United States Department of Agriculture

Eelgrass (*Zostera marina*) Restoration Suitability

A Subaqueous Soil Interpretation

Natural Resources Conservation Service

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Issued April 2018

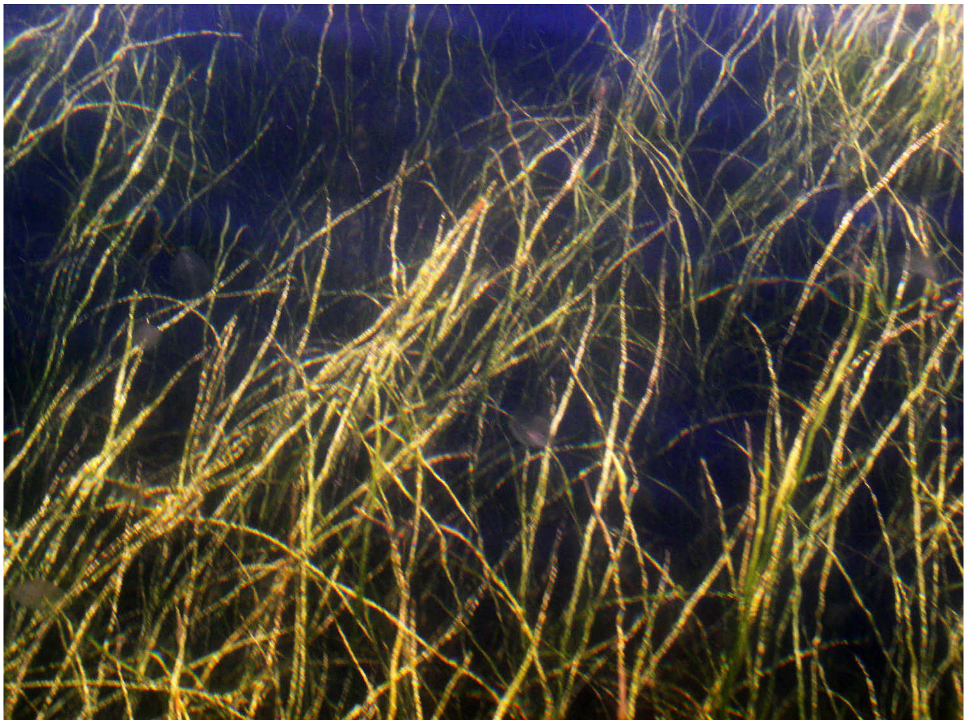


Figure 1.—Eelgrass beds on the shoreface in Little Narragansett Bay serve as a haven for crabs, scallops, numerous species of fish, and other wildlife. They provide these creatures with habitat, nursery grounds, and food.

Introduction

Submerged aquatic vegetation (SAV) is a term used to describe rooted, vascular plants that grow completely underwater except for periods of brief exposure at low tides. The term SAV is generally used for marine, estuarine, and riverine angiosperms and macrophytes.

Eelgrass, a kind of seagrass, is the only true marine SAV found in Long Island Sound and is Rhode Island's primary seagrass. Eelgrass, *Zostera marina*, is a flowering marine plant that forms extensive meadows or patchy beds interspersed with bare areas (fig. 1). The location of these beds can shift over time. Eelgrass beds are always completely submerged, and their roots, known as rhizomes, anchor the grass to the soil.

Eelgrass beds rank among the most productive of marine and estuarine plant habitats. Eelgrass habitat supports an abundant diversity of life, stabilizes seafloor sediments and adjacent shorelines, helps maintain water quality, and is a critical component of the marine food web. It grows in areas of specific, though diverse, environmental conditions. Substrate requirements range from sand and gravel to mud.

In Long Island Sound, eelgrass is at depths between 0.5 meter and 3.6 meters below mean low water (Koch and Beer, 1996). In Rhode Island, it grows in nearshore waters at depths ranging from 1 to 4.5 meters. The upper limit of growth is determined by physical factors such as wave action, ice scour, and desiccation (Long Island Sound Study, 2003).

Purpose

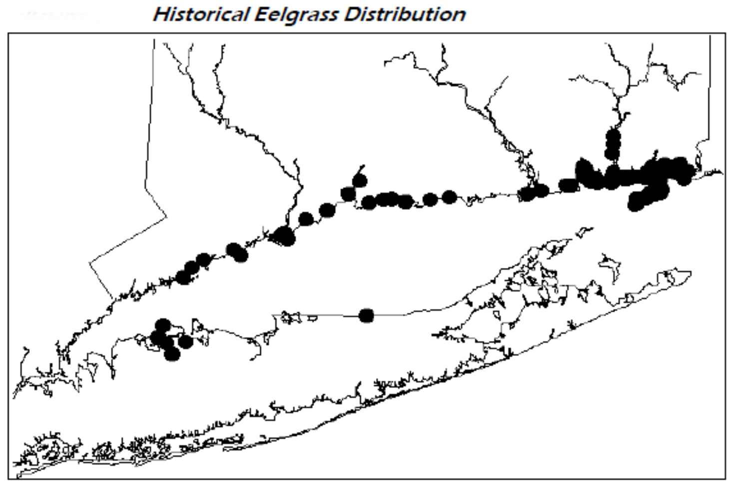
Eelgrass habitat is at risk (fig. 2). Over the last century, seagrass coverage worldwide has declined by about 30 percent (WWF, 2015). During the 1930s, much of the eelgrass succumbed to a wasting disease, a widespread infection partly attributed to the slime mold *Labyrinthula zosterae*. Within 2 years, 90 percent of all eelgrass populations in the North Atlantic (from Canada to North Carolina) disappeared (et al., 2012).

This soil interpretation is intended to help identify appropriate sites for eelgrass restoration. While conservation and protection of existing eelgrass beds are the best strategies for addressing the risk of loss, restoring areas that supported eelgrass habitat in the past is a valuable management measure.

Because the habitats are underwater, the cost of collecting, preparing, and planting eelgrass can be significant. With the availability of more subaqueous soil data, preliminary GIS analysis for selection of successful eelgrass restoration sites will be significantly improved.

Eelgrass Restoration and Degradation

The recognition of the importance of eelgrass ecosystem services is explicitly mentioned in statutes such as the Clean Water Act [CWA Section 101 (a)(2)(b)], the Coastal Zone Management Act [CZMA Section 303 (2)(A)(C)], the Water Resource Development Act [WRDA Section 204 (c)], and the Wetlands Protection Act (WPA) (Massachusetts General Laws, Chapter 131, Section 40) as a significant reason for the protection and restoration of eelgrass beds.



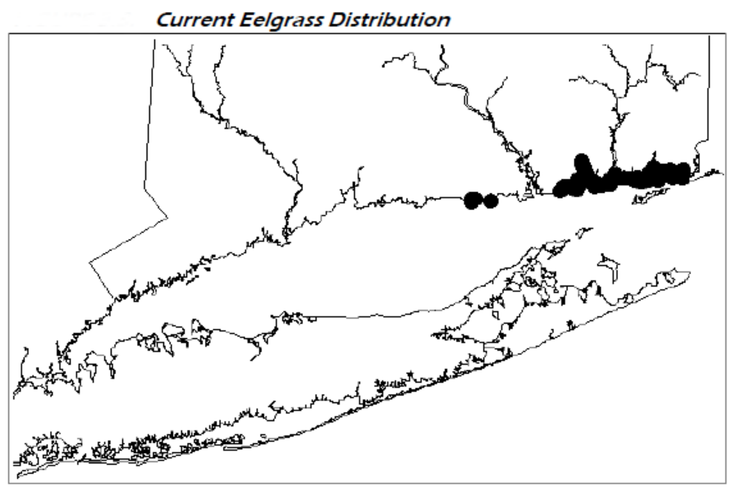


Figure 2.—Historical and current eelgrass distributions in Long Island Sound (from Long Island Sound Study, 2003).

In 1997, the Atlantic States Marine Fisheries Commission adopted an SAV policy that calls on States to protect existing beds, reduce pollution to promote comebacks, and set quantifiable SAV recovery goals. Specifically, member States are responsible for monitoring programs at 1.5-year intervals, evaluating current regulatory program effectiveness and recommending improvements, setting SAV restoration goals, educating the public, and supporting SAV research. Locally, SAV is broadly protected under the Rhode Island Coastal Resources Management Council, Connecticut Coastal Management Act, and New York State Seagrass Protection Act.

The Short and Kopp model (Short et al., 2002) takes into account numerous ecological variables that can affect whether a site is conducive to eelgrass restoration. The following are variables:

- Historical eelgrass distribution
- Current eelgrass distribution
- Proximity to natural eelgrass beds
- Sediment (soil characteristics)
- Water quality
- Wave exposure
- Water depth
- Bioturbation

In many cases of eelgrass bed degradation, there is a combination of stresses. For example, a widespread problem, such as impaired water quality, may be coupled with localized physical disturbances. It is important to note that bed density, size, and distribution all naturally fluctuate.

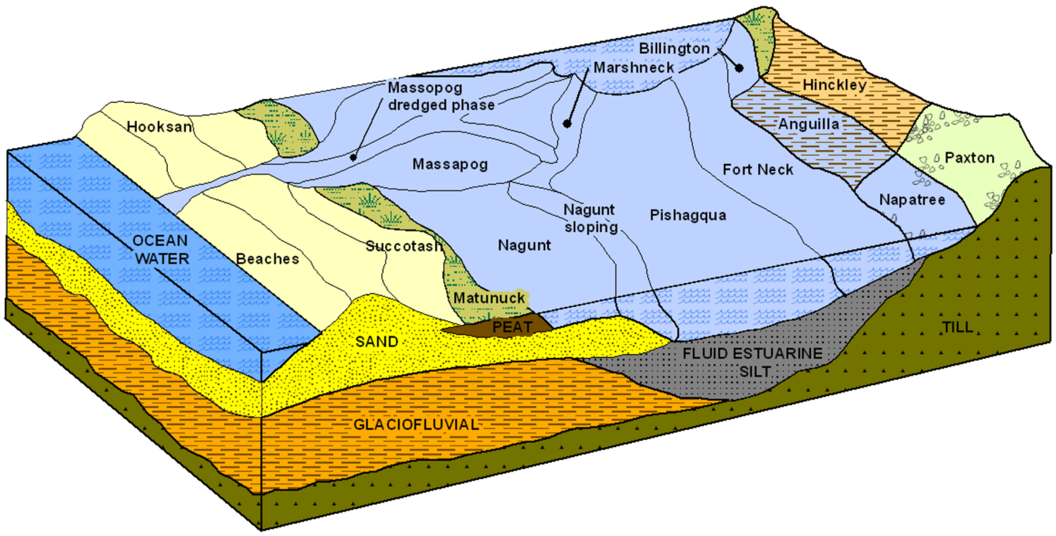


Figure 3.—Diagram of coastal and subaqueous soils, their parent materials, and landscapes.

Subaqueous Soil Survey

Traditional soil mapping is conducted by a field soil scientist trained to understand the interaction of soil-forming processes and soil-landscape relations. It involves mostly field work. The soil scientist traverses the landscape and digs many holes to observe the soil condition and classify the soil. Subaqueous soil mapping is performed in much the same way, except the soil is under water (fig. 3). Instead of using topographic maps to provide landscape position, subaqueous soil mapping uses bathymetric maps to identify landscapes and landforms. Augers and special tools, such as peat corers and vibracores, are used to obtain soil samples (fig. 4).

Figure 4.—A vibracore used to sample subaqueous soils.

Soil samples are described to depths up to 2 meters. Based on soil descriptions and landform maps, representative soils are sampled for laboratory analysis using a vibracore. If the soils are very soft and fluid (high “n value” soils) or high in organic material, the peat sampler or push tubes are used. Field observations and laboratory analyses indicate significant differences in such characteristics as particle-size class, organic carbon content, pH, and fluidity (n value). The boundaries of these soils are drawn on aerial photos and digitized for use with multiple types of data.

The National Cooperative Soil Survey (NCSS) is a nationwide partnership of Federal, regional, State, and local agencies and private entities and institutions. This partnership works to cooperatively investigate, inventory, document, classify, and interpret soils of the United States and disseminate and publish soil information. With national standards, taxonomy, and publication platforms, the NCSS provides a standard for collecting, developing, and distributing information on coastal soils.

Use and Explanation of Soil Interpretations

Soil survey interpretations are predictions of soil behavior for specified land uses and management practices. They are based on soil properties or characteristics that directly influence the specified use of the soil. The interpretations allow users of soil surveys to plan reasonable alternatives for the use and management of soils.

When soil interpretations are used in connection with delineated areas on soil maps, the information pertains to the soil for which the soil area is named. The named soil is the major soil component of the soil map unit. Other soils that are too small to map but are observed within the delineated area are called minor soil components or inclusions.

This soil interpretation does not include the minor soil components or inclusions. For example, a soil delineation with the name "Rhodesfolly fine sand, 0 to 1 meter water depth" may also include small, unmappable areas of other soils, such as Napatree and Anguilla. The interpretation applies to the Rhodesfolly part of the delineated soil area and not to the included soils. More detailed studies are required if small, specific sites are to be developed or used within a given soil delineation.

Soil interpretations do not eliminate the need for onsite study and testing of specific sites for design and construction for specific uses. Interpretations should be used as a guide to planning more detailed investigations and for avoiding sites undesirable for an intended use.

No consideration was given in this interpretation to the size and shape of a soil delineation or to the pattern of the delineation with that of other soils on the landscape. For example, some soil areas identified as desirable are too small, are too irregular in shape, or occur with less desirable soils in a pattern too complex for the intended use. Although not considered in the interpretation, these factors may influence the final selection of a site.

Web Soil Survey (WSS)

Web Soil Survey provides soil data and information produced by the National Cooperative Soil Survey (NCSS). It is operated by the USDA Natural Resources Conservation Service (NRCS) and provides access to the largest natural resource information system in the world. The site is updated and maintained online as the single authoritative source of soil survey information. In obtaining these data from USDA-NRCS, it is understood that the user has the right to use them for any internal purpose.

Soil Rating Classes

High Suitability: Soils in this rating class have a high potential for successful eelgrass restoration because they have the best soil properties or characteristics for a successful establishment of eelgrass beds.

Moderate Suitability: Soils in this rating class have a moderate potential for successful eelgrass restoration due to one or more somewhat limiting soil properties or characteristics, such as water depth, percent of silt and clay, percent of organic matter, presence of reduced monosulfides, oxidized pH, and electrical conductivity.

Low Suitability: Soils in this rating class have a low potential for successful eelgrass restoration due to multiple limiting soil properties or characteristics.

Not Suitable: Soils in this rating class are not suitable for eelgrass restoration because they are freshwater subaqueous soils that lack the appropriate salinity levels necessary for the establishment and growth of eelgrass.

Not Rated: These soils or miscellaneous areas are not subaqueous soils.

Evaluation Criteria

The evaluation criteria for this interpretation are based on soil properties or characteristics that are important in determining eelgrass growth, germination, survival, and distribution (fig. 5). These soil properties correspond to criteria identified and deemed significant by the USDA Natural Resources Conservation Service and National Cooperative Soil Survey partners. The evaluation criteria are explained below.

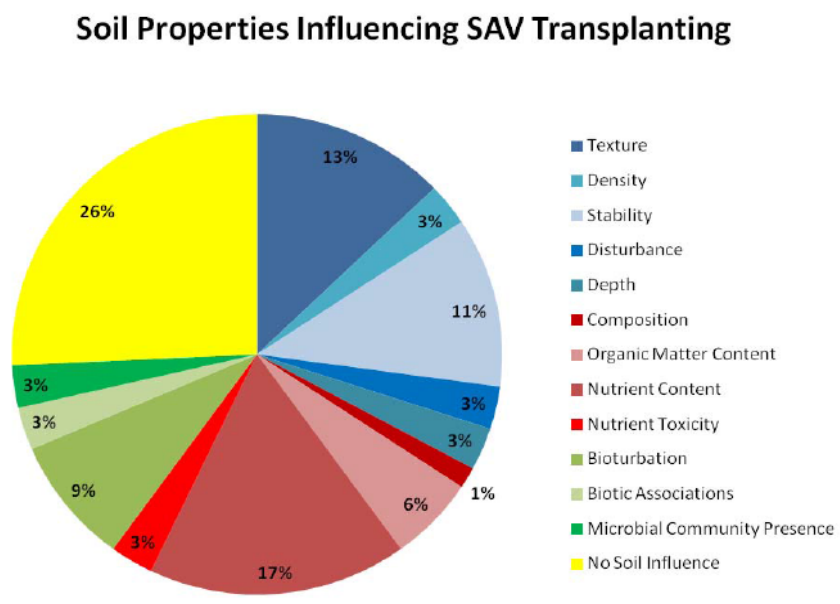


Figure 5.—A graph showing soil properties that influenced the transplanting of SAV in a study area in Florida (Ellis et al., 2013). "No Soil Influence" means that other environmental conditions, such as light availability, were not optimal.

Water Depth

Eelgrass beds usually grow in subtidal areas, at depths that receive adequate amounts of sunlight. The depths vary depending on water clarity, but eelgrass typically is not found deeper than 6 to 9 meters. Bradley and Stolt (2005) found eelgrass to be absent at depths between 0 and 0.5 meter possibly due to excessive solar irradiance and/or scour from wind or ice. The highest eelgrass cover was shown to occur at depths of 1 to 2 meters. For this interpretation, soils that are at water depths of 0 to 0.5 meter and of more than 9 meters are rated less than soils that occur at depths in between.

Soil Particle Size and Rock Fragments

Studies have shown that soil sediment characteristics are important in determining seagrass growth, germination, survival, and distribution (Short, 1987; Barko et al., 1991; Terrados et al. 1997; Halun et al., 2002; Bradley and Stolt, 2005). For example, sediment grain size has been suggested as an important variable influencing eelgrass growth (Kenworthy and Fonseca 1977; Short, 1987; Short et al., 1993).

Sandy textured sediments tend to diffuse oxygen more readily, obstruct rhizome elongation, and have lower fertility (Thayer and Fonseca, 1984; Fonseca et al., 1998; Koch et al., 2000). Conversely, finer textured sediments tend to have higher fertility and allow rhizome elongation (Koch et al., 2000). Eelgrass is able to survive in substrates ranging from mud to gravel, but it tends to grow better in surface sediments having silt and clay particles. Seagrass Long Island (CCE, 2012) found seagrass growth limitations in soils that have clay and silt contents above 20 percent. Short et al. (2002) found that the preferred sediment condition is soil with less than 70 percent silt and clay having no cobbles or stones, the moderately preferred sediment condition is soil with greater than 70 percent silt and clay, and the least preferred sediment condition is soil with cobbles or stones. These preferences are most likely due to the limited pore water exchange between soil pores and the overlying water column in finer textured soils, which may result in phytotoxin accumulation or nutrient limitations. Previous studies observed an increase in seagrass transplant growth in soils dominated by silts or in muddy soils, suggesting elevated nutrient levels promoted seagrass growth. More recent findings indicate that soils dominated by silty materials may provide the best environment for seagrass growth.

For this interpretation, the percent of silt and clay content as the percent of rock fragments at 0 to 30 centimeters from the soil surface and on the surface are used in the evaluation.

Soil Organic Matter

Seagrass growth and survival is also limited by elevated levels of soil organic matter. Research done by Koch (2001) has shown that soils with organic contents over 5 percent were generally detrimental to seagrass, and another study showed a maximum of 8 percent organic matter for seagrass growth (CCE, 2012). For this interpretation, the soil organic matter content at 0 to 30 centimeters from the soil surface is used in the evaluation.

Reduced Monosulfides and Oxidized pH

Seagrasses can thrive in sulfidic sediments due to two major detoxification strategies: (1) avoidance, by oxidation of sulfide, and (2) tolerance, by incorporation of sulfide into plant tissues. Future climate scenarios, which predict higher surface water temperatures, higher frequencies of hypoxic events, and increased sediment sulfide levels,

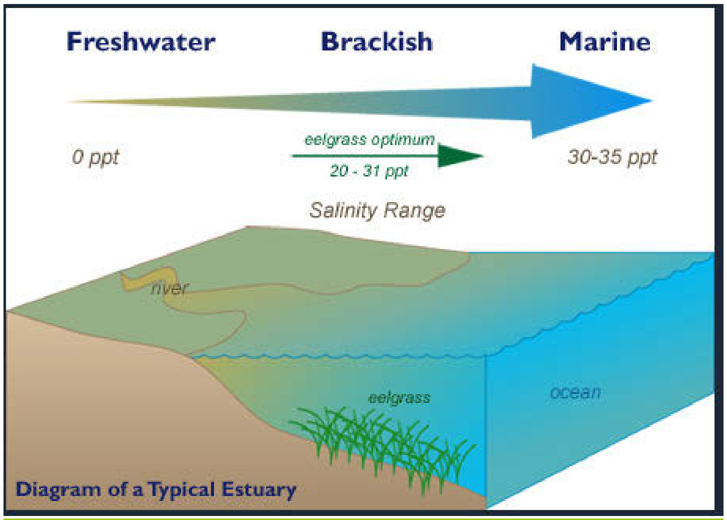


Figure 6.—Diagram showing location of eelgrass within a typical estuary. Image from the Cornell Cooperative Extension Marine Program.

show higher sulfide pressure on seagrass ecosystems (Hasler-Sheetal et al., 2015). Such conditions might exceed the sulfide tolerance and detoxification capacities.

Accumulation of sulfide has been shown to diminish photosynthetic rates and photosynthetic efficiency, potentially leading to diminished oxygen release into the rhizosphere and enhanced sulfide toxicity inhibition (Goodman et al., 1995). Research by Dooley et al. (2013) suggests that *Zostera marina* seedlings are consistently killed at concentrations of hydrogen sulfide. This may explain the lack of re-colonization at these sites.

The presence of reduced monosulfides is indicated by a soil color change within 10 seconds following the addition of 3 percent hydrogen peroxide solution. The color change is usually an increase in value by 2 or more units. Oxidation pH is used to test for the presence of sulfidic material and to predict the occurrence of sulfuric horizons. Soils are considered potential acid sulfate soils if the sulfide material is waterlogged mineral, organic, or mixed soil material with a pH of 3.5 or higher and if incubated as a 1-cm thick layer under moist, aerobic conditions (field capacity) at room temperature, show a drop in pH of 0.5 or more units to a pH value of 4.0 or less within 16 weeks or longer (if the pH is still dropping after 16 weeks) until the pH is nearly constant (Soil Survey Staff, 2014).

For this interpretation, the presence of both reduced monosulfides and oxidized pH at 0 to 30 centimeters from the soil surface are used in the evaluation. Soils that contain reduced monosulfides and have an oxidized pH of 4.0 or less after 16 weeks or more may have greater negative impacts on the growth and survival of eelgrass.

Electrical Conductivity

Distribution of eelgrass ranges from low-salinity (10 ppt) waters of inner estuaries and coastal ponds to high-energy locations fully exposed with salinity of 31 ppt (fig. 6). Eelgrass prefers polyhaline waters or estuarine waters with salinities ranging between 20 to 31 ppt. At low to intermediate salinities (10 to 20 ppt) eelgrass can survive, continuing to photosynthesize, but productivity is reduced by 50 percent.

Electrical conductivity for subaqueous soils is measured by the $1{:}5_{VOL}$ EC method, which does not correlate well with other methods. For this interpretation, the $1{:}5_{VOL}$ EC method was used to separate the freshwater subaqueous soils, which are less than 0.2 dS/m, from the saline subaqueous soils.

Evaluation Criteria Table

Criteria	High Suitability	Moderate Suitability	Low Suitability	Not Suitable	References
Water Depth	0.5 to 2 m	> 2 to 9 m	< 0.5 m and > 9 m		Bradley and Stolt (2005)
Silt and Clay (weighted average from 0 to 30 cm from soil surface)	< 70 %	> 70 %			CCE (2012); Koch (2001); Short et al. (2002)
Rock Fragments > 75 mm diameter (cobbles and stones) (weighted average from 0 to 30 cm from soil surface)	< 5 %	5 to 35 %	> 35 %		Kenworthy and Fonseca (1977); Short (1987); Short et al. (1993)

Criteria	High Suitability	Moderate Suitability	Low Suitability	Not Suitable	References
Rock Fragments on the surface > 75 mm diameter (percentage of surface covered)	< 0.01 %	0.01 to 0.1 %	> 0.1 %		Soil Survey Division Staff (2017); Kenworthy and Fonseca (1977); Short et al. (1987, 1993)
Soil Organic Matter (average weighted from 0 to 30 cm from soil surface)	< 5 %	5 to 8 %	> 8 %		CCE (2012); Koch (2001)
Reduced Monosulfides Presence (0 to 30 cm from soil surface)	No	Yes			Hasler-Sheetal et al. (2015); Goodman et al. (1995); Dooley et al. (2013)
Oxidized pH (0 to 30 cm from soil surface)	pH > 4	pH 4 or less			Hasler-Sheetal et al. (2015); Goodman et al. (1995); Dooley et al. (2013)
Electrical Conductivity 1:5 Method (weighted average from 0 to 30 cm from soil surface)				< 0.2 dS/m	CCE (2012); Soil Survey Staff (2014)

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