LAKE SINISSIPPI IMPROVEMENT DISTRICT
ANTHONY ISLAND SHORELINE AND NEAR-SHORE LAKEBED ASSESSMENT AND SHORELINE RESTORATION PLAN

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Lake Sinissippi Improvement District

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PROJECT SCOPE

In early October of 2017, the Lake Sinissippi Improvement District (LSID) formally engaged Eco-Resource Consulting, Inc. (ERC) to conduct a shoreline and near-shore lakebed investigation of the undeveloped southern one-half of the island and use this information to develop a Shoreline Restoration Plan (Plan) for eroded shoreline areas on portions of Anthony Island on Lake Sinissippi in Hustisford, Wisconsin. The first phase of this project was for ERC Ecologists to assess current conditions of the shorelines on the south half of the island. Based upon this data, ERC will develop a Plan that includes recommendations to reduce shoreline erosion and to stabilize the shoreline with a combination of Best Management Practices (BMPs) specifically applicable to the island.

The consensus of LSID members is that Anthony Island, particularly the southern and western shorelines of the island have been receding at an accelerated pace. Based on aerial image comparisons from 1941 aerial imagery to modern times, the shoreline has receded anywhere from 30 to 60 feet (Appendix A, Figure 1). The LSID has elected to move towards a proactive solution to reduce shoreline recession and stabilize the shorelines with appropriate hard and/or soft armoring methods.

PROJECT AREA GENERAL DESCRIPTION

Lake Sinissippi is a flowage impoundment lake in Hustisford (Dodge County), Wisconsin. The lake has a maximum depth of 8 feet and a mean depth of 5 feet (WDNR web page). Due to the shallow water and low oxygen levels, the lake is considered eutrophic. A concrete dam lies at the southern end of the lake, which impounds the 3,078-acre lake. The current concrete gated dam was built in 1939 to replace the original log dam which was built in 1845. The dam is owned and operated by the Village of Hustisford. The pool level in 2017 ranged between 854.50 and 855.90 mean feet above sea level. The dam gauge level was reported at 855.40 on the day of ERC's assessment on October 25th, 2017 (Village of Hustisford Web Site).

Anthony Island is a 30-acre island that lies near the southeast end of the lake. Eighteen people reside on the north half of the island, which has numerous cottages and homes. Each resident of Anthony Island owns a deeded section of the south half of the island. The shoreline is completely developed on the north half of the island and the shoreline is armored with round field stone rock nearly continuously on the north half of the island. The south half of the island is undeveloped and forested and is the focus of this assessment and Plan. Approximately 2,183 linear feet of shoreline is natural and unimproved on the south half of the island. The island is a drumlin, which is defined by the United States Geological Survey (USGS) as "an elongated ridge of glacial sediment sculpted by ice moving over the bed of a glacier. Generally, the down-glacier end is oval or rounded and the up-glacier end tapers" (USGS Web page).

ASSESSMENT OF CURRENT CONDITIONS

ERC Ecologists conducted an assessment of the Anthony Island shoreline on October 25th, 2017. The island was accessed by kayak. The undeveloped shoreline on the south half of the island was surveyed from the water by kayak. ERC Ecologists also landed the kayaks to collect data at several shoreline locations. Meander-type survey methodology was utilized for field data collection. Data was collected specific to botanical species, shoreline geomorphology, substrate composition and depth, water depth, bank height, soil conditions, and degree/type of shoreline erosion.

For the purposes of the assessment, the "shoreline" is defined as the area from the water's edge to approximately 35 feet inland, and the "near-shore lakebed" was defined as the area form the shoreline to approximately 100 feet lakeward. Field data was collected or inventoried at or near the shoreline to measure and inventory the following elements: Several aspects of database resource assessment were also considered as part of this Plan development. These desktop reviews included data from USDA soil maps, topographical maps, Village of Hustisford dam data, and historical aerial images.

SHORELINE CONDITIONS

<u>Shoreline Vegetation Summary</u>

ERC assessed shoreline vegetation conditions from the water's edge, to 35 feet inland. Shoreline vegetation in each Shoreline Zone (SZ) is dominated by native woody vegetation (shrubs and trees) with low densities of woody invasive species in a few select locations (Figure 2). Herbaceous vegetation is sparse within in each Shoreline Zone but where present, is comprised of native sedges, grasses, mosses, and forbs. Most shoreline areas are devoid of herbaceous vegetation, with exposed tree and shrub root systems and/or undermined vertical banks. See Appendix B for representative photographs.

In most shoreline locations, tree and shrub root systems are the primary component maintaining structural integrity of the banks. Several species of native shrubs are prevalent on the shorelines, growing under canopy of mature deciduous trees in many locations. Shrub density is lower on the east shoreline (SZ-1) of the island as native trees exist along the east shoreline with higher density relative to other shoreline locations. Figure 3 indicates bank conditions along each Shoreline Zone.

Shoreline Zones and Shoreline Reference Points

Upon reviewing field data collected during the assessment, four distinct Shoreline Zones (SZs) were established between five separate Shoreline Reference Points (SRPs). Shoreline Zones and Shoreline Reference Points are arranged in clockwise pattern, starting with SRP-A and SZ-1 on the northeast corner of the area of study. Shoreline Zones and Shoreline Reference Points are indicated on Figure 4. The Shoreline Zones were established based on distinctions in shoreline vegetation conditions, erosional mechanisms, and bank structural conditions.

Shoreline Tree loss

Root systems of woody plants are undermined and exposed in most shoreline locations, and the bank is undermined behind the roots indicating a significant amount of soil erosional loss around these tree roots. Shoreline erosion has resulted in a significant number of trees falling into the water. This tree loss has been occurring for a long period of time, based on the range of decomposition and sizes of woody material in the water. Trees that have been in the water for a longer period of time have either become partially submerged and have lost all bark and small limbs. Trees that have recently fallen into the water still have smaller limbs and bark intact, and remain perpendicular to the shoreline.

As shoreline recession occurs, trees growing on or near the banks begin to lean towards the water as wave erosion undermines the roots from the water's edge. On the west side of the island many trees with weakened root zones are blown inland during heavy west winds, resulting in exposed root masses at the shoreline. If a tree falls into the water the tree's intact root system tends to keep the tree in a near-perpendicular angle to the shoreline for a period of time. Intact root systems structurally support the bank for a period of time, until subsequent erosion removes soil behind the roots. The exposed roots oxidize and break down leading to further bank destabilization.

Many shoreline trees area also weakened and stressed by root zone undermining but remain leaning over the water and exposed to high winds during storm events. Exposed limbs die on these weakened trees and snap off into the water in high winds. These snapped limbs do not have roots to secure their placement, and eventually wave action pushes the limbs parallel to the shoreline. Those trunks and limbs parallel to the shoreline serve the dual function of dissipating wave energy against the shoreline and providing wildlife habitat for bird, fish, and herpetofaunal species.

Native species

Overall, the shoreline supports a very healthy diversity of native species, with the overstory canopy supporting native deciduous hardwoods such as; red oak (*Quercus rubra*), pin oak (*Quercus ellipsoidalis*), white oak (*Quercus alba*), bur oak (*Quercus macrocarpa*), silver maple (*Acer saccharinum*), red maple *(Acer rubrum*), sugar maple (*Acer saccharum*), basswood (*Tilia americana*), shagbark hickory (*Carya ovata*), black cherry (*Prunus serotina*), bigtooth aspen (*Populus grandidentata*), and green ash (*Fraxinus pennsylvanicus*).

The shoreline supports a very healthy density of native shrubs and one native vine including; highbush cranberry *(Viburnum trilobum)*, maple-leaved viburnum (*Viburnum acerifolium*), nannyberry viburnum (*Viburnum lentago)*, gray dogwood *(Cornus racemosa*), red osier dogwood (*Cornus sericea*), American hazelnut (*Corylus americana*), and riverbank grape (*Vitis riparia*).

Herbaceous species at the shoreline include brown fox sedge (*Carex vulpinoidea*), common woodland sedge (*Carex blanda*), moss (unknown sp.), Pennsylvania sedge (*Carex pennsylvanicus*), riverbank wildrye (*Elymus riparius*), wild golden glow (*Rudbeckia lacineata*), purple-leaved willowherb *(Epilobeum coloratum)*, northern bedstraw (*Galium boreale*), and white woodland aster (*Eurybia divaricata*).

Invasive species

Several small spatial areas of invasive species exist along the shoreline. These species include Asian honeysuckle (*Lonicera sp.*), common buckthorn (*Rhamnus cathartica*), black locust (*Robinia pseudoacacia*), Asian bittersweet (*Celastrus orbiculatus*), winged euonymus (*Euonymus alatus*), reed canary grass (*Phalaris arundinacea*), and purple loosestrife (*Lythrum salicaria*). Of these invasive species, Asian honeysuckle was the most prevalent and was found in numerous locations on the west and southwest shorelines. A clonal population of mature black locust is associated with the steepest bank area along Shoreline Zone 4. Remaining invasive species were found in isolated locations in relatively low density as indicated on Figure 2.

Invasive species are typical in locations of soil disturbance. In this case, the primary disturbance is the erosional force of water. Invasive species are more prevalent on the west shoreline as wave erosion and overland flow erosion combine to sour surface soils, creating ideal conditions for invasive species to gain a foothold. The only location where black locust and Asian honeysuckle are dominant species along the shoreline exist within Shoreline Zone 4. Shoreline Zone 4 also has the steepest and tallest bank heights relative to other Shoreline Zones on the south half of the island.

Inland Vegetation

It is notable that the core area of the south half of the island is dominated by mature native deciduous hardwood trees such as; red oak, white oak, pin oak, bur oak, shagbark hickory, and sugar maple. A healthy and diverse native shrub understory has helped prevent the establishment of woody invasive species such as buckthorn and Asian honeysuckle. In fact, garlic mustard (*Alliaria petiolata*) was observed in only one single location along a path. Oak and hickory regeneration (seedlings and saplings) is occurring at good rates with numerous oak seedlings and saplings being observed. Numerous oaks appear to be succumbing to oak wilt. Without a select harvest to thin mature oak and remove diseased trees, the mature oak overstory will continue to decline. Utilizing some of the harvested oak trunks and limbs for bank armorment and wave energy dissipation will be a potential option addressed in a subsequent section of this Plan.

<u>Topography and Surface Drainage</u>

Fifty-five feet of topographical relief exist on the south half of the island from the apex of the drumlin to the lake. With numerous ridges and valleys, four distinct sub-watersheds drain surface water to the lake (Figure 4).

Sub-watershed 1: 2.8 acres

Sub-watershed 1 drains to the east. Despite the relatively low total drainage area, this sub-watershed is the steepest drainage area on the island with a 20% slope. The northern and southern extents of Sub-watershed 1 correlate precisely with Shoreline Reference Points A and B, respectively. Surface water from this sub-watershed is contributing to overland flow bank erosion within Shoreline Zone 1. Overland flow erosion is a secondary factor to bank erosion as the primary erosional factor is wave action.

Sub-watershed 2: 3.8 acres

Sub-watershed 2 drains to the south and is the second largest drainage area on the island with a 10% slope. The eastern and western extents of Sub-watershed 2 correlate precisely with Shoreline Reference Points B and C, respectively. The eastern and western extends of Sub-watershed 2 also correlate with the two most prominent topographical ridges on the island. This drainage constitutes the most direct and straightest valley which conveys surface water directly from the highest elevational point to the most scalloped and receded shoreline area on the island.

Sub-watershed 3: 5.2 acres

Sub-watershed 3 is the largest drainage area on the island. With the other primary drainage valley arcing to the southwest, this sub-watershed straddles Shoreline Zone 3 and Shoreline Zone 4. The slope here is only 9%. The southeastern ridge of Sub-watershed 3 correlates precisely with Shoreline Reference Point C, but the northern extend of this drainage area terminates mid-point between Shoreline Reference Points D and E. From an erosional standpoint, the pronounced valley of this drainage area is associated with the other visually detectable scalloped and receded shoreline area within Shoreline Zone 3. Relative to the east side of the island, root zone undermining and bank back-cutting is higher along the west shoreline. Overland flow from this largest drainage area is a secondary factor of this increased shoreline erosion on the west shoreline. Wave erosion is the primary factor of shoreline erosion on all shoreline areas.

Sub-watershed 4: 2.4 acres

Sub-watershed 4 drains to west and is the smallest and flattest drainage area on the island, with a slope of only 3%. Drainage is directed to Shoreline Reference Point E, which also correlates with the northern extent of Shoreline Zone 4. A portion of surface drainage within Sub-watershed 4 also drains onto the residential parcel just north of Shoreline Reference Point E. Despite a steepening of topography at the shoreline, this drainage area is not resulting in significant erosional conditions attributable to overland flow.

Two soil test pits were advanced on opposite sides of the island. Each test pit was advanced within 10-20 feet of the top of the bank in upland position. Soil test pit locations are indicated on Figure 4.

Upland Test Pit 1
0-6” 10 YR 3/2 sandy loam
6-12” 10YR 4/3 silty sand

Upland Test Pit 2
0-8” 10 YR 3/2 sandy loam
8-12” 10 YR 6/3 sand

Two soil types are mapped by the Natural Resource Conservation Service (NRCS) on the south half of the island, as indicated on Figure 5. The west half of the island is mapped as Kidder Loam, 6-12% slope, eroded. The east half of the island is mapped as Kidder Loam, 20-30% slope, eroded.

SHORELINE ZONES

Shoreline Zone 1

Shoreline Zone 1 (SZ-1) constitutes the entire east-facing shoreline of the south half of the island. SZ-1 lies between SRP-A and SRP-B and is approximately 702 feet in total linear distance. Bank heights range from 22 to 24 inches. A moderate level of shoreline erosion is occurring, primarily due to wave action. Overland flow is minimal due to a small relative watershed based on topography and drainage patterns (Figure 4). Banks are vertical and with water levels several inches below the Ordinary High Water Mark (OHWM), a moderate level of bank undermining is evident with 3-5 inches of undermining measured. Water depth at the bank ranged from 6.5 to 8 inches. Substrate at the bank consists of 2-3 inches of silty sand over a firm clay base. Wave Energy calculations result in “Low Energy” due to the short fetch distance to the east shore (Appendix C), however, boat generated wave energy is relatively high in this zone and is not considered with the WDNR’s Wave Energy Calculator.

Vegetatively, the banks are mostly devoid of herbaceous vegetation, with some spatial areas of Pennsylvania sedge, common woodland sedge, and mosses overhanding the banks. Hardwood leaf litter is dense up to the crest of the bank. Woody vegetation in SZ-1 is primarily comprised of mature native trees, with a few select mature common buckthorn trees near the north end (SRP-A). Green ash, shagbark hickory, aspen, maple (silver, red, and sugar) and oak are common and tree roots are typically exposed and undermined at the bank. Most mature trees on the bank are leaning over the water. A significant amount of dead trees lie in the water, and numerous shoreline trees have dead or dying limbs overhanding the water. Native shrubs exist in clonal thickets periodically at the bank and further inland. Shrubs include American hazelnut, red osier dogwood, gray dogwood, nannyberry viburnum, and highbush cranberry. A single oriental bittersweet plant and a single winged euonymus plant was found (locations indicated on Figure 2).

Shoreline Zone 2

Shoreline Zone 2 (SZ-2) is the south-facing shoreline which lies between SRPs B and C. The total linear distance of SZ-2 is approximately 494 feet. Wave-generated shoreline erosion is relatively low here, mainly due to the geomorphology of the shoreline (shallow grade) and a shorter fetch, relative to other shoreline locations. Wave Energy calculations result in “Low Energy” due to the short fetch distance to the east shore (Appendix D). Wave erosion is reduced due to a shorter fetch as the distance to the south shore of the lake is less than 1,000 feet. However, SZ-2 has experienced anywhere from 42 to 68 feet of recession since 1941 (Figure 1), which is partially attributable to the highest overland flow rates leading to bank sloughing, based on topographical surface water drainage.

This high rate of shoreline recession is primarily due to the concentrated drainage pattern based on topography and the largest sub-watershed within the south portion of the island. Over the last 75 years, overland stormwater flow erosion has back-cut the bank into a flat and shallow grade, creating a distinct scalloped bay. The bank heights within SZ-2 average only 7 inches which constitute the shortest bank heights of any other portion of the island. With short banks, undermining erosion on the banks is minimal. Substrate at the bank is mostly sand, which has eroded from the bank and shoreline area. Sand is also deposited here as river current slows and converges at the south tip of the island. Substrate depth averages 5 inches.

Vegetation within SZ-2 is dominated by native shrubs. Gray dogwood, red osier dogwood, and highbush cranberry comprise dense stands from several yards inland to the bank and overhang the bank in most locations. A few pockets of Asian honeysuckle exist, along with riverbank grape in some locations. Numerous mature oaks and aspen are found further back from the bank, many of which overhang the water entirely or have limbs overhanging the water. Far less mature tree canopy exists at the shoreline here compared to other areas. Ironically, less woody material (tree limbs and downed trees) in the water, which may indicate that woody material in the water has decomposed and/or been buried by sediment. Herbaceous plant material includes reed canary grass, common woodland sedge, riverbank wild rye, and purple willow herb.

Shoreline Zone 3

Moving north from SRP-C, Shoreline Zone (SZ-3) lies between SRP-C and SRP-D. SZ-3 faces southwest and is approximately 479 linear feet. Shoreline erosion is occurring here which is a function of combined wave erosion and overland flow erosion leading to bank sloughing. The fetch distance to the south shoreline of the lake is just over 3,000 feet (Figure 6). But with water depths within this fetch area averaging only 5 feet, the shoreline wave energy is categorized as "Low Energy" (Appendix D).

The bank heights range from 26 to 39 inches, with a trend of increasing bank height moving north from SRP-C to SRP-D. Bank height reaches a maximum height of 39 inches at SRP-D. Bank undermining ranges from a few inches up to 20 inches within areas of dense root masses.

Overland flow erosion is a factor in bank erosion here as the sub-watershed that drains to the central point of SZ-3 is the largest on the island. Despite a mass of exposed twisted live and dead tree and shrub roots on the bank, undermining and back-cutting behind the roots has scoured the sandy soil and deposited the soil at the shoreline edge. Decades of sediment deposition through the drainage valley have resulted in a series of terraces upslope from the top of the bank. This continued process has resulted in a maximum of 54 feet of shoreline recession here since the 1940s (Figure 1).

Vegetatively, the shoreline is dominated by dense native shrubs and a consistent deciduous native tree overstory. Most of the mature trees at or near the shoreline are leaning over the water and will drop into the water as undermining continues around the root systems. Reed canary grass, Virginia wild rye, Pennsylvania sedge, and common woodland sedge exist within more open locations. A few patches of Asian honeysuckle also exist amidst the dense native dogwood and viburnum thickets.

<u>Shoreline Zone 4</u>

Shoreline Zone 4 (SZ-4) faces entirely west and lies between SRP-D and E. At 507 linear feet, SZ-4 is experiencing the least amount of overland surface water drainage, but the highest levels of wave erosion. The WDNR's Wave Energy Calculator results in a "Moderate Energy" category (Appendix E). This is due to the longest fetch distance of any location on the south half of the island, at more than two miles considering a northwest wind direction (Figure 6). Additionally, SZ-4 is straddled by two separate sub-watersheds, each directing overland flow towards the outer extents of the Shoreline Zone.

Bank heights are also higher than any other Shoreline Zone, with a maximum bank height of 86 inches (>7'). This tall bank height is primarily a function of shoreline geomorphology. Steep topography drops rapidly along most of SZ-4, with a gradual descent into shorter bank heights towards the northern end of SZ-4. As expected, the steepest bank height area is associated with the most severe shoreline erosion, with sloughing and bank undermining at high levels. Shoreline erosion is constant and most significant with SZ-4 and has resulted in a sandy bank in several locations. Some undermined areas behind tree and shrub roots extend several feet horizontally into the bank.

Vegetation at the south end of SZ-4 is dominated by native shrubs with periodic native deciduous tree overstory. Herbaceous vegetation is sparse and lacking. Trending north, as bank heights and shoreline erosional increase, native shrubs fade into invasive trees and shrubs. Near the area of tallest bank heights and steepest shoreline topography, a black locust clone exists at the top of the bank. This highly invasive tree species is thriving in highly disturbed well-drained soil conditions near the central portion of SZ-4. Asian bush honeysuckle also exists along SZ-4 in higher densities than any other shoreline location.

MECHANISMS OF SHORELINE EROSION ON ANTHONY ISLAND

Several combined factors are contributing to shoreline erosion on Anthony Island. Dominant bank erosion processes were wind-wave erosion, capillary wave erosion during high-water periods, groundwater-induced sliding, freeze-thaw processes, rain splash, stormwater overland flow, and boat-generated waves. However, because of the complexity of the interrelationships of these and many other bank erosion processes and the variability of the processes at and between sites, it would be necessary to make site-specific measurements and observations year-round to evaluate the processes that are active along a particular bank (Gatto, 1987).

Bank undermining and recession is the long-term process of soil loss primarily due to the erosional force of water scouring soil. In this case, wave action is the primary aspect of shoreline erosion. A secondary aspect of shoreline erosion is sloughing and undermining erosion because of stormwater overland flow through at least two distinct surface drainages on the island (Figure 4).

Wave Erosion

Wave erosion is the primary mechanism of shoreline erosion on Anthony Island. As stated above, the erosional forces that have caused the shoreline recession on Anthony Island are primarily from wind-wave energy. Other causes include, capillary wave erosion during high-water periods, groundwater-induced sliding, freeze-thaw processes, rain splash, stormwater overland flow, and boat wakes.

ERC completed the WDNR Erosion Intensity (EI) Calculation that resulted in a score of 67 (Appendix F). This score is the value that separates a Moderate Energy Site and a High Energy Site. This EI calculation is a metric indicating that a significant erosion setting is present and was evaluated by ERC to provide the recommendations of riprap revetment and other soft-armor options.

Erosion Intensity Calculation Definitions:

High Energy Site – a site where the storm-wave height calculated is greater than or equal to 2.3 feet or where the erosion intensity score calculated has a score of greater than 67.

Moderate Energy Site – a site where the storm-wave height is greater than or equal to 1.0 foot, but less than 2.3 feet, or where the erosion intensity score calculated has a score of 48 to 67.

Low Energy Site – a site where the storm-wave height is less than 1.0 foot, or where the erosion intensity score calculated has a score of 47 or less.

Ice Erosion

Erosion processes occur during frozen periods through the ice sheet process of freeze/thaw cycles. The mechanical properties of a reservoir ice cover are variable and complex, and difficult to assess at its dynamic interface with the dam and reservoir boundaries (Bouaanani et al., 2004). The importance of ice-related erosion along a reservoir bank would depend primarily on water level, but ice conditions and bank sediment characteristics would also be important. If the reservoir water level is at bank level, ice could directly erode a bank face. If the water is below the bank, ice would have no direct effect on it. However, ice could indirectly increase bank instability by disrupting and eroding nearshore and beach zones, which could lead to bank erosion (Gatto, 1984).

It was not clear during the site assessment activities that ice erosion has occurred on the southern half of Anthony Island. Mr. Todd Tessmann of the Village of Hustisford reported that water levels are typically lower on the lake during winter but that water levels are also a function of watershed drainage and the dam operations at Horicon Marsh (personal communication).

Overland Flow Erosion

A less significant aspect of shoreline erosion is attributable to overland stormwater flow during heavy rain events. Two major drainages exist on the south half of Anthony Island. Each drainage trends from northeast to southwest (Figure 4). These drainages have resulted in two locations of more advanced shoreline recession, evident as two shallow bays recessed into the southwest shoreline. One of these drainages (equidistant between SRP-C and SRP-D) is associated with steeper trending shorelines and bank heights that exceed two feet. At this location bank undermining and sloughing is severe.

SHORELINE AND BANK TREATMENT OPTIONS

The assessment data collection and evaluation indicate that there are four shoreline zones of similar physical characteristics and erosional processes. Based on shoreline erosional conditions, ERC will recommend the following options for shoreline and bank treatments.

Shoreline Stabilization and Restoration

Shoreline Zones 1 and 2 exhibit a reduced amount of bank erosion and a combination of bioengineered options will better suit these two shoreline zones. Wave erosion is reduced within these two zones due to a reduced fetch (compared to the west side); however, river flows and boat wake energy will continue to be erosive factors.

A combination of bioengineered soft armoring such as coir logs, brush bundles, live stakes, emergent plantings, and log-placement may be adequate and relatively inexpensive prescriptions for bank stabilization and restoration within Shoreline Zones 1 and 2 (Streambank and Shoreline Protection Manual).

Coir Logs:

Coconut fiber coir logs are cylindrical structures comprised of coconut husk fibers bound with twine into a linear fashion. These erosion control devices are commonly used for shoreline stabilization and restoration. Coir logs are staked (wood stakes) onto the shoreline at the water's edge and are intended to break up wave action and stabilize the shoreline behind the log until plantings (herbaceous and/or woody) can root in and stabilize the bank. The coir logs will biodegrade within a few years, allowing the native plants installed behind and into the coir log to contribute to bank armorment. Coir logs should be selected in 16' or 20" diameters for this application.

Brush Bundles:

Brush bundles are elongated bundles of branch cuttings bound together in cylindrical structures. The bundles may be 2' in diameter and 3-5' long. They would be staked and tied (to existing shoreline root material) at the water's edge within more exposed shoreline areas. The intention of the brush bundle is to dissipate wave energy and reduce shoreline erosion. Woody material may be used to construct brush bundles from the removal of woody invasive species on and near the shorelines such as buckthorn, black locust, and Asian honeysuckle.

Live Stakes:

Live staking involves the insertion of live, rootable cuttings of woody plants into the banks and shorelines. Cuttings are typically 2-3' long and are generally 1.5" to 1" in diameter. Species such as buttonbush, nannyberry, dogwoods, arrowwood and numerous willow species are accessible in specialty markets as live stakes. Live stakes are best installed from late fall to early spring, during the dormant season.

Emergent Plantings:

A critical aspect of long term shoreline stability and sustainability will be native herbaceous emergent plants. Dozens of species of native rushes, sedges, grasses, and forbs should be installed as plugs (live plants) into the shoreline at various locations and water depths. Emergent plantings should be installed in shallow water locations (less than 12" of water depth) behind and within coir logs or brush bundles. Species should be selected based on light and substrate conditions. Emergent plantings (plugs) could be installed in spring and summer months.

Log Placement:

Larger tree material is readily available on the shoreline areas and within the island's interior. Trees that are in the water or leaning over the water would be likely first options. Trees should be felled, bucked into manageable sections, and placed parallel to the shoreline. Trees must be cabled and/or staked into position to prevent dislodging and transport.

Estimated Cost Range: $55.00 to $65.00 per linear foot

Shoreline Revetment, Replenishment and Restoration

The assessment data indicate that the two zones of greatest erosion are Shoreline Zones 3 and 4, and these are the southwest and western portions of Anthony Island, respectively. These zones have the longest fetch, steepest and the most vertical banks, significant bank undermining and instability, and warrant permanent hard armoring.

The recommendation for these two zones would be the installation of a large riprap revetment at the or near the existing bank along this stretch. The installation of riprap revetment would allow the primary causes of bank erosion to be focused lakeward of the current bank and allow for lakebed "replenishment" behind or landward of the revetment and establishment of emergent wetland restoration. The revetment would be at the approximate location of the former bank location in the 1940s (Figure 7) and would extend approximately 1,040 feet.

The proposed revetment would include installing large riprap (12-24") over a construction fabric that will support the riprap and reduce the rate of the riprap sinking into the lake sediments. This is a very common form of riprap installation and has a reasonable longevity. Erosion caused by ice action is frequently reduced by a nearshore ice barrier (Outhet 1974). This would allow the wave energy to be reduced before it reaches the existing bank during normal water levels, and during times of severe flooding, will cause the fine-grained sediments to settle out landward of the riprap. This type of revetment has been used on Lake Koshkonong, another reservoir on the Rock River in Jefferson County, Wisconsin.

The linear installation of the revetment will allow a more laminar flow pattern to occur and reduce eddies along the currently scalloped shoreline, thereby reducing additional scouring along the irregular shoreline.

A secondary extension of riprap revetment could also be considered for SZ-2 on the south side of Anthony Island that has receded significantly since the 1940s. This zone would be a prime candidate for a shallow marsh emergent wetland restoration between the shoreline and the revetment. This treatment option would also utilize logs (from the island), coir logs, emergent native plants (sedges, wetland grasses, rushes, forbs), and woody debris for wildlife habitat. This revetment extension is indicated as a dashed line on Figure 8 and would be approximately 585 feet.

Estimated Cost Range: $200.00 - $250.00 per linear foot

Permitting and Planning

Permitting from agencies will be required in advance of any installation, construction or restoration activities can be conducted. It is also likely that a hydrologist or hydrologic engineer may be needed to prepare design schematics for permit applications. At this time, it is undetermined as to whether or not an engineer will be needed for the permitting process.

ERC has a long-established and trusted hydrologic engineering firm that has assisted ERC and its clients with numerous permit applications. This firm is Montgomery Associates: Resource Solutions (MARS). In the event that LSID pursues permits and/or approvals for work on the lake, MARS would be the recommended engineering partner.

Wisconsin Department of Natural Resources (WDNR) and US Army Corps of Engineers (USACOE) will administer permits for riprap placement.

Dodge County Land Resources and Parks Division will oversee permitting and authorization for cutting of vegetation from the shoreline to 35 feet inland (buffer zone), erosion control permits, and riprap permits.

The Village of Hustisford may also have ordinances and permits in place for shoreline restoration and riprap installation.

At this time, it is not certain that ERC will need to enlist an engineering firm and conduct significant additional lakebed data collection. This leads to the wide estimated cost range below.

Estimated Cost Range: $50,000.00 - $100,000.00

BUDGET

Installation costs will depend on a number of factors, but can be ranged as follows:

Bioengineering (Soft Armoring)

Cost for a combination of soft-armoring bank treatment (Shoreline Zones 1 and 2) will range from $55.00 to $65.00 per linear foot. These cost ranges were determined based on previous projects managed by ERC. Cost for stabilization of Shoreline Zone 1 would be approximately $65.00 per linear foot or $45,175.00. Cost for stabilization of Shoreline Zone 2 would be approximately $55.00 per linear foot or $26,620.00.

Hard Armoring (Rip Rap Installation)

Cost for the primary riprap revetment (Shoreline Zones 3 and 4) will range from $200.00 to $250.00 per linear foot. With 1,040 total linear feet of revetment under consideration for the primary revetment, total cost would range from $208,000.00 to $260,000.00.

Addition of off-shore revetment to the secondary area (Shoreline Zone 2) would increase the revetment distance by 585 linear feet. In this scenario, the total linear distance of revetment would be 1,625 linear feet. The cost range for the revetment at the primary and secondary level would be $325,0000.00 to $406,250.00

These costs are based on numbers obtained from Lake Rip Rap, Inc. in Girard Illinois (http://www.lakeriprap.com/). Lake Rip Rap, Inc. has considerable experience in the installation of off shore riprap revetments.

Permitting, Engineering Design and Plans & Specifications

Due to the many unknowns at this time, ERC has included a very conservative estimate and a wide range due to the uncertainty of services needed. This cost range will likely be $50,000.00 to $100,000.00.

Opinion of Probable Cost (with primary revetment only)

Shoreline Zone 1:	$45,175.00
Shoreline Zone 2:	$26,620.00
Shoreline Zones 3 & 4:	$260,000.00 (high end)
Planning and Permitting:	$100,000.00 (high end)
Total:	$431,795.00

Opinion of Probable Cost (with primary AND secondary revetment)

Shoreline Zone 1:	$45,175.00
Shoreline Zones 2, 3, & 4:	$381,000.00 (high end)
Planning and Permitting:	$100,000.00 (high end)
Total:	$526,175.00

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Gatto, Lawrence, W. 1984. Reservoir bank erosion caused by ice. Cold Regions Science and Technology. Volume 9, Issue 3, August 1984, Pages 203-214.

Gatto, L.W. & Doe, W.W. 1987. Bank conditions and erosion along selected reservoirs. Environ. Geol. Water Sci 9: 143.

Outhet, D.N. 1974. Progress report on bank erosion studies in the Mackenzie River delta, N.W.T. In Hydrologic Aspects of Northern Pipeline Development, Task Force on Northern Oil Development, Environmental-Social Program, Northern Pipelines, Report No. 74-12. pp. 297-345.

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Appendix A. Figures

Drawn By:
Daniel Fuhs

Date:
12/19/2017

Project Number:
17142

Figure 1

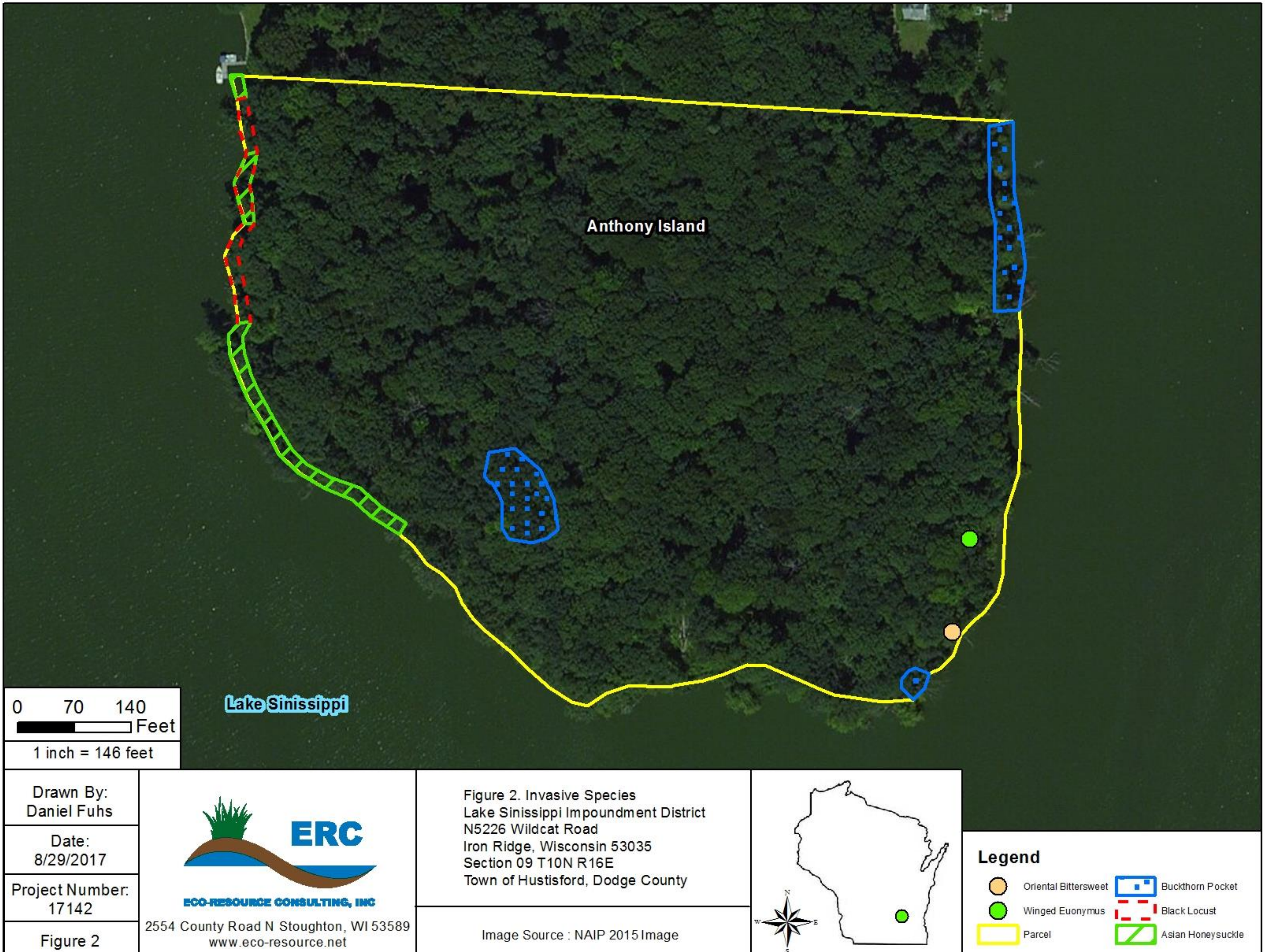
ERC
ECO-RESOURCE CONSULTING, INC
2554 County Road N Stoughton, WI 53589
www.eco-resource.net

Figure 1. 1940 vs 2017 Shorelines
Lake Sinissippi Impoundment District
N5226 Wildcat Road
Iron Ridge, Wisconsin 53035
Section 09 T10N R16E
Town of Hustisford, Dodge County

Image Source : Google Earth 2017 Image

Legend

- Shoreline Loss ~ Width 31'
- 2017 Shoreline
- 1940 Shoreline
- Shoreline Loss - 1.57 Acres



Drawn By:
Daniel Fuhs

Date:
8/29/2017

Project Number:
17142

Figure 2

ERC
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Figure 2. Invasive Species
Lake Sinissippi Impoundment District
N5226 Wildcat Road
Iron Ridge, Wisconsin 53035
Section 09 T10N R16E
Town of Hustisford, Dodge County

Image Source : NAIP 2015 Image

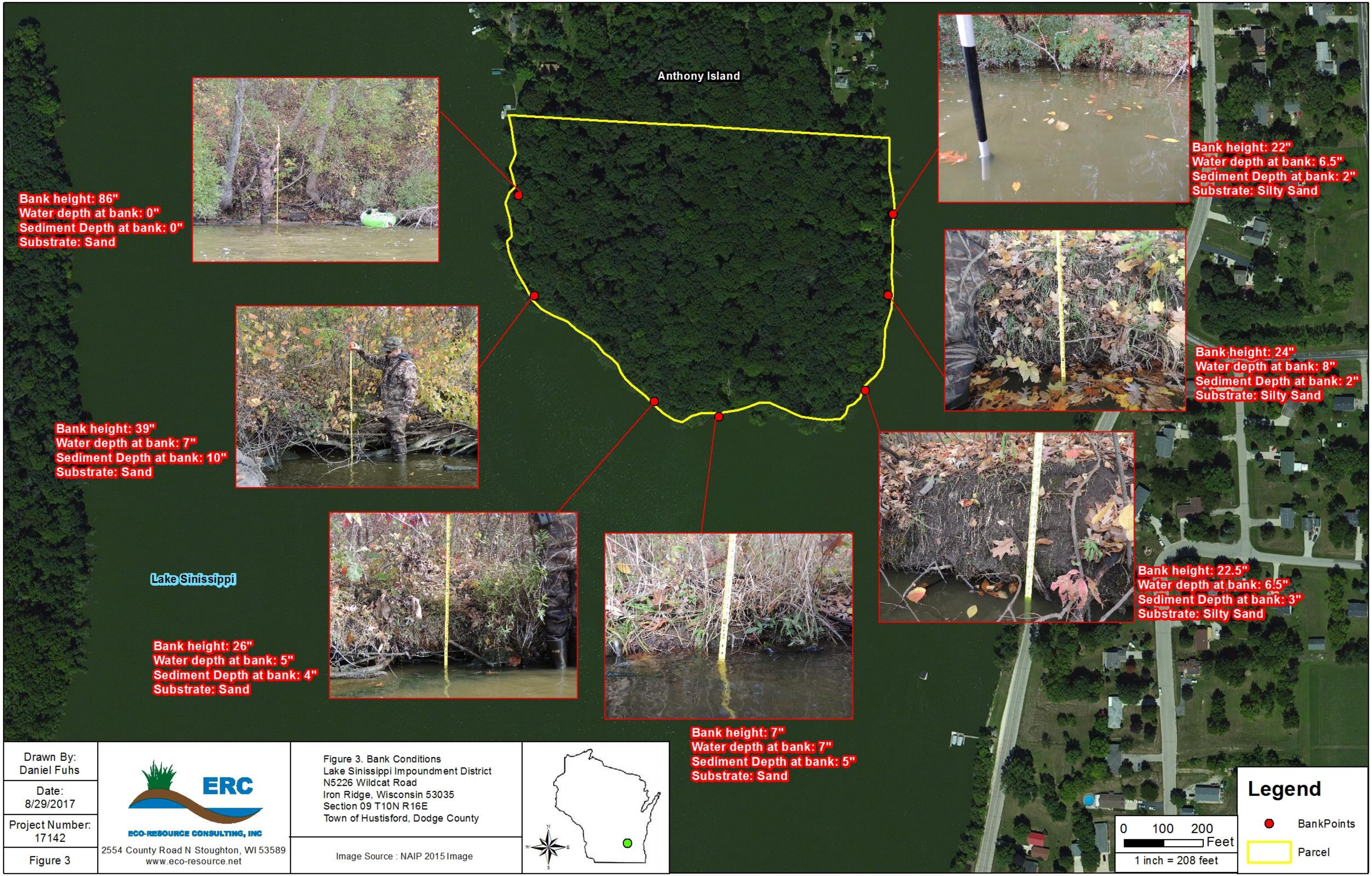
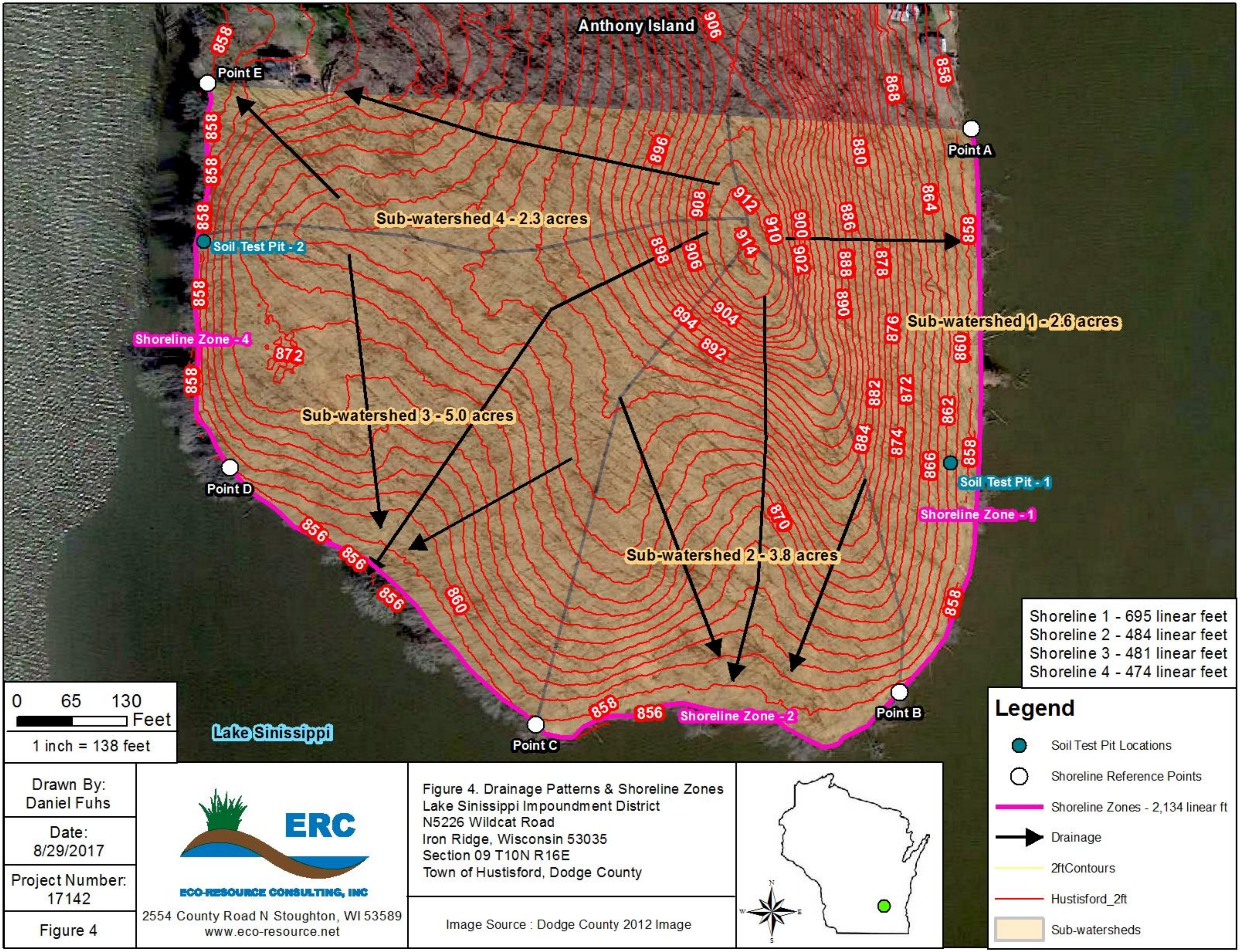


Figure 3. Bank Conditions
Lake Sinissippi Impoundment District
N5226 Wildcat Road
Iron Ridge, Wisconsin 53035
Section 09 T10N R16E
Town of Hustisford, Dodge County



Drawn By: Daniel Fuhs

Date: 8/29/2017

Project Number: 17142

Figure 4

2554 County Road N Stoughton, WI 53589
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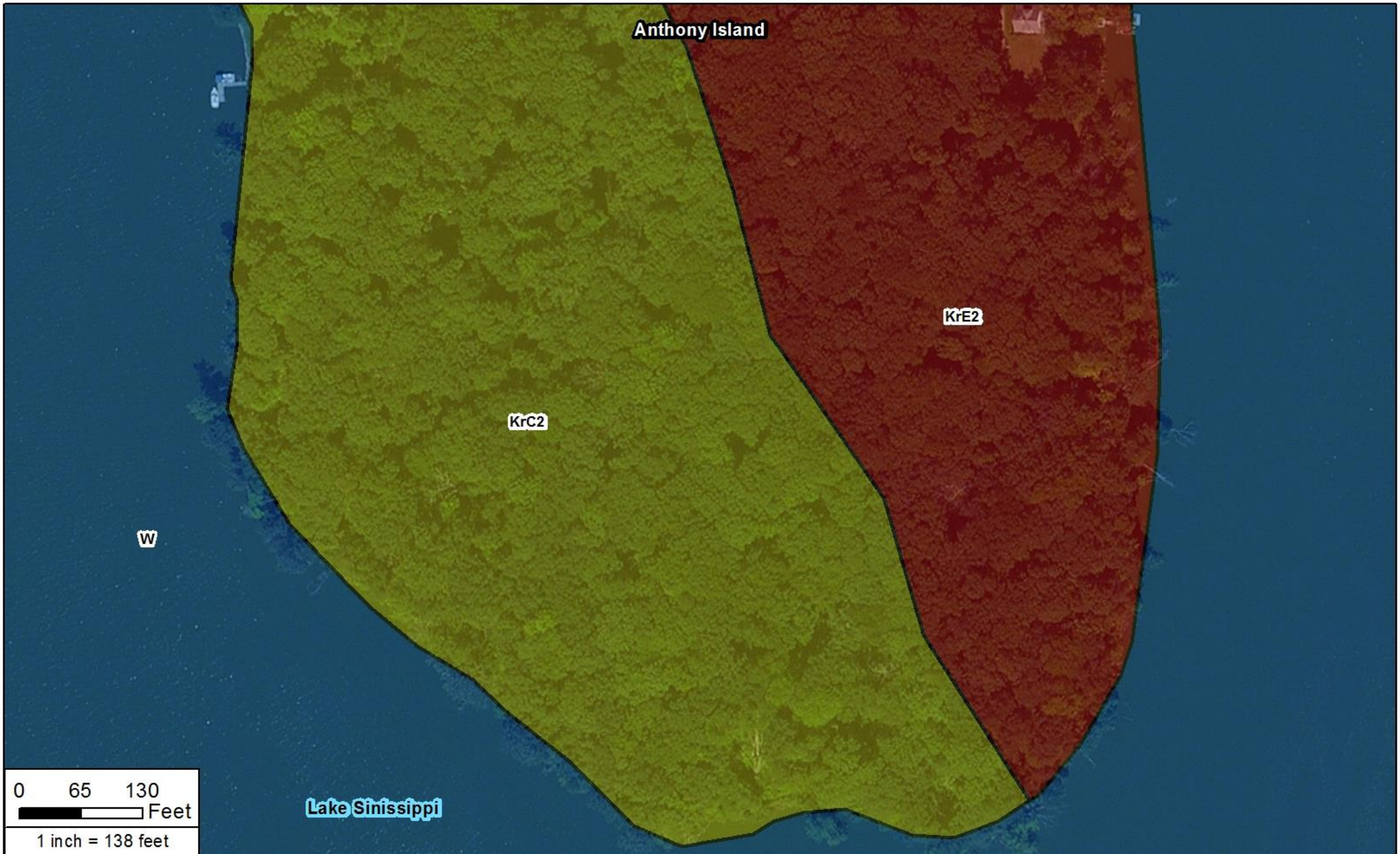
Figure 4. Drainage Patterns & Shoreline Zones
Lake Sinissippi Impoundment District
N5226 Wildcat Road
Iron Ridge, Wisconsin 53035
Section 09 T10N R16E
Town of Hustisford, Dodge County

Image Source : Dodge County 2012 Image



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Daniel Fuhs

Date:
8/29/2017

Project Number:
17142

Figure 5

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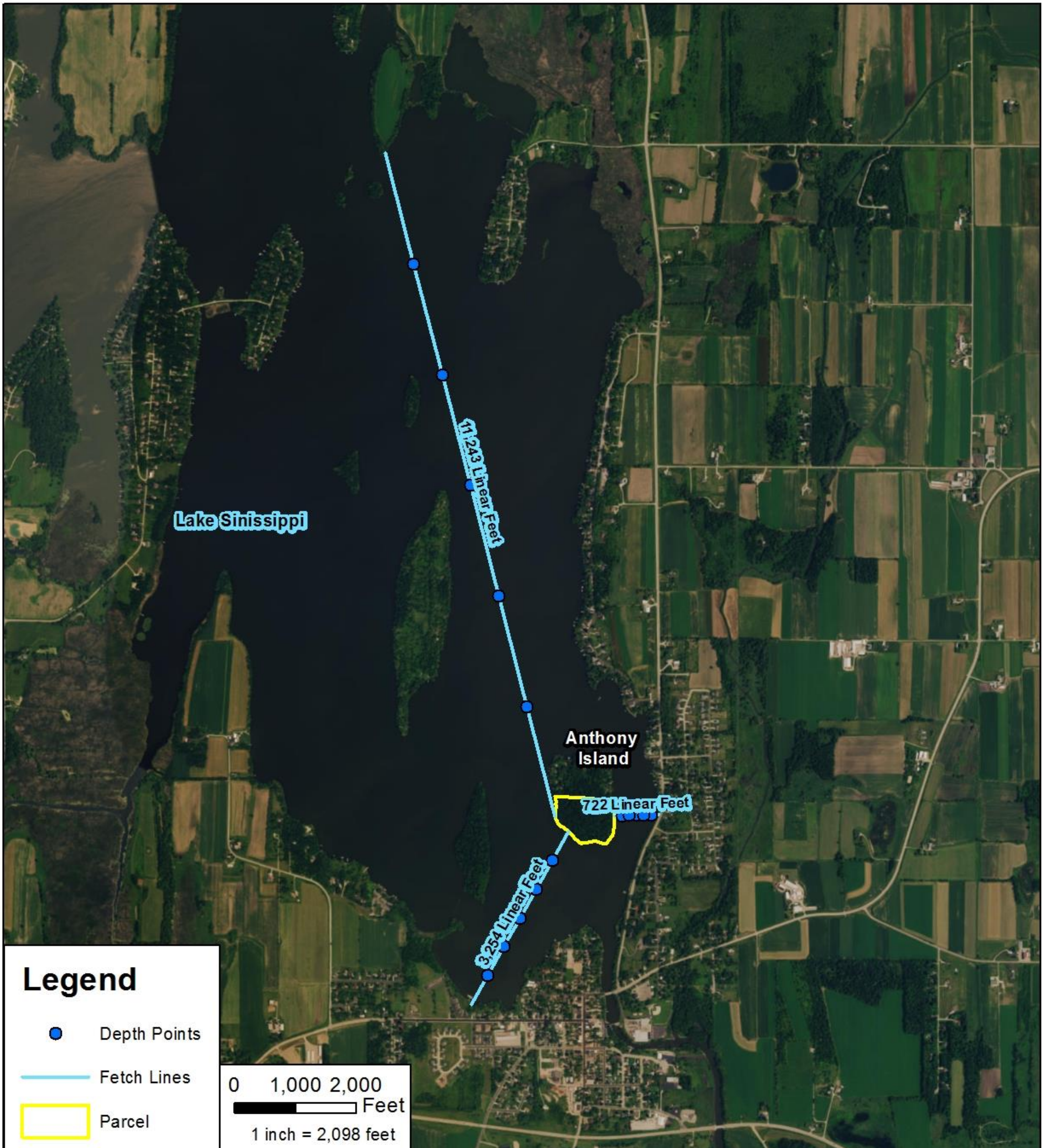
Figure 5. NRCS Web Soil Survey
Lake Sinissippi Impoundment District
N5226 Wildcat Road
Iron Ridge, Wisconsin 53035
Section 09 T10N R16E
Town of Hustisford, Dodge County

Image Source : NAIP 2015 Image

Legend

- KrC2 - Kidder Loam, 6-12% Slope, Eroded
- KrE2 - Kidder Loam, 20-30% Slope, Eroded



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Daniel Fuhs

Date:
11/6/2017

Project Number:
17142

Figure 6

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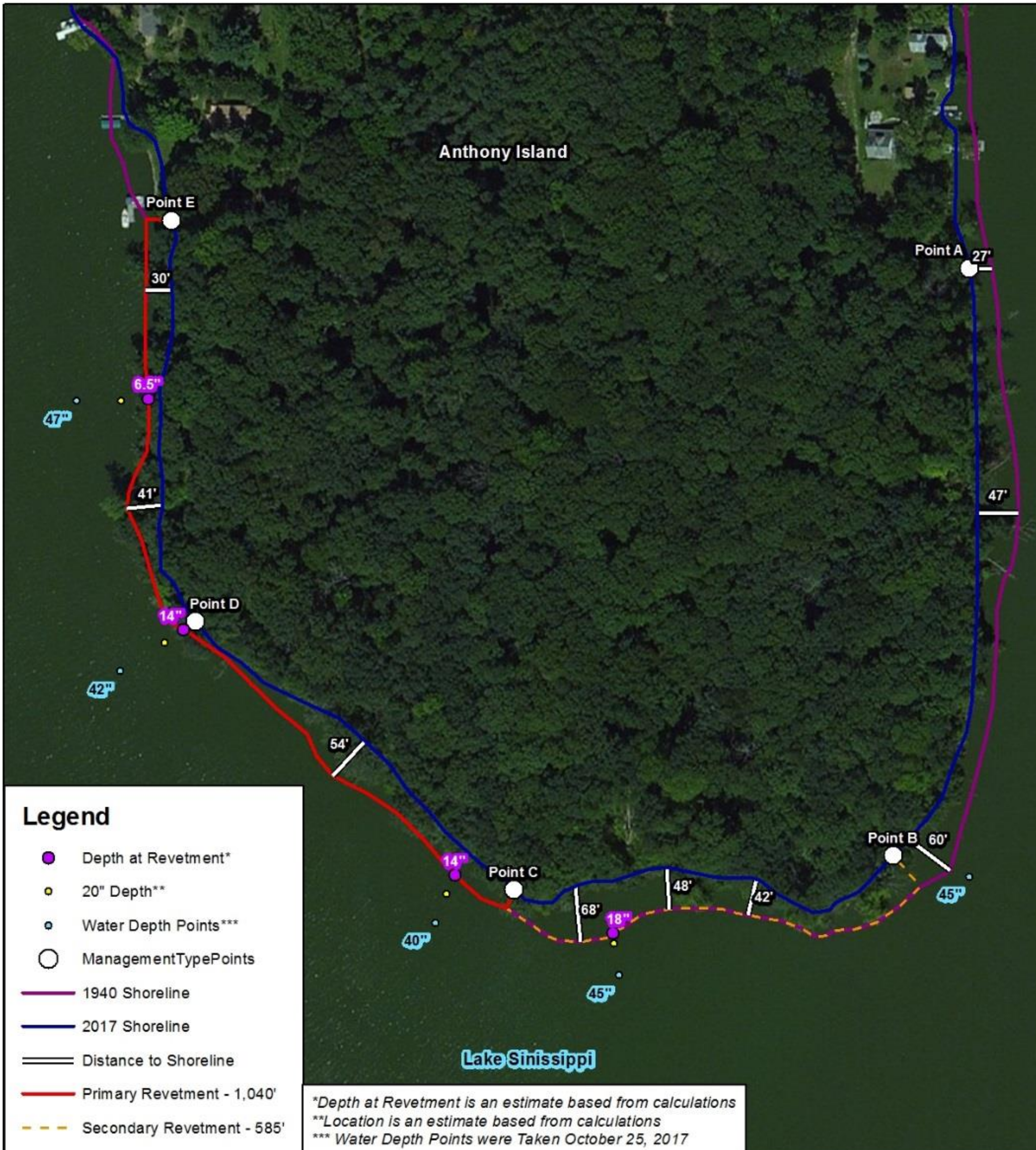
Figure 6. Fetch Lines
Lake Sinissippi Impoundment District
N5226 Wildcat Road
Iron Ridge, Wisconsin 53035
Section 09 T10N R16E
Town of Hustisford, Dodge County

Image Source : NAIP 2015 Image



Drawn By: Daniel Fuhs	ERC ECO-RESOURCE CONSULTING, INC 2554 County Road N Stoughton, WI 53589 www.eco-resource.net	Figure 7. Management Recommendations Lake Sinissippi Impoundment District N5226 Wildcat Road Iron Ridge, Wisconsin 53035 Section 09 T10N R16E Town of Hustisford, Dodge County	
Date: 10/26/2017			
Project Number: 17142		Image Source : NAIP 2015 Image	
Figure 7			

Appendix B. Photographs

Shoreline Zone 1

Shoreline Zone 2

Shoreline Zone 3

Shoreline Zone 4

Appendix C. Shoreline Zone 1 Erosion Calculator

Waterway and wetland permits: calculating energy along a shoreline

NOTE: For best results, use Microsoft Internet Explorer browser version 8 or higher

Follow these steps to obtain an accurate calculation of energy along your shore line:

1. Print out the map for your lake shore site (include the scale)
2. Figure out the correct feet-per-inch value using the map scale and your ruler, and enter the number here: **1 inch** = [2098] **feet**
3. Mark your shore line site on the lake map.
4. Draw the longest unobstructed straight line originating from your site across the water to any other point on the shore; this is the fetch at your site. Use this example [PDF 289KB] for reference.
5. Using a ruler, measure the length of the fetch line and record this value: [0.3441372] **inches**
6. To convert the ruler measurement of fetch to actual distance, multiply feet per inch (found in step 2) by the measured fetch line (found in step 5):
   Lake Fetch = [2098] **feet/inch** x [0.3441372] **inches = 722.0000000000001 feet or 0.137 Miles**
7. Measure the mean depth along your fetch line
   1. Locate and mark at least 5 equally-spaced points along your fetch line.
   2. Estimate and record the depths at these equally spaced points (for example: 45 ft, 105 ft, 75 ft, 55 ft and 25 ft).
   3. Add these depth values together and then divide by the number of sample points taken, and record the result. For example, (45 ft + 105 ft + 75 ft + 55 ft + 25 ft)/5 = 61 feet.) Use this example [PDF 273KB] for reference.
8. Using the two values obtained in steps seven and eight, fetch from your site and mean depth on your fetch line, use the wind wave model below to calculate the storm wave height at your site. The storm wave height is used to determine the energy category at your site.

Lake fetch from my site [0.137] Miles (found in step 6)

Mean water depth along my fetch [3] Feet (found in step 7)

Storm wind speed 51.33 ft/sec

[Calculate]

Results

Wave energy/length weight = 0.00893941

Storm wave height = 0.378 feet

Appendix D. Shoreline Zones 2 and 3 Erosion Calculator

Waterway and wetland permits: calculating energy along a shoreline

NOTE: For best results, use Microsoft Internet Explorer browser version 8 or higher

Follow these steps to obtain an accurate calculation of energy along your shoreline:

1. Print out the map for your lakeshore site (include the scale)
2. Figure out the correct feet-per-inch value using the map scale and your ruler, and enter the number here: **1 inch** = 2098 **feet**
3. Mark your shoreline site on the lake map.
4. Draw the longest unobstructed straight line originating from your site across the water to any other point on the shore; this is the fetch at your site. Use this example [PDF 289KB] for reference.
5. Using a ruler, measure the length of the fetch line and record this value: 1.551000 **inches**
6. To convert the ruler measurement of fetch to actual distance, multiply feet per inch (found in step 2) by the measured fetch line (found in step 5):
   Lake Fetch = 2098 **feet/inch** x 1.551000 **inches = 3254.000000000001 feet or 0.616 Miles**
7. Measure the mean depth along your fetch line
   1. Locate and mark at least 5 equally-spaced points along your fetch line.
   2. Estimate and record the depths at these equally spaced points (for example: 45 ft, 105 ft, 75 ft, 55 ft and 25 ft).
   3. Add these depth values together and then divide by the number of sample points taken, and record the result. For example, (45 ft + 105 ft + 75 ft + 55 ft + 25 ft)/5 = 61 feet.) Use this example [PDF 273KB] for reference.
8. Using the two values obtained in steps seven and eight, fetch from your site and mean depth on your fetch line, use the wind wave model below to calculate the storm wave height at your site. The storm wave height is used to determine the energy category at your site.

Lake fetch from my site 0.616 Miles (found in step 6)

Mean water depth along my fetch 5 Feet (found in step 7)

Storm wind speed 51.33 ft/sec

Calculate

Results

Wave energy/length weight = 0.0374931

Storm wave height = 0.775 feet

Appendix E. Shoreline Zone 4 Erosion Calculator

Waterway and wetland permits: calculating energy along a shoreline

NOTE: For best results, use Microsoft Internet Explorer browser version 8 or higher

Follow these steps to obtain an accurate calculation of energy along your shoreline:

1. Print out the map for your lakeshore site (include the scale)
2. Figure out the correct feet-per-inch value using the map scale and your ruler, and enter the number here: **1 inch =** 2098 **feet**
3. Mark your shoreline site on the lake map.
4. Draw the longest unobstructed straight line originating from your site across the water to any other point on the shore; this is the fetch at your site. Use this example [PDF, 289KB] for reference.
5. Using a ruler, measure the length of the fetch line and record this value: 5.3589132 **inches**
6. To convert the ruler measurement of fetch to actual distance, multiply feet per inch (found in step 2) by the measured fetch line (found in step 5):
   Lake Fetch = 2098 **feet/inch** x 5.3589132 **inches = 11243.000000000002 feet or 2.13 Miles**
7. Measure the mean depth along your fetch line
   1. Locate and mark at least 5 equally-spaced points along your fetch line.
   2. Estimate and record the depths at these equally spaced points (for example: 45 ft, 105 ft, 75 ft, 55 ft and 25 ft).
   3. Add these depth values together and then divide by the number of sample points taken, and record the result. For example, (45 ft + 105 ft + 75 ft + 55 ft + 25 ft)/5 = 61 feet.) Use this example [PDF, 273KB] for reference.
8. Using the two values obtained in steps seven and eight, fetch from your site and mean depth on your fetch line, use the wind wave model below to calculate the storm wave height at your site. The storm wave height is used to determine the energy category at your site.

Lake fetch from my site 2.13 Miles (found in step 6)

Mean water depth along my fetch 5 Feet (found in step 7)

Storm wind speed 51.33 ft/sec

Calculate

Results

Wave energy/length weight = 0.101530

Storm wave height = 1.27 feet

Appendix F. Erosion Intensity Score Worksheet

Section V: Erosion Intensity (EI) Score Worksheet.

Applicants and department staff shall use this worksheet to calculate erosion intensity pursuant to s. NR 328.08(2). Where an applicant or the department believes that, as a result of site conditions, storm-wave height as calculated in sub. (1) may inaccurately predict the degree of erosion, the erosion intensity score may be calculated to determine erosion. When the department or applicants assess erosion intensity (EI) at the shore protection site they shall apply methods outlined in this worksheet. Wherever EI and storm-wave height result in different energy categories, the site shall be placed in the category as determined by EI.

SHORELINE VARIABLES	DESCRIPTIVE CATEGORIES — EROSION INTENSITY VALUE IS LOCATED IN PARENTHESIS ON LEFT SIDE OF EACH CATEGORY BOX							ASSIGNED EI
AVERAGE FETCH[1] - average distance (miles), across the open water to the opposite shore measure 45° either side of the perpendicular to the shoreline	(0) <1/10	(2) 1/10 – 1/3	(4) 1/3-1	(7) 1 – 3	(10) 3-10	(13) 10-30	(16) >30	4
DEPTH AT 20 FEET, Depth of water (feet) 20 feet from shoreline	(1) <1	(2) 1-3	(3) 3-6	(4) 6-12	(5) >12			2
DEPTH AT 100 FEET, depth of water (feet) 100 feet from shoreline	(1) <1	(2) 1-3	(3) 3-6	(4) 6-12	(5) >12			3
BANK HEIGHT[2], height of bank (feet), measure from toe of the bank to top of the bank lip	(1)<1	(2) 1-5	(3) 5-10	(4) 10-20	(5) >20			2
BANK COMPOSITION composition and degree of cementation of the sediments	(0) rock, marl, tight clay, well cemented sand (dig with a pick)	(7) soft clay, clayey sand, moderately cemented (easily dug with a knife)	(15) uncemented sands or peat (easily dug with your hand)					15
INFLUENCE OF ADJACENT STRUCTURES, likelihood that adjacent structures are causing flank erosion at the site	(0) no hard armoring on either adjacent property	(1) hard armoring on one adjacent property	(2) hard armoring on both adjacent properties	(3) hard armoring on one adjacent property with measurable recession	(4) hard armoring on both adjacent properties with measurable recession adjacent to both structures			2
AQUATIC VEGETATION[3] type and abundance of vegetation occurring in the water off the shoreline	(0) rocky substrates unable to support vegetation.	(1) dense or abundant emergent, floating or submerged vegetation	(4) scattered or patchy emergent, floating or submergent vegetation	(7) lack of emergent, floating or submergent vegetation				7
BANK VEGETATION, type and abundance of the vegetation occurring on the bank face and immediately on top of the bank lip	(0) bank compose of rocky outcropping unable to support vegetation	(1) dense vegetation, upland trees, shrubs and grasses, including lawns	(4) clumps of vegetation alternating with areas lacking vegetation	(7) lack of vegetation (cleared), crop or agricultural land				1
BANK STABILITY, The degree to which bank and adjacent area (within 10 feet of the bank lip) is stabilized by natural ground, shrub, and canopy vegetation (outside a 10 foot access corridor). Human disturbance is typified by tree removal, brushing, mowing, and lawn establishment.	(0) established lawn with few canopy trees	(1) established lawn with moderate to dense canopy trees	(4) moderate to dense natural ground vegetation and canopy trees with shrub layer substantially reduced; or few canopy trees with moderate to dense natural shrub layer.	(7) moderate to dense canopy trees with moderate to dense natural shrub layer; or other natural features prevents establishment of vegetation.				7
SHORELINE GEOMETRY general shape of the shoreline at the point of interest plus 200 yards on either side	(1) coves or bays	(4) irregular shoreline or straight shoreline	(8) headland, point, or island					8
SHORE ORIENTATION[4] geographic direction the shoreline faces	(0) < 1/3 mile fetch	(1) north to east to south-southeast (349°-360°, 1°-168°)	(4) south to west-southwest (169°-258°)	(8) west to north-northwest (259°-349°)				4
BOAT WAKES[5] proximity to and use of boat channels	(1) no channels within 100 yards, broad open water body, or constricted shallow water body; or channels within no-wake zones	(6) thoroughfare within 100 yards carrying limited traffic, or thoroughfare 100 yards to ½ mile offshore carrying intensive traffic	(12) thoroughfare within 100 yards carrying intensive traffic (unregulated boating activity)					12
EROSION INTENSITY SCORE (EI) ⟶								67