– Summit Area, Utah, Parts of Summit, Salt Lake and Wasatch Counties										
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Ponding			Flooding	
				Upper limit	Lower limit	Surface depth	Duration	Frequency	Duration	Frequency
				Ft	*Ft*	*Ft*				
145—Horrocks-Cutoff complex, 30 to 60 percent slopes										
Horrocks	B	Very high	Jan-Dec	—	—	—	—	None	—	—
Cutoff	B	Very high	Jan-Dec	—	—	—	—	None	—	—
155—Manila-Ant Flat loams, 8 to 15 percent slopes										
Manila	C	High	Jan-Dec	—	—	—	—	None	—	—
Ant flat	C	High	Jan-Dec	—	—	—	—	None	—	—
161—Pits, gravel										
Pits, gravel	—	—	Jan-Dec	—	—	—	—	None	—	—
175—Snyderville cobbly loam, 5 to 10 percent slopes										
Snyderville	B	Medium	Jan-Dec	—	—	—	—	None	—	—
179—Wanship-Kovich loams, 0 to 3 percent slopes										
Wanship	C	Very low	March	—	—	—	—	None	Brief	Very rare
	C	Very low	April	3.0-5.0	>6.0	—	—	None	Brief	Rare
	C	Very low	May	1.6-2.5	>6.0	—	—	None	Brief	Rare
Kovich	D	Low	April	1.0-2.0	>6.0	—	—	None	Brief	Rare
	D	Low	May	1.0-2.0	>6.0	—	—	None	Brief	Occasional

Figure 16 Ksat ratings, parts of Summit, Salt Lake, and Wasatch Counties, UT

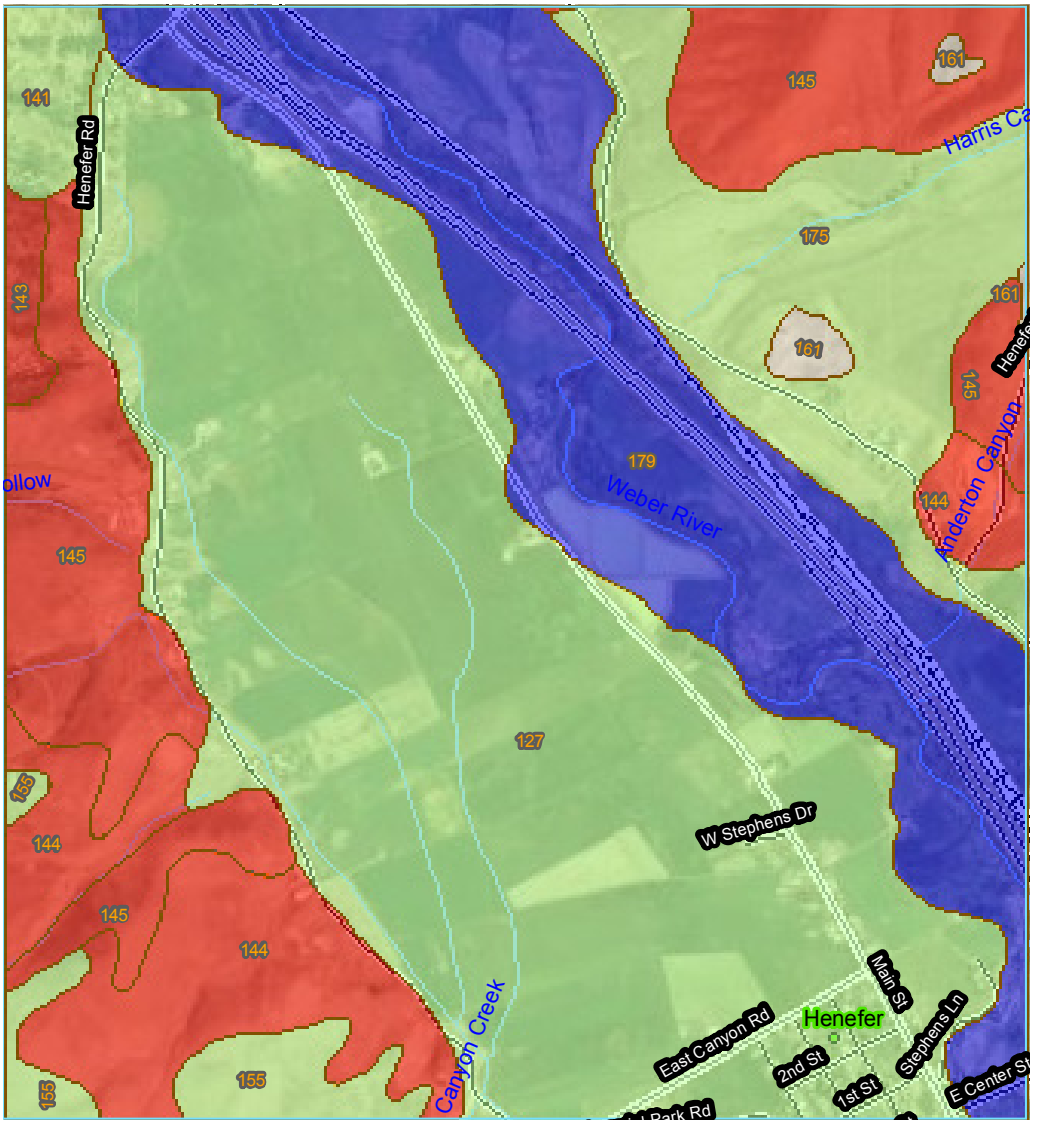


Figure 17 Physical soil properties report, parts of Summit, Salt Lake, and Wasatch Counties, UT

Physical Soil Properties– Summit Area, Utah, Parts of Summit, Salt Lake and Wasatch Counties														
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*					
175—Snyderville cobbly loam, 5 to 10 percent slopes														
Snyderville	0-10	-42-	-38-	18-20- 22	1.20-1.30	4.23-14.11	0.11-0.14	0.0-2.9	2.0-5.0	.15	.24	3	7	38
	10-16	-42-	-38-	18-20- 22	1.25-1.35	4.23-14.11	0.11-0.14	0.0-2.9	1.0-3.0	.17	.32			
	16-28	-39-	-37-	22-25- 27	1.30-1.40	4.23-14.11	0.08-0.12	0.0-2.9	0.5-1.0	.10	.28			
	28-35	-84-	- 9-	5- 8- 10	1.40-1.60	42.34-141.11	0.03-0.05	0.0-2.9	0.0-1.0	.05	.20			
	35-60	-96-	- 2-	0- 3- 5	1.40-1.60	141.11-705.00	0.02-0.03	0.0-2.9	0.0-0.5	.02	.20			
179—Wanship-Kovich loams, 0 to 3 percent slopes														
Wanship	0-8	-40-	-38-	18-23- 27	1.20-1.30	14.11-42.34	0.14-0.17	0.0-2.9	5.0-10.0	.17	.20	3	6	48
	8-14	-40-	-38-	18-23- 27	1.25-1.35	14.11-42.34	0.14-0.17	0.0-2.9	1.0-5.0	.28	.32			
	14-24	-40-	-38-	18-23- 27	1.25-1.35	14.11-42.34	0.14-0.17	0.0-2.9	1.0-5.0	.28	.32			
	24-26	-81-	-16-	0- 3- 5	1.40-1.55	42.34-141.11	0.02-0.04	0.0-2.9	0.0-1.0	.05	.20			
	26-60	-81-	-16-	0- 3- 5	1.40-1.55	42.34-141.11	0.02-0.04	0.0-2.9	0.0-1.0	.05	.20			
Kovich	0-9	-39-	-37-	20-24- 27	1.30-1.40	4.23-14.11	0.14-0.17	0.0-2.9	5.0-10.0	.24	.24	4	6	48
	9-22	-35-	-38-	20-28- 35	1.30-1.40	1.41-4.23	0.14-0.18	3.0-5.9	1.0-5.0	.28	.28			
	22-29	-35-	-38-	20-28- 35	1.30-1.50	1.41-4.23	0.14-0.18	3.0-5.9	1.0-5.0	.28	.20			
	29-44	-61-	-21-	15-18- 20	1.40-1.50	4.23-14.11	0.08-0.12	0.0-2.9	0.0-1.0	.10	.20			
	44-60	-79-	-16-	0- 5- 10	1.50-1.60	4.23-14.11	0.05-0.06	0.0	0.0-1.0	.05	.15			

Figure 18 Endosaturated floodplain macrotopographic feature

Case 3

DEPRESSIONAL—Recharge, Playa

This site, depicted in the hydric soil map in figure 19, contains two separate DEPRESSIONAL HGM wetland type areas, which are typically referred to as playas. The site is located in Lubbock County, Texas.

Map unit 42, Randall Clay, is the only one shown in green,which indicates that it is partially hydric. As in the previous examples, the term "partially hydric" indicates the potential for a combination of hydric and nonhydric soils. The hydric soil list for Lubbock County, Texas, states that the Randall Clay series covers 65 percent of the Randall map units. The taxonomic name for Randall Clay is Epiaquerts. Since it has the Epi formative feature in the great group name, it is supplied with water from the surface. The landscape is in an upland location, so stream flooding is not part of the hydrology. The only potential sources of water are surface runoff from the surrounding watershed and direct precipitation. Episaturated soils in depressions can be expected to experience ponding; this is verified with the evidence in figure 20, which shows the ponding frequency class.

The blue color indicates a ponding frequency of occasional. The flooding frequency class (not shown) is none. Although the frequency is occasional, the duration is long term and occurs from May through November, as shown on the water features report in figure 21.

For a soil to be able to maintain long-term ponding of surface water, the saturated hydraulic conductivity must be fairly low, usually because of high clay content or inherent parent materials properties. Figure 22 shows the physical soil properties report.

The 0.01 to 0.42 micrometers per millisecond range is in the lowest category. The high clay content and low sand content is in keeping with the low Ksat. The constant Ksat range from the surface to a depth of 42 inches indicates that there is no discrete perching layer.

Summary for case 3
The Randall Clay soil is an Epiaquert supplied with water from surface runoff and maintains this water in a long-term ponded condition. The wetland hydroperiod typically occurs from May through November. The low permeability layer is basically the entire A and B soil horizons, so there is little need to maintain or replace a thin perching layer in a restoration. In addition, the OSD (not shown) does not describe any interpretive perching soil horizon, such as a Bt layer. Also, any successful drainage of these wetlands must be done by diverting surface runoff away from the depression, or draining it out with surface ditching.

Figure 19 Hydric soil rating, Lubbock County, TX

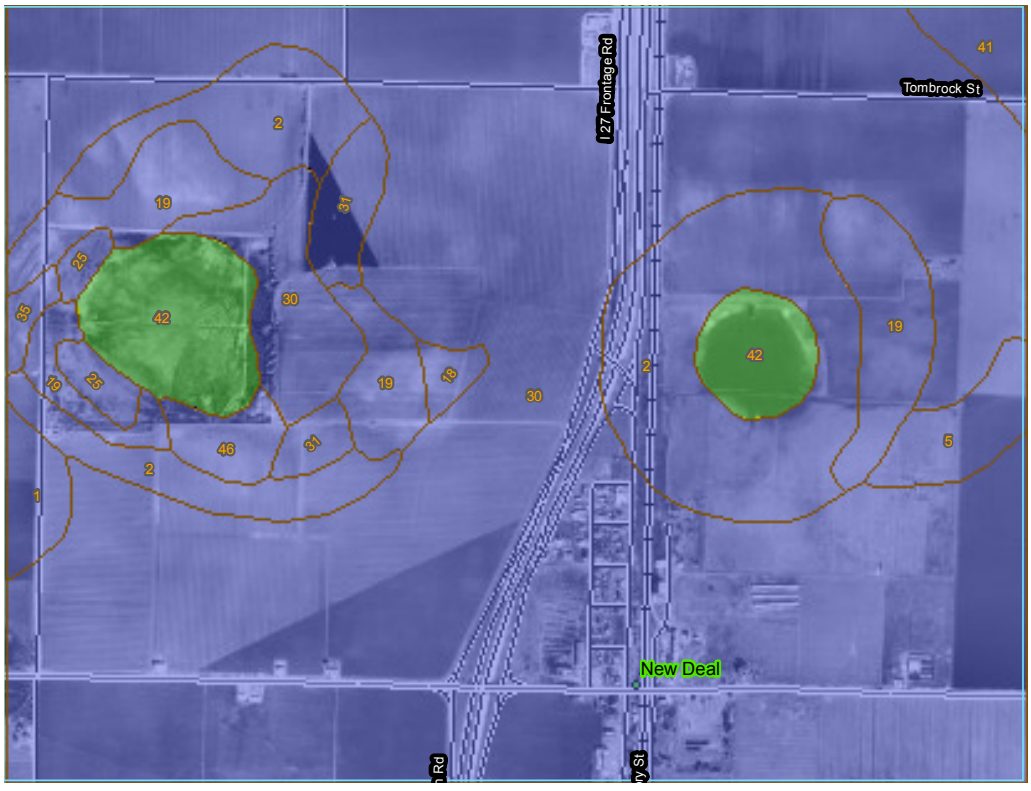


Figure 20 Ponding frequency class , Lubbock County, TX

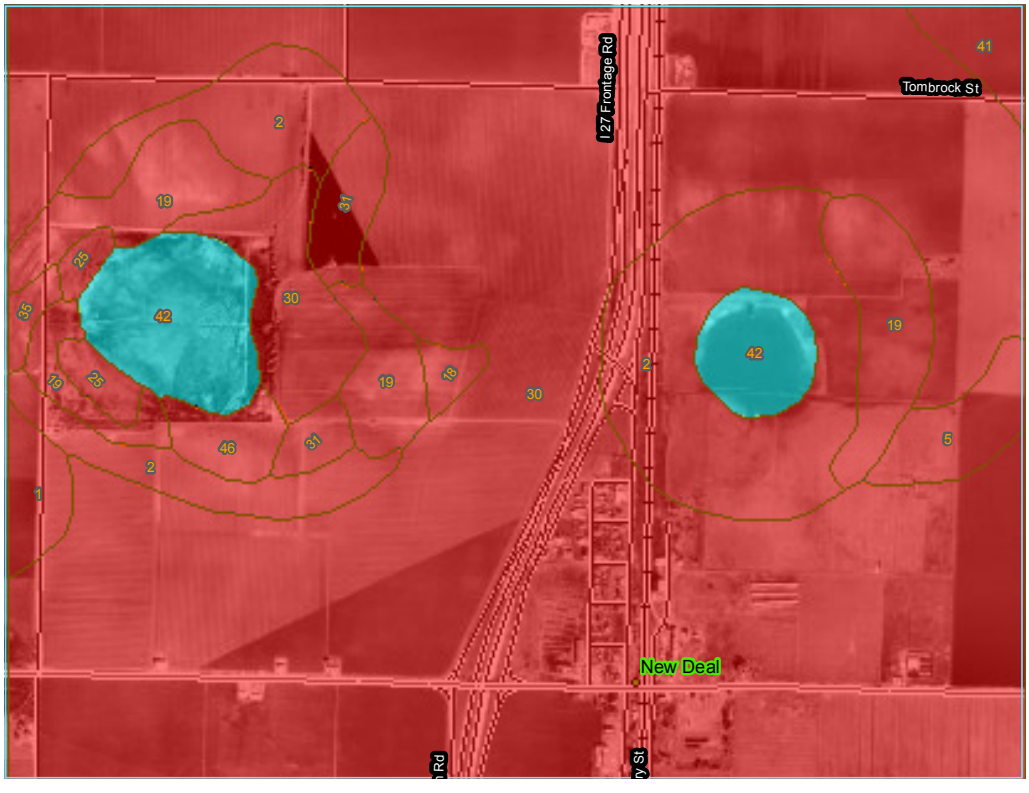


Figure 21 Water features report, Lubbock County, TX

Water Features– Lubbock County, Texas										
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Ponding			Flooding	
				Upper limit	Lower limit	Surface depth	Duration	Frequency	Duration	Frequency
				Ft	*Ft*	*Ft*				
35—Posey fine sandy loam, 1 to 3 percent slopes										
Posey	B	—	Jan-Dec	—	—	—	—	None	—	—
41—Pullman clay loam, 0 to 1 percent slopes										
Pullman	C	—	Jan-Dec	—	—	—	—	None	—	—
42—Randall clay										
Randall	D	—	May	0.0	>6.0	0.0-3.0	Long	Occasional	—	None
	D	—	June	0.0	>6.0	0.0-3.0	Long	Occasional	—	None
	D	—	July	0.0	>6.0	0.0-3.0	Long	Occasional	—	None
	D	—	August	0.0	>6.0	0.0-3.0	Long	Occasional	—	None
	D	—	September	0.0	>6.0	0.0-3.0	Long	Occasional	—	None
	D	—	October	0.0	>6.0	0.0-3.0	Long	Occasional	—	None
	D	—	November	0.0	>6.0	0.0-3.0	Long	Occasional	—	None
46—Zita loam, 0 to 1 percent slopes										
Zita	B	—	Jan-Dec	—	—	—	—	None	—	—

Figure 22 Physical soil properties report, Lubbock County, TX

Physical Soil Properties– Lubbock County, Texas														
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*					
42—Randall clay														
Randall	0-6	-17-	-28-	50-55- 60	1.20-1.40	0.01-0.42	0.12-0.18	9.0-25.0	0.5-2.0	.32	.32	5	7	38
	6-32	-17-	-28-	50-55- 60	1.25-1.40	0.01-0.42	0.12-0.18	9.0-25.0	0.1-1.0	.32	.32			
	32-80	-17-	-28-	50-55- 60	1.30-1.45	0.42-1.40	0.11-0.15	9.0-25.0	0.1-0.5	.32	.32			
46—Zita loam, 0 to 1 percent slopes														
Zita	0-12	-39-	-37-	20-24- 35	1.30-1.45	4.00-14.00	0.15-0.20	0.0-2.9	1.0-3.0	.28	.28	5	5	56
	12-36	-34-	-37-	25-30- 35	1.35-1.50	4.00-14.00	0.15-0.20	3.0-5.9	0.1-0.5	.32	.32			
	36-66	-34-	-37-	25-30- 35	1.40-1.55	4.00-14.00	0.10-0.16	0.0-2.9	0.1-0.5	.32	.32			

Case 4

DEPRESSIONAL—Discharge, Recharge, Flow through

The site for this case is in Day County, South Dakota, located in the Prairie Pothole Region. The prairie pothole wetland areas visible in figure 23 are DEPRESSIONAL. The Web Soil Survey view shown is the ponding frequency class and was chosen because the best contrast between the pothole areas and the remainder of the landscape was provided.

The hydric soil map shows all soil map units to be partially hydric. This means that there are potential nonhydric components in all of these map units.

Prairie pothole depressions can be grouped into three broad categories based on their hydrodynamics. Figure 24 illustrates the hydrodynamics of all three cases.

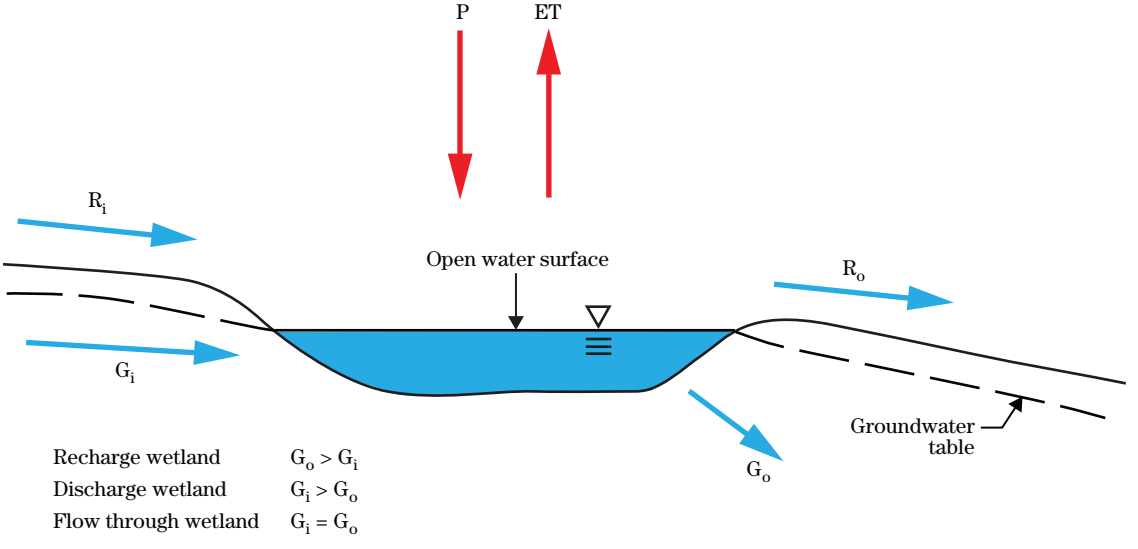
Recharge depressions have upland runoff as the dominant water source and discharge water downward through the soil substrate to a lower local water table, in much the same way as playa wetlands on the High Plains. The direction of movement is vertical downward. The Recharge depressions may receive groundwater as a secondary water source, but the volume of groundwater outflow (G_o) is greater than the volume of inflow (G_i). Discharge wetlands have groundwater as their dominant water source and lose water mainly through surface runoff when the depression overflows and evapotranspiration (ET). Water is lost from groundwater outflow as well, but G_i is greater than G_o. Flow through wetlands are those where groundwater inflows and outflows are in equilibrium (G_o=G_i).

In reality, prairie pothole wetlands seldom exist neatly within these broad categories. Many potholes reverse the direction of water movement as the wetland hydroperiod progresses. For instance, in the spring, a pothole may receive a large influx of surface runoff from snowmelt, setting up strong Recharge hydrodynamics because high water surface provides strong Recharge head. At the end of the summer, as the surface water leaves through ET, the direction of flow reverses, and a strong groundwater inflow exists.

Even though these systems have complex hydrodynamics, the use of interpretative data available in the Web Soil Survey can provide valuable information about the long-term dynamics of a given wetland site. This case study will examine the data needed to differentiate Recharge potholes from the Flow through and Discharge systems. Differentiating between Discharge and Flow through wetlands themselves is beyond the scope of this technical note, as it involves the collection of field information that is not available from the Web Soil Survey. The distinction between Discharge and Recharge is important because issues related to water quality, salinity, pH, aquatic habitat, and biogeochemical functions are directly related to this hydrodynamic. There are four soil map units, in light and dark blue, shown on the site map in figure 23. They are Tonka, Parnell, and Southam.

Figure 23 Ponding frequency class map or depressional wetlands in the Prairie Pothole Region, Day County, SD

Figure 24 Prairie pothole wetland hydrodynamics



Tonka series

On this site, the Tonka soil only appears in a small area in the northwest corner. The dark blue color indicates a ponding frequency class of frequent. The taxonomic class is Argialboll. The t on the Bt horizon designates translocation of clays. The direction of movement must be vertically downward to provide the translocation for the Bt horizon formation, and this movement must be dominant and long term. Thus, the wetland is potentially a Recharge wetland, with surface runoff as the dominant water source and water losses due to G_o, which moves vertically downward, and ET. The OSD describes a Bt1 and a Bt2 layer beginning at 19 inches and extending to a depth of 34 inches. In addition, there is an E horizon from 13 to 19 inches. The E means eluviated, or stripped of clay particles, which also requires a process where strong vertically downward movement of water is dominant. This E horizon is also in keeping with the alb formative element in the taxonomic name. The E horizon is an albic horizon, meaning it is stripped of clays and/or iron oxides. Thus, presence of the E and Bt horizons in the same profile is indicative of a steady water source moving vertically downward and translocating clay particles with it.

The soil physical properties shown in figure 25 indicate that the Ksat for Tonka for the layer from 24 to 49 inches is 0.42 to 1.40 micrometers per millisecond, which is the second lowest category. This value for Ksat corresponds roughly to the location of the Bt horizons in the OSD.

Figure 25 Soil physical properties with Tonka soils, Day County, SD

Physical Soil Properties– Day County, South Dakota														
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*					
Sw—Southam silty clay loam														
Southam	0-7	-19-	-48-	27-34- 40	1.10-1.40	1.40-4.00	0.18-0.23	3.0-5.9	5.0-20.0	.37	.37	5	4L	86
	7-51	- 8-	-50-	35-43- 50	1.20-1.50	0.42-1.40	0.14-0.20	6.0-8.9	1.0-10.0	.28	.28			
	51-60	- 8-	-51-	18-41- 50	1.20-1.50	0.42-4.20	0.13-0.17	6.0-8.9	0.0-3.0	.28	.28			
To—Tonka silt loam														
Tonka	0-17	-25-	-53-	18-23- 27	1.00-1.50	4.00-14.00	0.18-0.23	0.0-2.9	5.0-10.0	.37	.37	5	6	48
	17-42	- 8-	-52-	35-40- 45	1.40-1.65	0.42-1.40	0.14-0.19	6.0-8.9	0.0-2.0	.43	.43			
	42-60	-19-	-52-	18-29- 39	1.40-1.70	1.40-4.00	0.14-0.19	3.0-5.9	0.0-1.0	.37	.37			
Vh—Vallers-Hamerly loams														
Vallers	0-11	-40-	-38-	18-23- 27	1.20-1.35	4.00-14.00	0.22-0.24	0.0-2.9	5.0-8.0	.28	.28	5	4L	86
	11-18	-34-	-38-	18-28- 35	1.40-1.55	1.40-4.00	0.15-0.19	3.0-5.9	1.0-3.0	.28	.28			
	18-60	-34-	-38-	18-28- 35	1.50-1.70	1.40-4.00	0.17-0.19	0.0-2.9	0.0-0.5	.37	.37			
Hamerly	0-11	-40-	-38-	18-23- 27	1.30-1.60	4.00-14.00	0.18-0.24	3.0-5.9	3.0-7.0	.24	.24	5	4L	86
	11-28	-38-	-36-	18-27- 35	1.20-1.60	4.00-14.00	0.15-0.19	3.0-5.9	1.0-3.0	.28	.28			
	28-60	-35-	-38-	18-28- 35	1.30-1.60	1.40-4.00	0.14-0.19	3.0-5.9	0.0-0.5	.37	.37			

Parnell series

The Parnell series occurs at five small locations on the site view in figure 23. It is quite similar to the Tonka series. The taxonomic classification is Vertic Argiaquolls. The fact that it is in a Vertic subgroup, an Argillic great group, and in an Aquic suborder provides a stronger indication of the influence of the clay texture and inherent nature of parent materials on its hydrodynamics. The subgroup and great group formative elements are backed up by the OSD horizon information, which describes two separate Bt layers from 22 to 55 inches

Summary for Tonka and Parnell soils

Both have taxonomy and horizon development that can only be caused by long-term dominant water movement which is vertically downward. This movement is required for the translocation of the fine-grained clay particles to form the strong Bt horizons. This layer, in turn, created a perching condition for surface water. If Discharge wetland hydrodynamics (groundwater inflow) dominated, the Bt horizon formation would have been halted or reversed. We can also consider these soils to be episaturated in terms of wetland hydrodynamics because they receive most of their water from the surface. The wetlands that exist on these soils are Recharge wetlands. The hydrodynamics are unidirectional, and vertical downward.

Southam series

The Southam soils are Endoaquolls and have a much simpler soil horizon. It basically consists of Ag layers over Cg layers. The absence of a B horizon or any layer with an accumulation of clay particles is evidence that water movement has been dominated by groundwater inflow. The ponding potential map indicates that the soil inundation is nearly continuous. The wetland areas with Southam soils can be described as either a Discharge or Flow through wetland, and this hydrodynamic occurs virtually year round. There are no other complex water pathways caused by vegetation or a change in water regime throughout the hydroperiod. The ponding frequency rating of frequent is the highest in the class and is in keeping with the endosaturated great group, which is the wettest formative element.

Vallers-Hamerly complex

These soils exist in a concentric ring around the Southam series and have a lower ponding frequency rating. Both are Calciaquoll, instead of Endoaquolls, so a ponding frequency rating of occasional instead of frequent is in keeping with placing these soils in the Calcic great group rather than the Endo great group. Figure 26, the drainage class map, shows the Vallers-Hamerly complex to be a lighter blue and poorly drained, in contrast with the very poorly drained Southam soils in the deeper depression area.

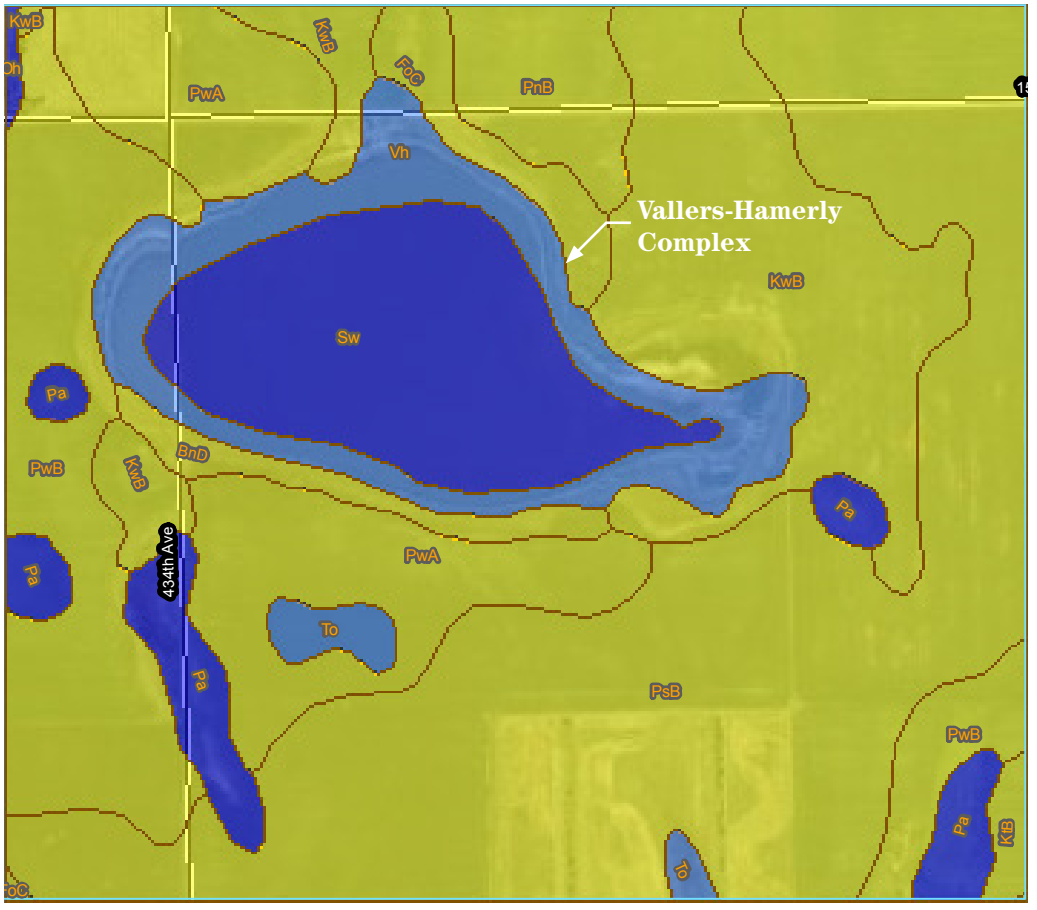
The Calcic great group designation, along with the soil horizon features, indicates the presence of a condition called local edge focused flow (Richardson and Vesprakas 2001). The deeper area of the depression comprising the Southam soils receives water from groundwater inflow with dissolved carbonates. The edges of this depression, comprising the Vallers-Hamerly complex, are shallower. Emergent hydrophytic vegetation growing in this area draws water upward due to matric potential from evapotranspiration. Mineral deposits are left behind, which is evidenced by the Bk horizons of both soil series described in the OSD. The hydrodynamics required for this Calcic deposition are unidirectional, horizontal, and unidirectional, vertical upward.

Summary for Southam and Vallers-Hamerly complex soils

These soils commonly occur adjacent to each other. The Vallers-Hamerly Complex, by itself, cannot be described as having Recharge, Discharge, or Flow through hydrodynamics. It can only be analyzed as part of a system that includes the Southam portion of the depression. The system is not a Recharge system because of the lack of a Bt soil horizon or other evidence of strong vertical downward movement. However, the available Web Soil Survey evidence cannot readily differentiate between Discharge and Flow through. The evidence does indicate that it cannot be a Recharge system.

There are profound differences between the Southam and Vallers-Hamerly complex map units. The Southam is wetter, as evidenced by the gleyed soil horizons and the taxonomic great group designation of Endoaquolls. The Vallers-Hamerly complex is saturated for a shorter duration and shows pronounced deposition of carbonates, based on the Calcic great group designation and the Bk soil horizons.

Figure 26 Drainage class map—Vallers-Hamerly Complex, Day County, SD



Case 5

SLOPE—Topographic—Large scale, organic soil

This site is in western New York, in the Finger Lakes region. Figures 27 and 28 show the hydric soil map and ponding frequency map. The brown areas, classed as all hydric, consist mainly of the Carlisle muck series. The dark blue areas in the ponding frequency map have a rating of frequent and the red areas are rated as none. The OSD shows the taxonomic class as Haplosaprists. Histosols are hydric by definition. The morphology, hydrodynamics, and soil features of this landscape are unique. On the map scale, the Carlisle appears to be a linear feature and, in fact, the extent of the Carlisle map unit extends well past the top and bottom limits of the map. This gives the appearance of a stream valley and there is, in fact, a very low valley gradient from the bottom of the map to the top. There also appears to be a tributary stream entering the map area at the northeast corner. However, there is no stream channel in evidence. There is a straight, linear feature oriented north-south on the portion south of the diagonal road that is a drainage ditch. The site has been modified by drainage for agriculture.

It is important, then, to determine whether the site originally exhibited a stream channel with an adjacent floodplain. If this was the case, the wetland would be a RIVERINE HGM wetland type, and the soil hydrodynamics would be based on the same type of dynamics as in case 1 or 2. In reality, local knowledge of reference wetland sites would suffice to make this determination. However, a description of soil taxonomy alone can shed light on this determination. Organic soils can only be formed and maintained in a state of near-continuous surface saturation. They are highly erosive and can only exist in a stagnant water regime. The dynamic nature of streamflow and stream hydrograph fluctuation will not allow the formation of organic soils.

The conditions that are conducive to organic soil formation are where groundwater moving laterally and vertically upward expresses itself as surface water. This flow must be long term and occur virtually year-round. This hydrodynamic is consistent with the dominant water source and hydrodynamics of a SLOPE wetland. It is important to note that the designation of this landscape as a SLOPE HGM wetland type is made in the context of dominant water source and hydrodynamics only. This site also exists in a very shallow depression. Based on landscape position, it could be considered to be a DEPRESSIONAL wetland type. Also, the large areal extent puts this wetland in consideration for including it in the ORGANIC FLAT HGM wetland type. The wetland is described as a SLOPE wetland for the case illustrated here, as it is in keeping with the soils interpretations being presented. Figures 29 and 30 illustrate the hydrodynamics schematically.

This type of SLOPE wetland is in a subset called topographic slope and is one where the land surface contours create a concave landscape position which forces groundwater to the surface. These areas commonly occur in the extreme headwaters of stream systems. Organic soils or soils with organic features such as histic epipedons will form at locations where the groundwater emerges if it causes continuous surface saturation.

In this case illustrated, the groundwater supply and flat landscape combine to allow water to emerge on the surface and spread across a large area. The vegetation supported by this situation grows, senesces, and decays in an anaerobic state caused by the continuous surface saturation. Anaerobic soil conditions allow the decayed plant matter to build up without conversion to carbon dioxide, and the surface builds up until equilibrium is reached between the land surface and the available groundwater head.

If the site were a concave depression such as a large prairie pothole or lake, the water depth would not allow the growth of emergent aquatics across the site needed for the organic soil buildup, even though the dominant water source is the same. There are instances where large depressions with groundwater supply have gradually filled in with organic soil from edges inward until the entire area is now a large organic flat. The Nebraska Sandhills area has extensive fen wetlands, which have formed in this way. However, the site in this case was never an extensive depression, and thus cannot be considered to be a DEPRESSIONAL wetland. Furthermore, excess surface water flows out through the low valley gradient. In its unaltered condition, the site appeared much the same as the site in figure 31, which is shown near the peak of the wetland hydroperiod.

To further reinforce the placement of the wetland in a type other than RIVERINE, the evidence of the flooding and ponding frequency maps can be used. The flood frequency rating is none, and covers the entire site. Flooding refers to dynamic floodwater supplied by a stream hydrograph. The rating of “none” is in keeping with the determination that the site is not a RIVERINE system. The ponding frequency rating in figure 28, however, shows the Carlisle mmuckuck areas to be colored dark blue, which denotes a ponding frequency rating of frequent. Although the organic soil surface is in equilibrium with the local groundwater head, the presence of a deeper ponding regime is still possible on these sites for part of the year and does not interfere with the formation and maintenance of

the organic soils. The water features report for Carlisle muck, shown in figure 32, puts the information together.

The flooding duration and frequency, as mentioned earlier, are not pertinent. The ponding duration class is very long and the frequency class is frequent, except in the time period from June through September. Again, this is in keeping with a system that is not RIVERINE. The ponding is provided by surface runoff from the adjacent uplands in addition to increased groundwater flow during wet periods. These are commonly associated with spring snowmelt events. Although the ponding is listed as frequent for 8 months of the year, it is not extensive outside of this spring period, except after infrequent high intensity rainfall events.

Although these systems are dominated by a saturation ponding regime, the water in the system is not completely stagnant. The main loss of the ponded water is surface outflow under the energy of the low downstream gradient. In a typical system in this area, the flow appears to be a streamflow with a quite high discharge rate, as shown in figure 33, as the flow exits a culvert through a county road.

However, there is no streambed, banks, or defined floodplain, and the water depth evident in the foreground decreases only gradually toward the margins of the wetland. The flow area shown is only a preferential flow path where the vegetative resistance is lower.

One other feature of this system is that the contributing watershed is forested, and the sediment delivery rates are quite low. Stream channel and floodplain systems must have a certain amount of sediment to transport on a continuous basis to maintain their morphology. The combination of a low sediment supply, low downstream gradient, and high supply of groundwater all work together to maintain this system's hydrodynamics. It is important to recognize that this system is not a stream, and stream fluvial geomorphology principles are not pertinent to the restoration of this landscape.

Figure 27 Hydric soil map, Oswego County, NY

Figure 28 Ponding frequency class map, Oswego County, NY

Figure 29 Plan view of topographic SLOPE wetland

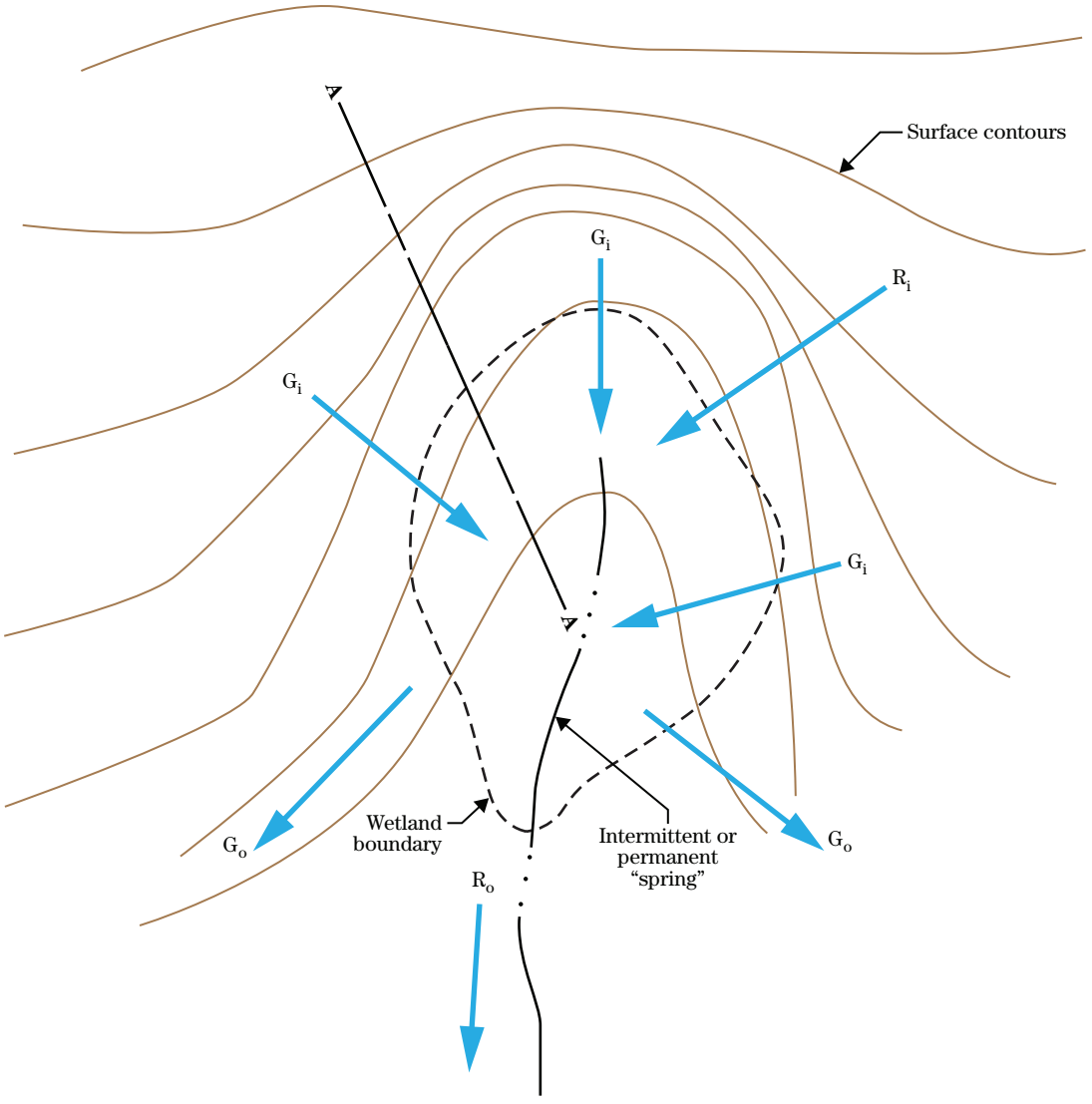


Figure 30 Cross-sectional view of topographic SLOPE wetland

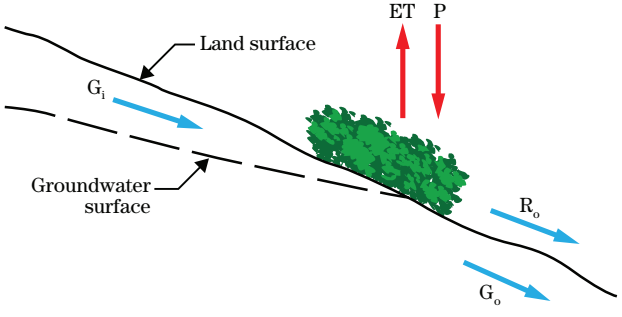


Figure 31 Nondegraded SLOPE wetland in Finger Lakes Region

Figure 32 Water features report, Carlisle muck, Oswego County, NY

Water Features– Oswego County, New York										
Map unit symbol and soil name	Hydrologic group	Surface runoff	Month	Water table		Ponding			Flooding	
				Upper limit	Lower limit	Surface depth	Duration	Frequency	Duration	Frequency
				Ft	*Ft*	*Ft*				
Cd—Canandaigua silt loam										
Canandaigua	D	—	January	0.0-1.0	>6.0	0.0-1.0	Long	Frequent	—	None
	D	—	February	0.0-1.0	>6.0	0.0-1.0	Long	Frequent	—	None
	D	—	March	0.0-1.0	>6.0	0.0-1.0	Long	Frequent	—	None
	D	—	April	0.0-1.0	>6.0	0.0-1.0	Long	Frequent	—	None
	D	—	May	0.0-1.0	>6.0	—	—	None	—	None
	D	—	November	0.0-1.0	>6.0	0.0-1.0	Long	Frequent	—	None
	D	—	December	0.0-1.0	>6.0	0.0-1.0	Long	Frequent	—	None
Ce—Carlisle muck										
Carlisle	A/D	—	January	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None
	A/D	—	February	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None
	A/D	—	March	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None
	A/D	—	April	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None
	A/D	—	May	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None
	A/D	—	June	0.0	>6.0	—	—	None	—	None
	A/D	—	September	0.0	>6.0	—	—	None	—	None
	A/D	—	October	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None
	A/D	—	November	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None
	A/D	—	December	0.0	>6.0	0.0-0.5	Very long	Frequent	—	None

Figure 33 Excess surface runoff exiting a road culvert

Case 6 SLOPE—Topographic—small scale

Small scale

Figure 34 shows an aerial image of Kossuth County, Iowa, located in the Des Moines Lobe area of the Prairie Pothole region. Wetlands exist in depressions and flats in this landscape, as well as in small scale SLOPE wetlands, which form the headwaters of stream networks. This case focuses on soil map units that exist in proximity to the drainage ditch labeled as Mud Creek. This ditch was formed to receive the inflow from subsurface drainage networks and carry it as surface flow to an existing stream as part of a local drainage project.

When making interpretations of wetland hydrology, it is important to understand the conditions that formed the original soils. In this unique landscape, DEPRESSIONAL, RIVERINE, and SLOPE HGM wetland types may exist in close proximity to each other, with subtle transitions between them. This case uses soils interpretations to determine if the map units adjacent to the drainage ditch, which flows from the upper end of the photo to the lower end (north to south), are SLOPE, RIVERINE, or DEPRESSIONAL wetlands. The upper end of the drainage ditch is within a half mile of a very indistinct watershed boundary. This boundary area (not shown) is dominated by a complex set of depressions, and a large part of this drainage area is noncontributing in terms of surface runoff. Thus, a significant amount of the direct precipitation and surface runoff is captured in depressions and can only leave through evapotranspiration or groundwater movement. Of course, drainage systems now remove this water through drain tiles.

Figure 35 shows the hydric soil map for the area at the lower (south) end of the photo, which is the focus area for this case. With the exception of map unit 203, Cylinder Loam, the map units for the entire reach are mapped as hydric, in brown. Map unit 203 is partially hydric. Figure 36 shows the ponding frequency map for the area.

Map units 221 Palms muck, Okoboji silty clay loam, and 90 Okoboji mucky silt loam have a ponding rating of frequent. The rest of the area has a rating of none.

Figure 37 shows the taxonomic classification of soil series in the area. Not shown is the depth to water table report. With the exception of map unit 203, the depth is 0 to 25 centimeters, which is the shallowest category. The water features report lists the duration class as long for all the map units with a ponding rating, as well.

Table 1 shows the map unit name, ponding frequency class, and taxonomy in order of flow from upstream to downstream.

The Palms muck is a Histosol. The ponding rating seems to indicate that the site is dominated by standing water. This is misleading because the presence of continuous saturation to the surface creates this rating, as well as standing water at any depth. Histosols can only form under conditions of continuous surface saturation, but not open water, as described in case 5. This condition is only created by the constant supply of groundwater inflows. The map unit cannot be capable of ponding surface runoff to a significant depth, because this would preclude the formation and maintenance of the organic soil. Because of this, the map unit cannot be a DEPRESSION HGM wetland type. It also cannot be RIVERINE for the same reasons as stated in case 5. Before the construction of the drainage ditch, this map unit delivered low-energy surface and groundwater downstream to the Harps clay loam map unit.

The Harps loam is a Calciaquoll. A Calcic soil horizon developed in this soil under the same dynamic as in case 4. Groundwater inflows supplied the long-term water source, and the matric potential of vegetation created a vertical upward flow. The plants extracted water, leaving the calcium carbonate dissolved in the water behind in the soil profile. The saturated zone was somewhat below the soil surface and was held in equilibrium by the evapotranspiration of vegetation. Since this map unit has no ponding rating, surface runoff delivered to the upstream Palms muck also flows though this map unit and cannot be a DEPRESSIONAL wetland.

The Okoboji silty clay loam is a Calcic Endoaquoll. The hydrodynamic that created the Calcic horizon is slightly less prominent than that of the Harps loam. However, the dominant water source and direction of movement is the same. The Canisteo clay loam is a calcareous, mesic Typic Endoaquoll. The calcareous modifier means that the hydrodynamic creating the Calcic layer is even less prominent, but it still exists to some extent. The Cylinder loam is currently within the path of the drainage ditch, but it was probably not in the flow path of surface and groundwater discharge in the original system. The Okoboji mucky silt loam has the “mucky” modifier, which indicates that it has a significant build up of organic material at the surface. As with the Palms muck, this condition requires significant periods of surface saturation, with no long-term periods of ponding. As with the Palms muck, this can only occur with a steady supply of groundwater.

Summary for case 6

The system that includes the map units in the path of the current drainage ditch appears to be quite complex. Although there are five separate soil map units included, they share similar hydrodynamic attributes. All were formed under conditions where groundwater was the dominant long-term water source. They do not form a topographic depression and do not experience flooding. High-energy surface runoff cannot be a significant dynamic, as it would have precluded the presence of the Palms muck and the mucky phase of the Okojobi series. The dominant water source and hydrodynamics of this system place it in the SLOPE HGM wetland type.

The presence of the drainage ditch and the fact that it has been named Mud Creek may lead to the conclusion that this system originally existed as a small headwater stream that has been straightened. The soils interpretations prove that this was not the case. The original condition was one where rainfall and surface runoff was trapped by DEPRESSIONAL wetlands in the noncontributing watershed area. This provided a source of groundwater that moved as subsurface flow downstream through the map units in this area. The area can be described as a slough. A natural stream channel in this landscape would have lowered the local groundwater table and precluded the surface saturation of the organic soils. It would also have prevented the concentration of calcium, which requires a shallow groundwater table within the plant root zone. Short-term rainfall events may have created brief periods of high surface flow. Outside of these periods any flows were steady, shallow, low in magnitude, and with very low velocities. These flows likely ceased in mid to late summer and resumed again after spring snowmelt.

Figure 34 Aerial view—Des Moines Lobe area, Kossuth County, IA

Figure 35 Hydric soil map, Kossuth County, IA

Figure 36 Ponding frequency map, Kossuth County, IA

Figure 37 Hydric rating by map unit, Kossuth County, IA

Hydric Rating by Map Unit— Summary by Map Unit — Kossuth County, Iowa (IA109)				
Map unit symbol	**Map unit name**	**Rating**	**Acres in AOI**	**Percent of AOI**
6	Okoboji silty clay loam, 0 to 1 percent slopes	All Hydric	5.5	5.3%
55	Nicollet loam, 1 to 3 percent slopes	Partially Hydric	5.0	4.8%
62C2	Storden loam, 5 to 9 percent slopes, moderately eroded	Not Hydric	1.7	1.6%
62D2	Storden loam, 9 to 14 percent slopes, moderately eroded	Not Hydric	2.5	2.4%
90	Okoboji mucky silt loam, 0 to 1 percent slopes	All Hydric	24.9	23.9%
95	Harps clay loam, 0 to 2 percent slopes	All Hydric	12.1	11.6%
107	Webster silty clay loam, 0 to 2 percent slopes	All Hydric	7.1	6.8%
138B	Clarion loam, 2 to 5 percent slopes	Not Hydric	13.0	12.6%
138C2	Clarion loam, 5 to 9 percent slopes, moderately eroded	Not Hydric	4.8	4.6%
203	Cylinder loam, 32 to 40 inches to sand and gravel, 0 to 2 percent slopes	Partially Hydric	1.9	1.8%
221	Palms muck, 0 to 1 percent slopes	All Hydric	0.8	0.8%
335	Harcot loam, 0 to 2 percent slopes	All Hydric	2.8	2.7%
348	Fieldon loam, 0 to 2 percent slopes	All Hydric	0.0	0.0%
388	Kossuth silty clay loam, 0 to 2 percent slopes	All Hydric	1.7	1.6%
485B	Spillville loam, 2 to 5 percent slopes	Partially Hydric	2.5	2.4%
507	Canisteo clay loam, 0 to 2 percent slopes	All Hydric	11.2	10.8%
638B	Clarion-Storden loams, 2 to 5 percent slopes	Not Hydric	1.5	1.4%
655	Crippin loam, 1 to 3 percent slopes	Partially Hydric	5.0	4.8%
879	Fostoria loam, 0 to 2 percent slopes	Partially Hydric	0.1	0.1%
Totals for Area of Interest			**104.0**	**100.0%**

Table 1 Map unit data from upstream to downstream

Map unit name	Ponding frequency class	Taxonomic name
221—Palms muck	Frequent	Haplosaprists
95—Harps clay loam	None	Calciaquoll
6—Okoboji silty clay loam	Frequent	Calcic Endoaquoll
95—Harps clay loam	None	Calciaquolls
507—Canisteo clay loam	None	Endoaquolls
203—Cylinder loam	None	Hapludolls
507—Canisteo clay loam	None	Endoaquolls
90—Okoboji mucky silt loam	Frequent	Endoaquolls

Case 7 ORGANIC Flat

ORGANIC flats exist in broad flat upland landscapes or in the beds of relict lakes. Figure 38 shows the hydric soil map for a site in Palm Beach County, Florida.

The entire area is occupied by a single map unit, Torry muck. The area is southeast of Lake Okeechobee and is extensively drained for the production of high-value crops. The taxonomic designation is Haplosaprist. Since it is a Histosol, it is hydric by definition and was formed under conditions of continuous surface saturation. The ponding frequency class is frequent. The ponding designation is somewhat misleading, as it only indicates that surface saturation exists, even though the water is not present at any significant depth. Deep surface water would preclude the original formation of the organic soils. Histosols are commonly formed by hydrodynamics existing in SLOPE wetlands, which require a constant groundwater inflow from a contributing watershed collection area. In this large, flat landscape, the topography required to provide a catchment area and drive groundwater movement does not exist. The dominant water source is direct precipitation. In this high rainfall, humid climate, sufficient rainfall occurs to maintain the entire soil profile in a saturated state, creating conditions necessary for the buildup of organic soil. Excess precipitation not used by evapotranspiration is lost as groundwater flow to the underlying water table, or through very shallow overland flow. This soil map unit exists in an ORGANIC FLAT.

Figure 38 Hydric rating, Palm Beach County area, FL

Case 8 MINERAL Flat

Figure 39 is the hydric soils map of a site in Bossier Parish, Louisiana. The two map units shown are Wrightsville silt loam, 0 to 1 percent slopes (brown), and Gore silt loam, 1 to 5 percent slopes (blue). The Wrightsville soil is all hydric, and the Gore map unit is nonhydric. The Gore map unit is in the headwaters of a stream network, and surface water can drain off the site because of the steeper slopes. The Wrightsville map unit is very flat, and surface water has little opportunity to move from where it was deposited as rainfall. The taxonomic designation is Glossaqualf. Aquic suborders are hydric by definition. Figure 40 is a flood frequency map indicating a rating of none. The ponding frequency map is identical, with the same rating.

Based on this information, the soil map unit is not in a RIVERINE or DEPRESSIONAL HGM wetland type. This extent of this map unit is large, there is no adjacent groundwater catchment area, and the flat landscape provides no slope needed to drive groundwater movement. So there is no potential for the map unit to be a SLOPE HGM wetland type, either. The map unit is a MINERAL FLAT. The hydrodynamics of this system is unidirectional, vertical downward. The OSD information for the soil horizons is provided in the appendix of this technical note.

The thin Oi layer is an organic horizon, indicating that water exists at the ground surface for significant periods. The Eg1 and Eg2 horizons are eluvial soil layers, indicating a strong vertical downward movement of water, which has moved clay size particles out of this part of the profile. The Btb layer is the first layer where the clay fraction moved out of the E horizons above is deposited. The “g” designation also indicates long-term saturation, causing gleying. The successive Bt layers are further indication of illuviation, which is the deposition of clays from the E layer. The evidence, then, is of strong vertical downward movement, consistent with the hydrodynamics of a MINERAL FLAT HGM map unit.

Summary for case 8

The dominant water source is direct precipitation. The topography is flat, so there is no contributing watershed to deliver surface runoff. Also, the flat topography precludes groundwater movement in any other direction than vertically downward. The lack of a ponding or flooding rating precludes the map unit from being a DEPRESSIONAL or RIVERINE wetland, and the vertical direction of water movement precludes the soil from being in a SLOPE wetland type. Finally, the soil profile information provides evidence that the soil was formed and maintained by the strong vertical downward direction of water.

Figure 39 Hydric soil map, Bossier Parrish, LA

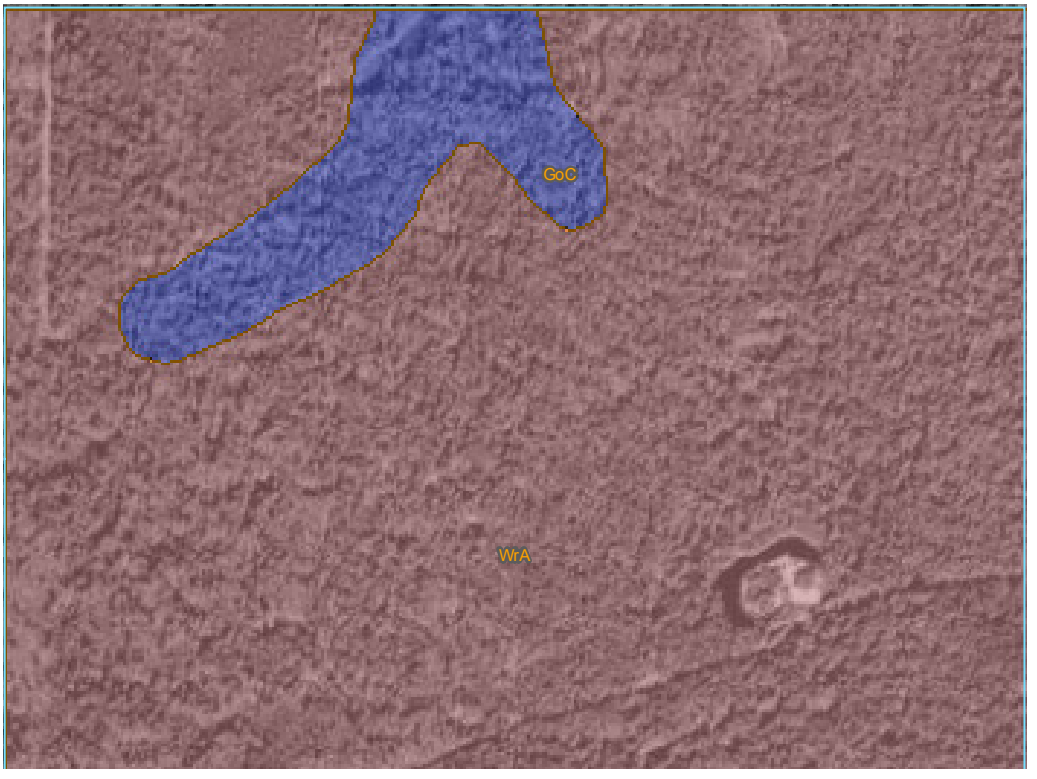
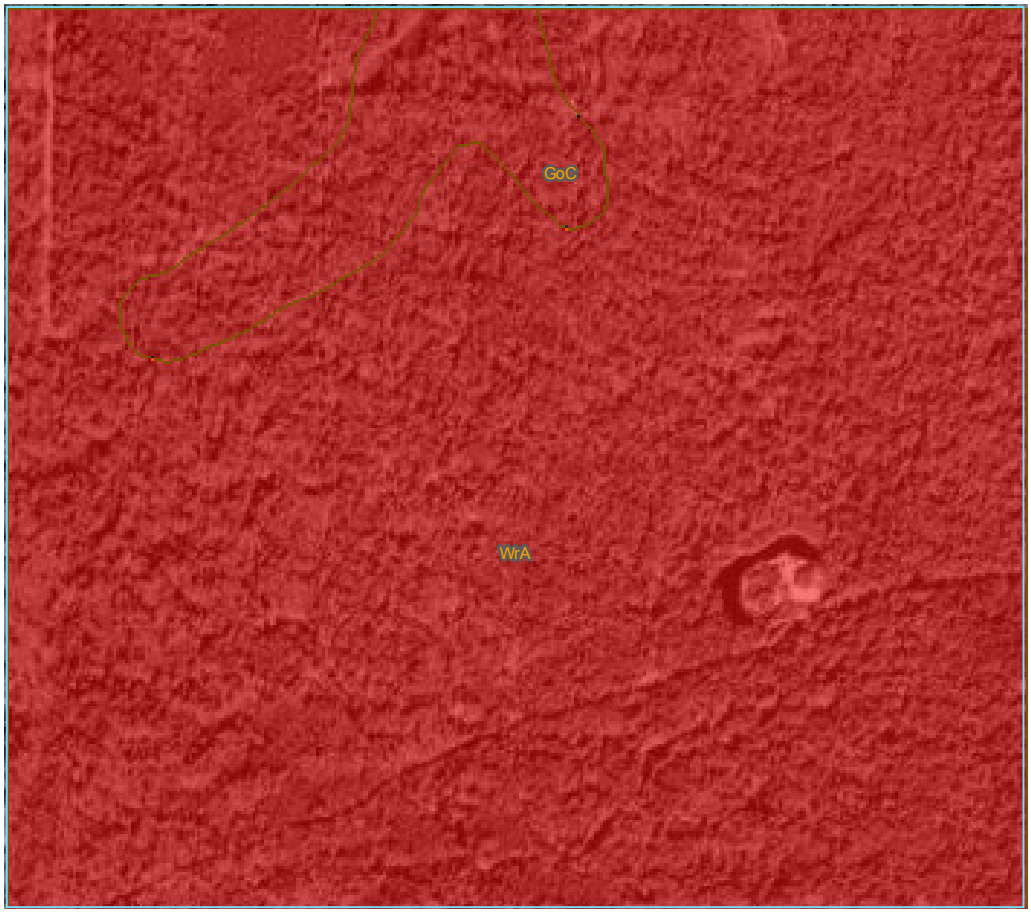


Figure 40 Flood frequency map



Case 9 ESTUARINE FRINGE

Figure 41 shows the soils map for an area on the Chesapeake Bay in Dorchester County, Maryland.

The entire area is in the single map unit 2, the Bestpitch and Transquaking complex. Not shown are the flooding, ponding, and water table maps. The water table depth is 0 inches, the flooding frequency is frequent, and the ponding rating is none for the entire area. The taxonomic designation is Sulfihemists. This flat area is within the tidal zone, has no source of water from surface runoff, no gradient to maintain groundwater flow, and does not exhibit any significant depressions. The soils are Histosols. It receives as much water from direct precipitation as a comparable site in an ORGANIC FLAT upland position, but this supply is overwhelmed by tidal inflow. The stream channel shown on the map is a tidal inlet, which moves salt water bidirectionally into and out of the interior of the wetland. This channel is not a stream in the common sense of the term, since it does not have a watershed. These inlets, referred to as "sloughs" in some areas, have a cross-sectional geometry based on the volume of water they move in and out of the wetland during the twice daily tidal cycles. The continuous supply of ocean water maintains the continuous surface saturation needed to build and maintain organic soils. Figure 42 shows a typical tidal inlet channel.

The OSD describes the map units on this site as existing in brackish marshes. ESTUARINE FRINGE wetlands can exist as freshwater marshes, salt marshes, or within any range of brackishness. Estuaries at the mouth of large streams may have a continuous supply of freshwater that is adequate to prevent the intrusion of saltwater. They are still dominated by tide dynamics, as the river water surface moves in response to tidal fluctuations. If the map unit is subject to dynamic river flow, the flow energy, sedimentation, and scour dynamics can prevent the formation of organic soils. The mineral soils that exist are typically fluvaquents.

Figure 43 shows an aerial view of a hydric soil map from a salt marsh in Coos County, Oregon. The hydric map units are shown in brown. Soil map unit 11 is Clatsop mucky peat. These map unit areas are in slackwater positions. Map units 12 and 34 are Coquille silt loam and Langlois silty clay loam, respectively, and are fluvaquents. These Entisols are young soils, which are subject to continuous deposition and scour from the high-energy streamflows. All of these soils are subject to tidal influence, however, and are ESTUARINE FRINGE wetland map units. The photo resolution is not fine enough to see the small inlet channels which carry water into and out of the marsh. Figure 44 shows an inlet channel from the map unit 11 location on the left side of the stream.

The integrity of these wetlands depends on protection from high-energy waves, particularly during storm events. This energy has the potential to quickly erode the fragile organic soils. This protection is provided by the presence of dunes, the location of the site within well-protected bays, and the dampening effect of the tidal inlet channel capacity.

Figure 41 Soils map, Dorchester County, MD

Figure 42 Tidal inlet channel

U.S. Geological Survey Center for Coastal Geology

Figure 43 Hydric soil map, Coos County, OR

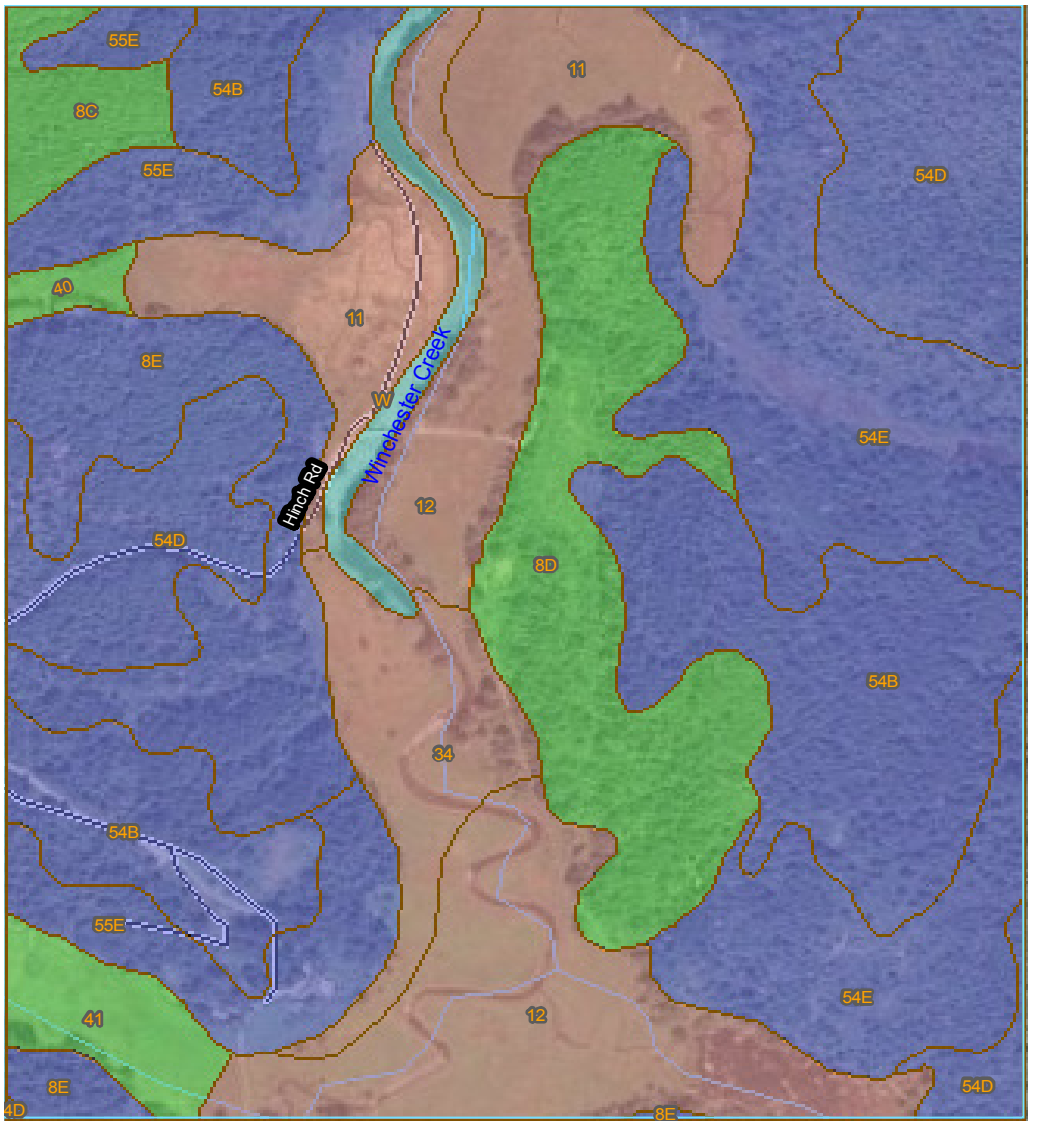


Figure 44 Tidal inlet channel, South Slough, Coos Bay, OR

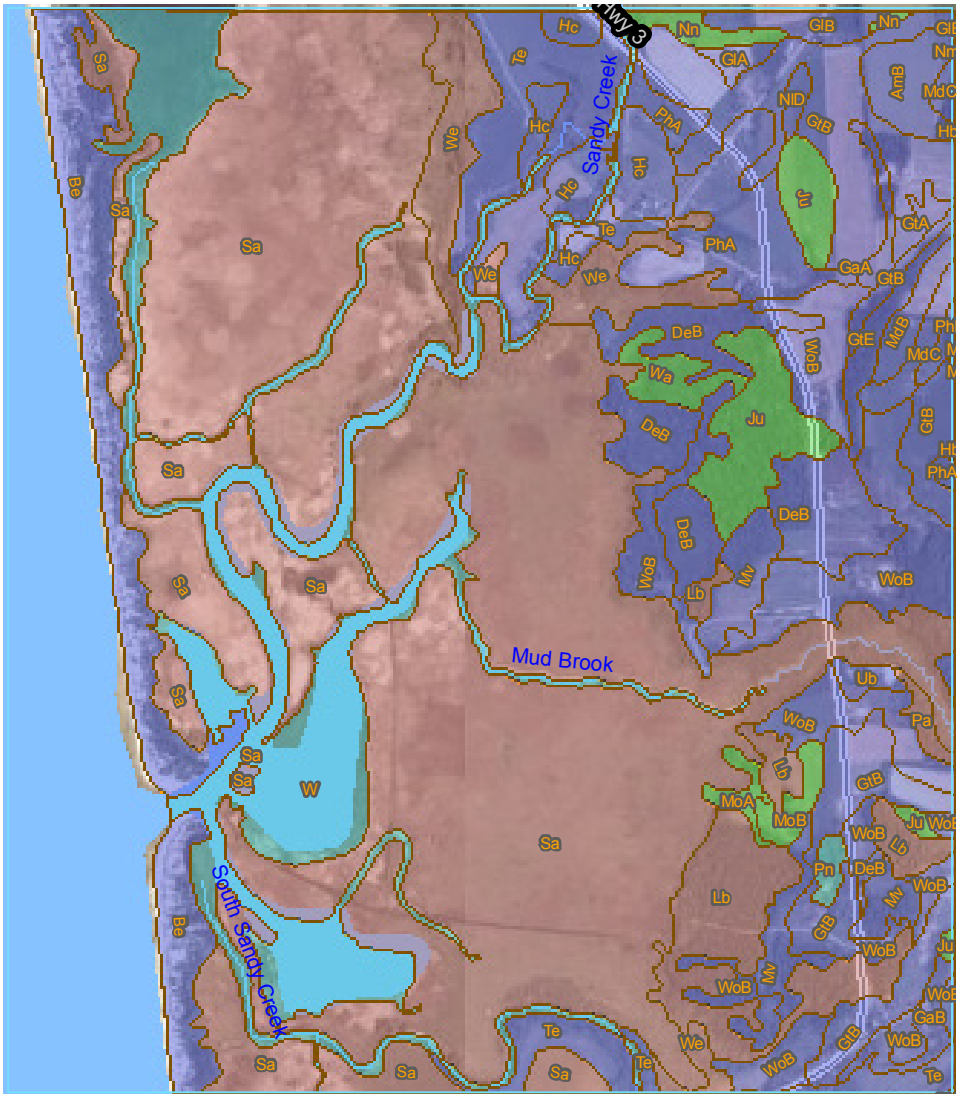
Photo by Richard Weber, NRCS

Case 10 LACUSTRINE FRINGE

Figure 45 shows the hydric soil map for a site on the shore of Lake Ontario in Jefferson County, New York.

The hydric soil area is dominated by the map units labeled Sa, Saprists, and Aquents, ponded. These Histosols and Entisols are in a flat landscape, which is supplied by water and a certain amount of sediment from numerous streams entering from the uplands to the east. The Saprists can be expected to occupy the low-energy slackwater areas, and the Aquents occupy areas adjacent to the streams, which are subject to scour and deposition from high-energy flows. As the streams meander and change location frequently in this low-gradient landscape, the two soil types become randomly located in relation to each other and the current location of the streams. The lake shoreline is dominated by the map unit labeled Beach, Be, and exists as a relatively high dune formation. The sediment provided by the streams flowing through the site provides the sand, which is acted on by wind and currents to form these dunes. The dunes, in turn, provide the protection from wave action, which allows the organic soils to remain in place. This unique set of landforms is typical of LACUSTRINE FRINGE wetlands. This wetland type is similar to ESTUARINE FRINGE wetlands. The major difference is that there is no tidal inflow and outflow. The only flow energy is provided by the stream hydrograph. The water regime in the wetland follows the lake level closely. In the case of Lake Ontario, this lake level is relatively steady. The stability of the system depends on the integrity of the lake dunes. The dunes, in turn, depend upon the sediment delivery from the streams to maintain equilibrium between wave erosion and deposition.

Figure 45 Hydric soil map, Jefferson County, NY



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Appendix Official Soil Series Description

OSAGE series

The Osage series consist of very deep, poorly drained, very slowly permeable soils that formed in thick clayey alluvium. These soils are on floodplains along major streams and have slopes ranging from 0 to 2 percent. Mean annual temperature is 61 degrees Fahrenheit, and mean annual precipitation is 39 inches.

TAXONOMIC CLASS: Fine, smectitic, thermic Typic Epiaquerts

TYPICAL PEDON: Osage silty clay—on a level area in a cultivated field. (Colors are for moist soil unless otherwise stated.)

Ap1—0 to 4 inches; very dark gray (10YR 3/1), rubbed, clay, gray (10YR 5/1), rubbed, dry; moderate fine granular structure; firm, moderately sticky and moderately plastic; many very fine and fine roots throughout; many fine and medium high continuity interstitial pores; common fine irregular yellowish brown (10YR 5/8) masses of iron accumulation between peds; moderately acid; abrupt smooth boundary.

Ap2—4 to 8 inches; very dark gray (10YR 3/1), rubbed, silty clay, gray (10YR 5/1), rubbed, dry; weak coarse angular blocky structure; extremely firm , very sticky and very plastic; common very fine roots between peds; common very fine low continuity tubular pores and few medium low continuity tubular pores; common fine irregular reddish brown (5YR 4/4) masses of iron accumulation between peds; slightly acid; abrupt smooth boundary.

A—8 to 13 inches; very dark gray (10YR 3/1), rubbed, clay, gray (10YR 5/1), rubbed, dry; moderate fine and medium angular blocky structure; extremely firm, very sticky and very plastic; common very fine roots between peds; common very fine low continuity tubular pores and few medium low continuity tubular pores; few fine rounded strong brown (7.5YR 5/8) masses of iron accumulation between peds; slightly acid; clear smooth boundary.

Bss1—13 to 23 inches; very dark gray (10YR 3/1), rubbed, clay, gray (10YR 5/1), rubbed, dry; moderate medium prismatic structure parting to moderate fine and medium angular blocky; extremely firm, very sticky and very plastic; common very fine roots between peds; common very fine and fine low continuity tubular pores; few distinct continuous intersecting slickensides on faces of peds; many medium irregular yellowish brown (10YR 5/6) masses of iron accumulation between peds and few medium rounded black (N 2/0) iron-manganese concretions throughout; moderately acid; clear wavy boundary.

Bgss2—23 to 36 inches; dark gray (2.5Y 4/1), interior, clay; moderate medium prismatic structure parting to moderate medium subangular blocky; very firm, very sticky and very plastic; common very fine roots between peds; common very fine and fine low continuity tubular pores; many prominent continuous intersecting slickensides on faces of peds; many medium irregular yellowish brown (10YR 5/6) masses of iron accumulation between peds and few fine rounded black (N 2/0) iron-manganese concretions between peds; slightly acid; gradual wavy boundary.

Bgss3—36 to 45 inches; dark gray (2.5Y 4/1), interior, clay; moderate medium prismatic structure parting to moderate medium subangular blocky; very firm, very sticky and very plastic; few very fine roots between peds; common very fine and fine low continuity tubular pores; common prominent continuous intersecting slickensides on faces of peds; many coarse irregular yellowish brown (10YR 5/6) masses of iron accumulation between peds; slightly acid; gradual wavy boundary.

Bgss4—45 to 60 inches; very dark gray (2.5Y 3/1), interior, clay; moderate medium subangular blocky structure; very firm, very sticky and very plastic; few very fine roots between peds; common very fine and fine low continuity tubular pores; few distinct continuous intersecting slickensides on faces of peds; many coarse irregular yellowish brown (10YR 5/6) masses of iron accumulation between peds; slightly acid; gradual wavy boundary.

Bg—60 to 80 inches; dark gray (5Y 4/1), interior, silty clay; moderate medium subangular blocky structure; firm, very sticky and very plastic; common very fine and fine low continuity tubular pores; many coarse irregular yellowish brown (10YR 5/6) masses of iron accumulation between peds; neutral.

TYPE LOCATION: Vernon County, Missouri; 100 feet north and 100 feet east of the center of sec. 35, T. 38 N., R. 31 W.

RANGE IN CHARACTERISTICS: The thickness of the solum ranges from 40 to 60 or more inches.

The A horizon Hue: 10YR or 2.5Y Value: 2 or 3, moist and 4 or 5, dry Chroma: 1 or 2 Redoximorphic features: None to common iron accumulations and none to common iron- manganese Texture: silty clay loam, silty clay or clay Rock fragments: 0 to 7 percent gravel Reaction: slightly acid to mildly alkaline.

Bgss horizon: Hue: 10YR, 2.5Y, 5Y Value: 3, 4 or 5 dry Chroma: 2 or less Redoximorphic features: Few to common iron accumulations in shades of brown or yellow, none to common iron-manganese accumulations Calcium Carbonate: none to common carbonate concretions Texture: clay or silty clay Clay content: 40 to 60 percent Sand content: less than 5 percent Rock fragments: 0 to 7 percent Reaction: medium acid to neutral in upper part; slightly acid to moderately alkaline in the lower part.

COMPETING SERIES:

Carl (T) (Missouri): Carl soils are on nearly level (0 to 1 percent), slightly concave terraces adjacent to streams on upland derived from a thin mantle of silty loess over clayey alluvium over gravelly alluvium.

Clearwater (Minnesota): Clearwater soils are in the frigid temperature regime and has 2 to 8 percent rock fragments throughout and formed in till.

Fargo (North Dakota): Fargo soils are in the frigid temperature regime and formed in lacustrine sediments.

Judice (Louisiana): Judice soils are in the hyperthermic temperature regime.

Pitvar (California): Pitvar soils are in the mesic temperature regime.

Terouge (Arkansas): Terouge soils are on floodplains and low terraces. They formed in alluvium from Blacklands, or intermingled areas of Blackland and Coastal Plain, MLRAs 135 and 133B. Slopes range from 0 to 3 percent. Average annual temperature near the type location is about 63 degrees Fahrenheit; average annual precipitation is about 49 inches.

GEOGRAPHIC SETTING:

Landscape: major streams in River Valley Landform: flood plains Slope: 0 to 2 percent Parent material: clayey alluvium Mean Annual Air Temperature: 59 to 65 degrees Fahrenheit. Mean Annual Precipitation: 38 to 44 inches. Thornwaite Annual PE Index: greater than 64.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the coarser-textured Cleora, Hepler, Lanton, Mason, McCune, Verdigris, and Wynona soils and the lighter-colored Lighting soils that are on nearby flood plains or low terraces.

DRAINAGE AND PERMEABILITY: Drainage: Poorly drained. Runoff: low or very low. Permeability: very slow.

USE AND VEGETATION: Soils are cropped to wheat, soybeans, and corn. Native vegetation was mostly tall grass prairie and in some locations deciduous hardwoods and understory of grasses.

DISTRIBUTION AND EXTENT: Southwestern Missouri, southeastern Kansas, and eastern Oklahoma. The series is extensive.

MLRA OFFICE RESPONSIBLE: Salina, Kansas.

SERIES ESTABLISHED: Bates County, Missouri, 1908.

REMARKS: Data on Cole taken from the Kansas-Oklahoma, 1973; Soil Characterization (Proj. No. 73ks–4c) is 0.12. S97KS–031–002: 14.5% S97KS–031–002: 14.5% S97KS–111–001: 16.3% S97KS–111–002: 14.3%

WRIGHTSVILLE series

The Wrightsville series consists of very deep, poorly drained, very slowly permeable soils that formed in old silty and clayey alluvium. These soils are on level to depressional areas on old stream terraces. Slopes are less than 1 percent. Mean annual temperature is 62 degrees Fahrenheit, and mean annual precipitation is 46 inches.

TAXONOMIC CLASS: Fine, mixed, active, thermic Typic Glossaqualfs

TYPICAL PEDON: Wrightsville silt loam, in woodland. (Colors are for moist soil unless otherwise stated.)

Oi-—0 to 1 inches; black (10YR 2/1) partially decomposed leaves, twigs, and roots; extremely acid.

A—1 to 2 inches; dark grayish brown (10YR 4/2) silt loam; weak fine granular structure; friable; many medium roots; extremely acid; abrupt smooth boundary. (0 to 5 inches thick)

Eg1—2 to 10 inches; grayish brown (10YR 5/2) silt loam; weak medium granular structure; friable; many medium roots; extremely acid; abrupt smooth boundary. (8 to 14 inches thick)

Eg2—10 to 17 inches; gray (10YR 6/1) silt loam; weak medium subangular blocky structure; friable; many medium and fine roots; common fine pores; common medium distinct yellowish brown (10YR 5/8) masses of iron accumulation in matrix; extremely acid; clear wavy boundary. (5 to 12 inches thick)

Btg/E—17 to 23 inches; (Btg) gray (10YR 5/1) silty clay loam; weak medium prismatic structure parting to weak medium subangular blocky; firm; common continuous distinct clay films on faces of peds; (E) about 20 percent of matrix consists of intrusions of albic material 0.5 to 2 inches wide that is light gray (10YR 7/1) silt loam; massive; friable; common fine roots mainly in Eg material; few fine pores mainly in Eg material; common medium distinct yellowish brown (10YR 5/6) masses of iron accumulation throughout; light gray (10YR 7/2) clay depletions on faces of prisms; extremely acid; gradual wavy boundary. (4 to 12 inches thick)

Btg1—23 to 39 inches; gray (10YR 5/1) silty clay; weak medium prismatic structure parting to strong medium subangular blocky; firm; few fine roots; few fine pores; continuous distinct clay films on faces of peds; about 10 percent of matrix composed of tongues 0.5 to 1 inch wide , interfingers and small pockets of light gray (10YR 7/2) silt loam clay depletions; light gray (10YR 7/2) clay depletions on prism faces; common medium distinct strong brown (7.5YR 5/6) masses of iron accumulation in matrix; extremely acid; gradual smooth boundary. (5 to 18 inches thick)

Btg2—39 to 49 inches; light brownish gray (2.5Y 6/2) silty clay loam; weak medium prismatic structure parting to strong medium subangular blocky; firm; few fine roots; many patchy distinct clay films on faces of peds; small pockets of light gray (10YR 7/2) silt loam clay depletions in matrix and on prism faces; many medium distinct strong brown (7.5YR 5/8) masses of iron accumulation in matrix; extremely acid; gradual smooth boundary. (8 to 13 inches thick)

Btg3—49 to 62 inches; light brownish gray (2.5Y 6/2) silt loam; weak coarse prismatic structure parting to moderate medium subangular blocky; firm; few fine roots; common patchy distinct clay films on faces of peds; common medium distinct strong brown (7.5YR 5/8) masses of iron accumulation in matrix; few small dark brown iron-manganese concretions; light gray (10YR 7/2) clay depletions on prism faces and in small pockets in matrix; extremely acid; clear smooth boundary. (10 to 15 inches thick)

Btg4—62 to 72 inches; gray (10YR 5/1) silt loam; moderate medium angular blocky structure; firm; few fine roots; few patchy distinct clay films on faces of peds; light gray (10YR 7/2) silt clay depletions in small pockets in matrix; common coarse prominent strong brown (7.5YR 5/8) masses of iron accumulation in matrix; extremely acid.

TYPE LOCATION: Conway County, Arkansas; about 5 miles northwest of Oppelo on Highway 154 and 0.5 mile west on county road in SW1/4NE1/4SW1/4 sec. 6, T. 5 N., R. 17 W.

RANGE IN CHARACTERISTICS:
Solum thickness: 40 to more than 72 inches
Clay content in the Control Section: 35 to 55 percent
Redoximorphic features: Depleted matrix with iron concentrations in shades of brown and yellow throughout the solum.
Other distinctive soil features: None
Concentrated minerals: None

A or Ap horizon:
Color—Hue 10YR, value 3 to 5, and chroma of 2. The Ap horizon, when present, has hue of 10YR, value of 4 or 5, and chroma of 2.
Redoximorphic features—one
Texture—Silt, silt loam or silty clay loam
Other features—None
Reaction—Extremely acid to strongly acid

E horizon:
Color—Hue of 10YR, value of 5 to 7, and chroma of 1 or 2, or with hue of 2.5Y, value of 6 or 7, and chroma of 2
Redoximorphic features—Iron accumulation and depletions are in shades of brown and gray
Texture—Silt or silt loam
Other features—None
Reaction—Extremely acid to strongly acid

Btg/E horizon:
Color—Hue of 10YR, value of 4 to 7, and chroma of 1 or 2, or with hue of 2.5Y, value of 5 to 7, and chroma of 2 in the Btg parts; and hue of 10YR, value of 5 to 7, and chroma of 1 or 2, or with hue of 2.5Y, value of 6 or 7, and chroma of 2 in the E parts
Redoximorphic features—Iron accumulation and depletions are in shades of brown, yellow, and gray
Texture—Silty clay, clay, and silty clay loam in the Btg parts; and silt or silt loam in the E parts
Other features—None
Reaction—Extremely acid to moderately acid

Upper part of the Btg horizon:
Color—Hue of 10YR, value of 4 to 7, and chroma of 1 or 2, or with hue of 2.5Y, value of 5 to 7, and chroma of 2
Redoximorphic features—Iron accumulation are in shades of brown or yellow
Texture—Silty clay, clay, clay loam, and silty clay loam
Other features—None
Reaction—Extremely acid to moderately acid

Lower part of the Btg horizon:
Color—Hue of 10YR, value of 4 to 7, and chroma of 1 or 2, or with hue of 2.5Y, value of 5 to 7, and chroma of 2
Redoximorphic features—Iron accumulation are in shades of brown or yellow
Texture—Silt loam, silty clay loam, silty clay, clay, and clay loam
Other features—None
Reaction—Extremely acid to moderately alkaline

C horizon: (where present)
Color—Hue of 10YR, value of 4 to 7, and chroma of 1 or 2, or with hue of 2.5Y, value of 5 to 7, and chroma of 2
Redoximorphic features—Iron accumulation are in shades of brown or yellow
Texture—Silt loam, silty clay loam, silty clay
Other features—None
Reaction—Extremely acid to moderately alkaline

2C horizon: (where present)
Color—Reddish hue
Redoximorphic features—Iron accumulation are in shades of brown or yellow
Texture—Clay or silty clay
Other features—None
Reaction—Neutral to moderately alkaline

COMPETING SERIES: There are no other series in the same family.

GEOGRAPHIC SETTING: Wrightsville soils are on level areas in depressions on old stream terraces. Slopes are less than one percent. This soil formed in old silty and clayey alluvium. Mean annual temperature ranges from 60 degrees to 65 degrees Fahrenheit, and the mean annual precipitation ranges from 44 to 52 inches.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Acadia, Elysian, Foley, Lafe, McKamie, and Muskogee series. Acadia soils are somewhat poorly drained and on slightly higher stream terraces. Elysian soils are moderately well-drained, have less clay in the control section, and are on circular mounds on terraces. Foley and Lafe soils have a natric horizon and are on lower sideslope positions on terraces. The well-drained McKamie soils and moderately well-drained Muskogee soils are on higher terraces. Acadia, McKamie, and Muskogee soils do not have aquic conditions within a depth of 20 inches, and do not have a depleted matrix within the upper 5 inches of the argillic horizon.

DRAINAGE AND PERMEABILITY: Wrightsville soils are poorly drained. Runoff is slow and permeability is very slow. The soil is wet in the layers below a depth of 0.5 to 1.5 feet and above the Btg horizon during December through May in normal years.

USE AND VEGETATION: Most of these soils are in forest or pasture. Some areas are used for rice, soybeans, and cotton. Native trees are sweetgum, water oak, and willow oak.

DISTRIBUTION AND EXTENT: Arkansas, Louisiana, Oklahoma, and Texas. The series is of moderate extent.

MLRA OFFICE RESPONSIBLE: Little Rock, Arkansas

SERIES ESTABLISHED: Pulaski County, Arkansas; 1922.

REMARKS: The series was updated in 2004 to allow clay loam texture in the Btg horizon, and for clay texture to continue into the lower parts of the Btg horizon. Diagnostic horizons and features recognized in this pedon are:
Ochric epipedon—Surface to a depth of 17 inches (A, Eg1 and Eg2 horizons).
Albic horizon—1 to 17 inches (Eg1 and Eg2 horizons).
Glossic horizon—17 to 23 inches (Btg and Eg horizon)
Argillic horizon—17 to 72 inches (Btg and Eg, Btg1, Btg2, Btg3, Btg4 horizons)