CEDAR LAKE AQUATIC ECOSYSTEM FEASIBILITY STUDY

CEDAR LAKE, INDIANA

APPENDIX B
PLAN FORMULATION

U.S. Army Corps of Engineers
Chicago District

July 2016

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LIST OF ACRONYMS

AHHUs	Average Annual Habitat Units
ASA(CW)	Assistant Secretary of the Army (Civil Works)
ASP	Available Sediment Phosphorus
CE/ICA	Cost Effective / Incremental Cost Analysis
CLEA	Cedar Lake Enhancement Association
EDC	Engineering During Construction
HSI	Habitat Suitability Index
HUs	Habitat Units
IDC	Interest During Construction
IDEM	Indiana Department of Environmental Management
IWR-PLAN	Institute for Water Resources Planning Suite Software
LERRDs	Lands, Easements, Rights-of-Way, Relocations and Disposal Areas
LPP	Locally Preferred Plan
MCACES	Micro Computer Aided Cost Estimating System
NED	National Economic Development
NER	National Ecosystem Restoration
OMRR&R	Operations, Maintenance, Repair, Replacement and Rehabilitation
P&G	Principles and Guidelines
PED	Preconstruction Engineering and Design
PPA	Project Partnership Agreement
PRP	Preliminary Restoration Plan
SDF	Sediment Dewatering Facility
TP	Total Phosphorus
TSI	Trophic State Index
USACE	U.S. Army Corps of Engineers
WRDA	Water Resources Development Act

APPENDIX B – PLAN FORMULATION

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1.0 Introduction

Cedar Lake is a 781-acre, glacially formed lake located in the Town of Cedar Lake, in Lake County, Indiana as shown in ***Figure 1***. The study area is located in west central Lake County, T34N/R9W/Sec.22, 23, 26, 27, 34 and 35. It lays 4.5 miles southwest of Crown Point and 40 miles southeast of Chicago. US Route 41 (Wicker Street), Lake Shore Drive, Parrish Avenue, Lauerman Street, 133rd Avenue, Morse Street and 141st Avenue are the main streets surrounding the lake. Historically, Cedar Lake supported a biologically diverse aquatic ecosystem with native plants and wildlife characteristic of northern glacial lakes. However, human activity over the past 140 years has altered the connectivity of aquatic habitat, aquatic communities, plant communities, and natural lake processes of Cedar Lake. These modifications have subsequently caused structural habitat degradation, fragmentation of tributaries, reduction of littoral zone and fringe wetlands, non-native species issues, and an abundance of fine-grained nutrient rich sediments. Although desirable native species such as Bowfin (*Amia calva*), Northern Pike (*Esox lucius*), Yellow Perch (*Perca flavescens*), Ring-necked Duck (*Aythya collaris*), American Coot (*Fulica americana*), Great Blue Heron (*Ardea herodias*), Snapping Turtle (*Chelydra serpentina*), Redear Slider (*Trachemys scripta elegans*), and Northern Water Snake (*Nerodia sipedon*) inhabit Cedar Lake, modifications within the watershed have significantly reduced native species diversity and abundance, and have suppressed biodiversity as a whole. Restoration efforts are needed to improve and enhance aquatic habitat structure and function as well as improve native species diversity and abundance. These efforts will allow the lake to support a healthier aquatic community of native aquatic organisms.

The Cedar Lake watershed is located within the Valparaiso Moraine and is characterized by distinct glacial topography. Since the 1800s, Cedar Lake has been described in numerous accounts, including reports of early surveyors, settlers, and explorers of natural resources (Large 1897, Indiana Academy of Science 1896, Blatchey 1900). Early accounts indicate that Cedar Lake was formed when the melt-water of retreating glaciers collected on clay deposits in a narrow valley. Processes that formed the lake created a relatively small and limited watershed covering about 7.6 square miles (4,864 acres), with all but the southern portions of the lake confined by steep slopes. One significant exception to the steep slopes of the surrounding basin is the 400 acre Cedar Lake Marsh on the south end of the lake. Cedar Lake Marsh is the largest contiguous marsh in Indiana (Goodwin and Neiring 1975). Nearly half of the entire Cedar Lake watershed drains into this marsh before reaching the lake (SPEA 1984). In addition to Cedar Lake Marsh, two small riparian wetlands are associated with intermittent tributaries on the north end of the lake.

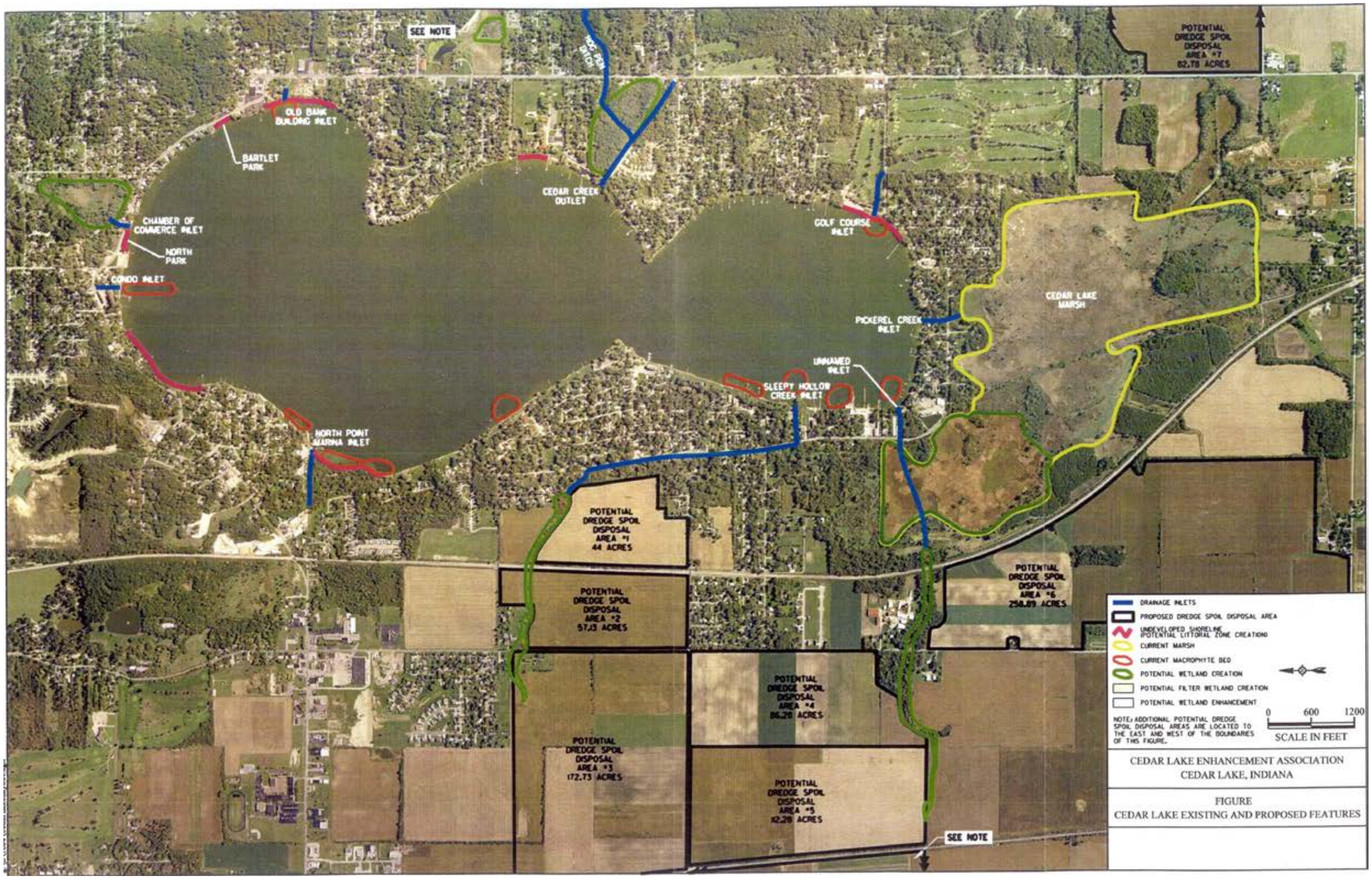

Figure 1: Layout Map of Cedar Lake, Indiana.

Extreme modifications were made to the lake itself in the 1870s when a channel was cut through the glacial ridges that impounded the lake on the east side, subsequently lowering the lake approximately 12 feet for the purpose of reclaiming about 200 acres of wetland at the south end of the lake. Following lowering of the lake level, maximum water depths of approximately 40 feet were reduced to less than 20 feet (Blatchley 1900). Lowering of the lake level resulted in the creation of the 400 acre Cedar Lake Marsh, which in its present configuration would have been part of the former lake bed. Despite being a relatively high quality wetland, the marsh is nevertheless an artifact from actions that occurred more than 140 years ago. Lowering the lake level also destroyed the natural riparian and lake features that existed during pre-settlement times, including intermittent, seasonal, and permanently flooded wetlands, fringe wetland and littoral habitat, and diverse aquatic communities.

Cedar Lake drains to Cedar Creek, which was fragmented from Cedar Lake with the construction of a broad-crested weir overflow structure. This structure was modified to provide a fish barrier designed to prevent non-native Common Carp and other fish species from migrating upstream into the lake. The overflow structure maintains a current lake surface area of about 781 acres, compared to a surface area of about 749 acres in 1900 (Blatchley 1900).

2.0 Project Goals and Authority

This study was initiated under the Section 206 authority of the Water Resources Development Act (WRDA) of 1996. Section 3065 of WRDA 2007 authorizes the Secretary to plan, design and construct an aquatic ecosystem restoration project at Cedar Lake, Indiana. The provision further directs the Secretary to expedite completion of the feasibility report that was initiated under Section 206 of WRDA 1996, and authorizes the use of funds previously appropriated under the Section 206 program. There are currently no funds appropriated for the implementation (construction) phase. The WRDA language establishes a cap of $11,050,000 for any future appropriations of Federal funds for this project.

The U.S. Army Corps of Engineers (USACE) and the Town of Cedar Lake, the non-Federal sponsor, have partnered to investigate the feasibility of an aquatic ecosystem restoration project. Section 206 provides authority for the USACE to support restoration projects in aquatic ecosystems such as rivers, lakes, and wetlands. These restoration projects must improve the quality of the environment, be in the public interest, and be cost effective. Under the authority provided by Section 206, USACE evaluates projects that could potentially benefit the environment by restoring, improving, or protecting aquatic habitat for plants, fish, and other wildlife species. Projects considered for funding must be justified and supported by a detailed investigation indicating that the proposed actions are technically feasible and environmentally acceptable, and that they provide cost-effective ecosystem restoration benefits.

USACE completed a Preliminary Restoration Plan (PRP) for Cedar Lake and determined the following overall project goals (USACE 2002):

- To restore the habitat within Cedar Lake through the restoration of fringe wetlands, littoral zone, and confluent streams and wetlands
- To gain outputs in native species biodiversity through increases in diversity and abundance of aquatic macrophytes, macroinvertebrates, and native glacial lake fishes

- To restore Cedar Lake to a mesotrophic status(i.e., lake with an intermediate level of productivity) and reduce turbidity within the water column for aquatic macrophyte growth and sight predators

Through the development of the Cedar Lake Feasibility Study and additional information gained through field sampling and modeling analyses, the overall project goals were distilled down to the following overarching goal:

- To determine a cost effective and ecologically beneficial plan which would increase biodiversity throughout the entire Cedar Lake ecosystem by targeting structural habitat and biological function within the fringe, littoral, and profundal lake zones as well as tributary riparian zones

2.1 Lake Environmental Conditions

The overall problem within the study area is the holistic decrease in biodiversity. Biodiversity is a term that is used to describe all aspects of biological variety including species diversity and abundance, ecosystem complexity, and genetic variation. Biodiversity has decreased in response to the loss of aquatic habitat connectivity, alteration of littoral processes, and land use change; collectively a reduction in physical complexity.

Historically, the Cedar Lake watershed was dominated by several naturally occurring habitat types including wetlands, glacial ponds, forests, woodlands, savannas, and prairies. By the late 1800s, many of these habitats, particularly prairies, savannas and wetlands, were converted to agricultural fields or developed for residential use. Remnant parcels of natural habitat types remain under pressure from ongoing human activities. Human induced disturbances to the remaining natural habitats generally include fire suppression, altered hydrology and hydraulics, landscape alterations, and introduction of non-native invasive species. While the natural habitat types can be described in terms of dominant organisms, the quality and function of the habitat they provide are directly related to the level at which natural processes function. For Cedar Lake, these natural processes include, but are not limited to groundwater recharge/discharge, nutrient cycling, water column mixing, and wave energy and patterns. Habitat quality displays a negative relationship to the amount of human disturbance in which the disturbance affects these driving functions and physical structure of the habitat itself.

The native glacial lake species assemblages have become significantly reduced in both species richness and abundance due to past disturbances. Past impairments to the lake, as previously described include lake level lowering, fragmentation through damming the outlet, removal of littoral zone plant communities, manipulation of inflowing streams, removal of fringe wetlands, residential development within the immediate coastal zone and adverse manipulation of the native fish community.

Cedar Lake is a naturally vulnerable system due to its small drainage area, its isolated location on top of the Valparaiso end moraine, and its natural condition as an oligotrophic lake (i.e., lake with low primary productivity). These factors limit natural processes from repairing past damages to physical and chemical components because the lack of flow coming into the system and the inability to flush unsuitable substrates downstream. As a result, any small addition of nutrients to such a nutrient starved and isolated ecosystem quickly pushes the system into disequilibrium resulting in rapid change to the biological community. The cumulative effects over time of the physical and chemical alterations to hydrology, littoral processes, and structural habitats has caused Cedar Lake's ecosystem to become imbalanced and hypereutrophic (i.e., very nutrient-rich lakes characterized by frequent and severe nuisance algal blooms and low transparency). Aquatic ecosystem impairments that may be addressed with the implementation of the ecosystem restoration project are as follows:

- Lack of suitable substrates for aquatic macrophytes, macroinvertebrates and benthic fishes
- Lack of submerged aquatic macrophyte beds within the littoral zone
- Lake of fringe emergent marsh along shallow flats of the littoral zone
- Absence of a functioning native glacial lake fish assemblage
- Inability for native fish to visually hunt, forage and spawn due to turbidity and unsuitable substrates
- Fragmentation of tributaries preventing passage of native fishes
- Dominance of non-native and invasive species due to overall physical and chemical impairments
- Imbalance of the physical matrix and chemical parameters of the physical habitat (i.e., substrate, water, soils)

The "overall health" of a lake is commonly characterized by determining the trophic status. Trophic state is defined as the total weight of living biological material (biomass) in a water body at a specific location and time and provides a measurement of biological response to forcing factors such as nutrient additions. Nutrients promote growth of microscopic plant cells (phytoplankton) that are fed upon by microscopic animals (zooplankton). Higher nutrient concentrations yield increases in microscopic plant and animal development thus making the water "cloudy." This relationship, called eutrophication, is a natural aging process of lakes, but it can be unnaturally accelerated by the addition of too many nutrients as is the case in Cedar Lake.

To determine reasonable and feasible restoration goals for Cedar Lake, data for similar lakes in the region were compared. Several natural lakes in Indiana were reviewed to determine their appropriateness for use as reference lakes. Reference lakes were selected based on their similar size and depth, similarly developed shoreline, and similar land uses in the watershed. Despite these similarities, all of the reference lakes have better water quality than Cedar Lake, and none of them experience the nuisance algal blooms that frequently occur in Cedar Lake. Reference lakes and their associated water quality data are included in ***Table 1***.

Table 1 presents aquatic ecosystem restoration goals for Cedar Lake compared to three reference lakes: Hamilton Lake, Webster Lake, and Syracuse Lake. Parameters used to calculate the TSI-Indiana are identified with an asterisk in ***Table 1***. One additional lake in Illinois, East Loon Lake, was also considered when determining aquatic ecosystem restoration goals for Cedar Lake. East Loon Lake has a similar shape and is part of the same morainal system as Cedar Lake. Because all of the necessary information was not available for East Loon Lake, it can only be compared to Cedar Lake qualitatively. Based on the data available for similar lakes in the region, the aquatic ecosystem restoration goals established for Cedar Lake are reasonable.

Table 1: Cedar Lake Aquatic Ecosystem Restoration Goals Compared to Reference Lakes.

Parameter	Cedar Lake[a,b]	Quantitative Reference Lakes[a,b,c]			Qualitative Reference Lake[c]	Cedar Lake Water Quality Restoration Goal[d]
		Hamilton Lake	Webster Lake	Syracuse Lake	East Loon Lake	
Maximum Depth (feet)	16	69.9	46.9	35		--
Mean Depth (feet)	8.6	20.7	7	12.9		--
Surface Area (acre)	781	802	774	564.1		--
Date Assessed	7/27/1999	8/5/2002	8/5/2003	8/4/2003	8/6/2003	--
Trophic State	M	NA	NA	O	NA	M
TP* (mg/L)	0.153 (0.208)	0.043 (0.232)	0.054 (0.149)	0.035 (0.07)	NA	0.07[e]
TKN (mg/L)	1.103 (1.275)	1.068 (1.723)	1.043 (3.64)	0.5 (0.572)	NA	0.87
NH_3-N* (mg/L)	0.018 (0.018)	0.031 (1.027)	0.018 (2.159)	0.018 (0.041)	NA	0.018[f]
NO_3-N* (mg/L)	0.022 (0.022)	0.013 (0.0235)	0.013 (0.013)	0.013 (0.013)	NA	0.013
Secchi Depth* (feet)	1.31	4.9	3.9	10.5	NA	3.9[g]
Temperature (°F)	86.5 (82.9)	83.1 (45.0)	80.1 (51.4)	79.7 (64.6)	77.6	--
DO* (mg/L)	10.2 (0.8)	7.6 (0.3)	7.1 (0.02)	7.6 (0.1)	8.32	7.4
pH	9.3 (8.9)	8.4 (8.4)	8.5 (7.6)	8.6 (7.6)	8.74	8.5

Trophic State: E = Eutrophic; H = Hypereutrophic; M = Mesotrophic; O = Oligotrophic

Nutrients: TP = Total phosphorus; TKN = Total Kjeldahl nitrogen; NH_3-N = Ammonia; NO_2-N = Nitrite; NO_3-N = Nitrate

DO Dissolved oxygen
mg/L Milligram per liter
NA Not available

* Parameter used to calculate the Indiana Trophic State Index (TSI)

[a] Data was collected during daylight hours by SPEA through the Clean Lakes Program and was obtained from databases maintained by IDEM (IDEM 2004).

[b] Water quality data were collected near the surface and near the bottom of each lake; values in parentheses were collected near the lake bottom.

[c] Reference lakes are all glacial lakes in northern Indiana. Data is provided for East Loon Lake in Illinois for comparative purposes only.

[d] The reference lakes have similar mean depths as Cedar Lake. However, because they have a much deeper maximum depth, they stratify in distinct thermal layers in the summer months, while Cedar Lake does not. As a result of its shallow depth, water quality measurements at depth in Cedar Lake are similar to surface measurements obtained for the stratified lake. Unless otherwise indicated, Cedar Lake water quality goals were determined using the average of the measurement obtained at the surface of the reference lakes.

[e] A water quality goal that is the average of the data obtained from near the surface of the reference lakes is not likely attainable for Cedar Lake. Therefore, the water quality goal was established using the lowest value from the bottom of a reference lake.

[f] Cedar Lake values are similar to the reference lake surface values; therefore, the goal is to maintain current Cedar Lake concentrations.

[g] The Secchi depth of Webster Lake was used as the Cedar Lake water quality goal because Webster Lake's mean depth is most similar to Cedar Lake.

Cedar Lake and reference lakes in Indiana have been evaluated by the Indiana Department of Environmental Management (IDEM) using the Indiana Trophic State Index (TSI-Indiana). The TSI-Indiana is a comparative measure of a lake's overall aquatic ecosystem health, based on physical, chemical, and biological parameters. Points are assigned to each parameter based on its association with nutrient conditions in the lake. Scores assigned to these parameters are then combined to produce a single multi-metric index score. The total score indicates a lake's trophic state – that is, whether it is under or over-nutrified. The multi-metric TSI-Indiana score can range from 0 for oligotrophic lakes that lack nutrients to a maximum score of 75 for hypereutrophic lakes that are highly over-nutrified (IDEM 2001). In 1986, Cedar Lake had a TSI-Indiana of 70, indicating that it received an excess of nutrients that were not used, cycled, or partitioned in ecosystem processes (IDEM 1986). The Indiana Trophic State Index is only used as a comparative index because the equation is technically flawed in its calculation and lack of scientific basis.

A more scientifically-based and widely used Carlson trophic state index quantifies the concept that changes in nutrient levels (measured by total phosphorus) causes changes in algal biomass (measured by chlorophyll a) which in turn causes changes in lake clarity (measured by Secchi disk transparency). The TSI was calculated for each restoration measure according to the following equation (Carlson 1977):

$$TSI = 14.42 \ln\left(P[\mu g / L]\right) + 4.15,$$

where P is the spatially averaged phosphorus concentration. Normalized and maximum phosphorus concentrations and TSI were calculated for each restoration measure and alternative plan and used to determine habitat output.

2.2 Restoration Goals

If the goals listed in *Section 2.0 Project Goals and Authority* and *Section 2.1 Lake Environmental Conditions* are achieved, the aquatic community in the restored lake would more closely resemble an unmodified glacial lake ecosystem. These ecosystems are typically ringed by emergent and submergent vegetation and contain a diverse assemblage of plants and animals. Over time, modification to the lake and its watershed have degraded the quality and reduced the abundance and diversity of aquatic organisms and aquatic vegetation in Cedar Lake (Bacone and Campbell 1980). Cedar Lake restoration activities will include the restoration of fringe and littoral zone aquatic macrophytes that can support a stable, glacial lake fish community.

Five submergent aquatic macrophytes and one advanced algae were selected based upon their historical occurrence in Cedar Lake (USACE 2002; Indiana Department of Natural Resources [IDNR] 2004), their common occurrence in Indiana lakes, or their importance to macroinvertebrates, fish, and waterfowl (USGS 2004). Fish species selected for the restoration community are known to occur in the Kankakee River watershed (NatureServe 2004) and occupy vegetated inland lakes (Hubbs and Lagler 1974).

3.0 Restoration Measures for Consideration

A wide range of restoration measures identified for Cedar Lake are summarized in ***Table 2***. The table also identifies the advantages, disadvantages, and unknowns associated with each identified measure. Each of these restoration measures were initially screened for their effectiveness in reaching project goals and ability to implement under the USACE aquatic ecosystem restoration authority. Some measures were eliminated from further consideration due to various factors including cost, effectiveness, local sponsor support, and ability to implement under the project authority. Measures that were kept for further consideration were evaluated for cost effectiveness based on habitat output and implementation costs. Combinations of restoration measures were formulated into restoration alternative plans for evaluation.

Thirteen types of restoration measures were considered for addressing aquatic ecosystem degradation at Cedar Lake. Through the initial screening process, six were eliminated from further analysis due to various reasons outlined in ***Table 2***. The remaining seven categories of restoration measures were kept for further analysis. Below is a list of restoration measures formulated and evaluated for Cedar Lake:

A. Physical Substrate Restoration
B. Chemical Substrate Restoration
C. Tributary Restoration
D. Creation of Habitat Islands
E. Littoral Macrophyte Restoration
F. Institutional Controls
G. Fish Community Management

A detailed description of site-specific restoration measures formulated and evaluated, including their various scales, are included in the sub-sections to follow.

Table 2: Summary of Restoration Measures Considered.

RESTORATION MEASURES		PROS	CONS	UNKNOWNS	SCREENING DECISION
Physical Substrate Restoration	Dredge top 1 ft (throughout lake)	- Reduce concentrations of nutrients over greater lake area - Increase depth over greater lake area reducing impacts from wind fetch	- Shallow dredging is less cost-effective - Sediment disposal required	- None identified	- **Kept** for further analysis - Investigate locations within the lake where dredging is most effective
	Dredge top > 2.5 ft (deep holes only)	- Highest concentrations of nutrients in deeper areas - Deeper holes would have ancillary benefits - Sediment traps would be created to store new sediment load	- Suspended solids will not be significantly reduced - Sediment disposal required	- None identified	- **Kept** for further analysis - Investigate locations within the lake where dredging is most effective
	In-lake disposal	- Creates additional wetland habitat - Not necessary to buy or lease land for dredge spoil disposal	- Must construct a sediment barrier - Return water must be cleansed - Dredged materials must be permanently stabilized - Reduces size of open water	- Willingness of landowners to establish wetland habitat adjacent to their properties - Willingness of public to reduce open water area	- **Kept** for further analysis - Investigate support for in-lake disposal
	Upland disposal	- Potential to deposits nutrient-rich sediment to increase fertility of farmland	- Must purchase or lease land - Must treat return water before it re-enters the lake	- Availability and land cost	- **Kept** for further analysis - Survey potential sites
Chemical Substrate Restoration		- Removes both suspended solids and algae - Forms colloidal seal over the sediment reducing nutrient diffusion from sediments - Clarifies the water column	- Alternative depends on successfully removing bottom rooting fishes - Retreatment needed over time	- Effectiveness of alum to survive carp foraging, tributary inputs and mixing from wind and boats	- **Kept** for further analysis - Model level of wind mixing and turbulence from boats at the lake bottom - Treatability testing
Tributary Restoration		- Immediate effectiveness - Decrease algae concentrations - Increase water quality	- Long retention time could negate benefits - Few nearby waterbodies - Large potential cost	- Lake hydrodynamics and morphology - Source limitations	- **Kept** for further analysis
Creation of Habitat Islands		- Reduce wind fetch length - Creates additional habitat	- Impacts to recreation - Reduces size of open water	- Willingness of landowners and lake users - Effectiveness	- **Kept** for further analysis

Table 2: Summary of Restoration Measures Considered (continued).

RESTORATION MEASURES		PROS	CONS	UNKNOWNS	SCREENING DECISION
Littoral Macrophyte Restoration	Create submergent macrophyte beds	- Adds oxygen to water through photosynthesis - Provides habitat - Binds nutrients from use by algae - Secures and stabilized the lake bottom	- Water must be clarified prior to establishment - Requires removal of carp - Sediments must be stabilized prior to establishment - Algae blooms must be discouraged prior to establishment - Aquatic macrophytes can be seen as a nuisance by lake users	- If water is clarified, algae blooms and density of macrophytes might increase	- **Kept** for further analysis
	Create emergent beds	- Stabilizes lake bottom - Provides habitat - Binds nutrients from use by algae	- Limited areas available for restoration - Beds susceptible to predation by carp, ducks, geese & muskrats	- Willingness of landowners to establish emergent beds adjacent to their properties	- **Kept** for further analysis
Shoreline Restoration	Create beach habitat	- Creates a recreational beach area - Discourages erosion - Provides habitat	- Limited areas available for restoration	- Willingness of landowners to establish beach habitat adjacent to their properties	- **Removed** from further analysis due to limited areas available
	Plant trees	- Provides cooler temps - Insects drop into water as fish food	- If planted too densely, shaded ground open to erosion - Limited areas available for restoration	- Willingness of landowners to plant trees on their properties	- **Removed** from further analysis due to ability to implement on private properties
	Native vegetation buffer strips	- Reduced sediment and nutrient loading to the lake - Aesthetic benefits	- Limited areas available for restoration	- Willingness of landowners to establish native vegetation buffer strips on their properties	- **Removed** from further analysis due to ability to implement on private properties
Institutional Controls	Motorboat restrictions	- No Wake zones are already identified	- Conversion of existing recreational use	- Effects of boat-caused turbulence on the lake bottom - Willingness of landowners to abide by additional restrictions	- **Kept** for further analysis - Model effects of boat-caused turbulence on the lake bottom

Table 2: Summary of Restoration Measures Considered (continued).

RESTORATION MEASURES		PROS	CONS	UNKNOWNS	SCREENING DECISION
Institutional Controls	Yard waste and maintenance practices	- Reduces the amount of nutrients entering the lake	- None identified	- Willingness of landowners to abide by additional restrictions	- **Removed** from further analysis due to ability to implement under authority
	Construction regulation within the watershed	- Reduces the amount of sediment to the lake - Model ordinances developed - Comprehensive plan completed	- None identified	- None identified	- **Removed** from further analysis due to action implemented by sponsor through new ordinances
Fish Community Management / Aquatic Invasive Species Control	Eradication	- Rotenone is available in many applications, not persistent in the environment, and has low toxicity to mammals and birds	- Small drainage basin makes desiccation impractical - Chemicals have been tried and failed in some cases - High cost - Lethal to non-target fish - Carp often survive rotenone	- None identified	- **Kept** for further analysis
	Physical removal	- No chemicals required - Increased opportunity for anglers	- Economic returns are marginal - Requires consistent and ongoing removal operations	- None identified	- **Removed** from further analysis due to effectiveness issues
	Biomanipulation	- No chemicals required - May help control algal blooms	- Introduction of piscivores has been tried and failed	- Seasonal succession of algae	- **Removed** from further analysis due to effectiveness issues
Bank Stabilization of Tributaries	Vegetation	- Stabilizes soil - Increases sediment deposition and bank protection - Improves riparian habitat - Provides aesthetic benefits	- None identified	- None identified	- **Removed** from further analysis due to actions implemented by sponsor
	In-channel structure	- Allows fish passage - Provides enhanced DO levels - Provides habitat for fish and aquatic macroinvertebrates	- Potential flooding impacts	- None identified	- **Removed** from further analysis due to actions implemented by sponsor

Table 2: Summary of Restoration Measures Considered (continued).

RESTORATION MEASURES	PROS	CONS	UNKNOWNS	SCREENING DECISION
Stormwater Management	- Reduces pollution and sediment loading - Sponsor evaluating storm sewer system upgrades	- None identified	- Stormwater discharges are unidentified	- **Removed** from further analysis due to ability to implement under authority
Farmland Improvements	- Reduces sediment loading	- None identified	- Willingness of farmers to employ soil conservation practices	- **Removed** from further analysis due to ability to implement under authority - Coordinate with NRCS
Woodland Management	- Reduces pollution loads - Improves habitat value and ecological quality	- None identified	- Potential locations for woodland management	- **Removed** from further analysis due to ability to implement under authority
Creation of Filtration Wetlands	- Cedar Lake Marsh has retained high natural values - Improved filtration and retention capacity of wetlands	- Approval of landowners required before surrounding marshes can be enhanced	- Potential for enhancement of Cedar Lake Marsh and smaller marshes on north end of lake	- **Removed** from further analysis due to ability to implement alterations to existing high quality wetland

3.1 Physical Substrate Restoration

Currently, the lake bottom is comprised of fine-grained nutrient rich sediments. These sediments are easily suspended within the water column by rooting benthic fish [e.g., Common Carp, Brown Bullhead], wind induced currents, and recreational boat propellers. Suspension of these fine-grained nutrient rich sediments causes turbid conditions which in turn can inhibit aquatic plant growth (i.e., sunlight needed for photosynthesis is unable to penetrate through the water column to aquatic plants) and inhibit colonization by sight predator fish species. The physical removal of these fine-grained nutrient rich sediments would allow aquatic macrophytes to become established, which are important for stabilizing sediments (e.g., roots) and providing cover for macroinvertebrates and juvenile fish species. In addition, removal of these sediments would aid in restoration of spawning habitat for lake species, restoration of littoral zone vegetation, and restoration of profundal (i.e., deep aquatic habitat) zone habitat.

Measures under this category involve physical removal of bottom sediments aimed at reducing both the internal nutrient loading as well as turbidity caused by resuspension. Eight dredging scenarios were chosen to analyze the performance of two distinct dredging approaches. Total phosphorus (TP) concentrations of daylighted sediments (those exposed after dredging) were assumed to be 400 mg/kg regardless of the dredging depth based upon concentrations measured at various depths in three sediment cores taken within Cedar Lake (Echelberger 1984). ***Table 3*** below contains descriptions of each of the measures and the volume calculations. ***Figure 3*** shows a layout map of the dredging measures.

The long term effectiveness of physical substrate restoration would vary according to the quantity and location of dredging. None of the evaluated scenarios completely remove all unsuitable sediments. Modeling analyses as detailed in *Appendix A – Hydrology & Hydraulics* show that turbidity would continue as a result of unnatural sediments day lighted by dredging. Although nutrient concentrations are less in deeper sediments and loadings would be reduced, reductions would not be to levels low enough to eliminate the adverse feedback loop due to resuspension.

Eight scales of physical substrate restoration were formulated and evaluated ranging from 263,000 cy to 8,240,000 cy. Initially the layout of measures A.1 through A.6 were developed based on field measurements of bottom sediment TP concentrations taken in 1998 (Harza 1998a). This data provided a starting point for evaluating removal options. Since substrate restoration measures are generally more costly than other restoration measures, careful consideration to optimizing the removal quantities and locations that result in the most efficient water quality and ecosystem benefits were investigated. Two removal approaches were evaluated using the Environmental Fluid Dynamics Code (EFDC) model (James 2007): shallow dredging over a large extent versus deeper dredging over a small extent (concentration in "hotspots"). Model results showed that shallow dredging over a large area was more efficient in removing phosphorus from the water column. It also showed that Measure A.4 provided the most efficient reduction in phosphorus concentration per volume of sediment removed.

Using the physical substrate restoration extent of Measure A.4 as a guide, a sediment sampling plan was developed to define the existing sediment conditions necessary to obtain required permits. The analysis was also refined with the addition of newer data. Sediment sampling results from 2007 for TP varied in both magnitude and distribution from those collected in 1998 (USACE 2007). The greatest concentrations of TP moved from the northern basin to the southern basin, which corresponds to modeled direction of sediment transport. Based on the new distribution of sediments, the layout of dredging measure A.4 was revised to correspond with the new TP concentration distribution. Additional sediment sampling was performed as part of the chemical substrate restoration measures in 2008. As laid out in *Appendix H - Alum Treatment Analysis*, available sediment phosphorus (ASP), which is the fraction of total phosphorus available to the water column, was measured. This ASP data was mapped and provided the best source for laying out the extent of dredging for each of the measures. Using this data, measures A.7 and A.8 were formulated to target areas of greatest ASP.

Various dredging methods were evaluated. Cost and implementability were the major factors in the evaluation of each method. Through field collection and analysis, sediments within Cedar Lake were determined to contain a relatively high percentage of fine particles. Also, the average sediment density was quite low indicating that material is very light and fluffy.

Initially, hydraulic dredging using a cutter head and suction pump was considered the best option for removal due to the muck nature of the sediments. Slurry consisting of bottom sediments and lake water would be pumped to a sediment dewatering facility for disposal. Due to the high concentrations of ammonia, dewatering effluent would need to be treated prior to returning to the lake.

Mechanical dredging using an excavator bucket and barge was also evaluated and compared to hydraulic means. Dredged material would be offloaded from a hopper barge to trucks for transport to a sediment dewatering facility for disposal. Dewatering effluent would also need to be treated, however, the volume of effluent produced would be considerably less than that produced by hydraulic dredging.

A cost comparison between hydraulic and mechanical dredging options was done and broken down into four major components: removal, transport, dewatering/disposal, and effluent treatment. Among the components, hydraulic dredging was less expensive in terms of actual removal and transport of material, but mechanical dredging was less expensive in terms of dewatering/disposal and effluent treatment. The cost associated with treating additional effluent produced by hydraulic dredging significantly outweighed the inefficiencies of the mechanical removal.

A third hybrid option that utilizes the most efficient aspects of both methods was also considered. Mechanically removing the sediments and hydraulically transporting them to the sediment dewatering facility was evaluated. Effluent would be recycled by returning it to the hopper barge to slurry the material and hydraulically pumped for disposal. The volume of effluent requiring treatment is similar to the mechanical dredging option. The cost associated with this hybrid option was determined to be the least costly and, therefore, utilized for all substrate restoration measures.

Numerous upland disposal sites were investigated throughout the study process, including sites identified on ***Figure 2*** as sites A through H. Additional sites had been investigated during earlier planning stages but were screened out for further consideration due to site development. Site Alternatives A and B were both controlled by either option or ownership by a developer. At the time of initial review, the sites were open and would not have required relocations. The sites would have required pumping slurry and return waters through residential areas and across or under streets. Sites A and B were offered for the SDF on a lease basis and were later eliminated from consideration due to the owner's intention for future development and request that the sites be returned to initial condition upon completion of the restoration project. The request for future physical substrate restoration put a large uncertainty into the cost portion of the plan formulation process due to the need for double handling and future disposal or materials. Placement of dredged material would have significantly elevated the site topography requiring additional storm water drainage features to control erosion from runoff. In addition, building on top of dredged material would have required more costly foundation designs due to the lower bearing capacity of the newly placed material. As such, the land owners required that dredged material placed on the site would have needed to be removed in order to be in agreement with the development plans. Removing the material once dewatered would have significantly increased the project costs.

Site Alternatives C, D, and E were under consideration as possible development sites and the non-Federal sponsor concluded that the advanced stage of planning for development would complicate a schedule for acquiring real estate rights for the properties. Planning was already underway for the development of these sites and there would have had to have been a commitment to the landowners to return the sites to initial conditions within a certain timeframe so the owner's development of the properties would not have been delayed. In addition, sites C and E would have required pumping both slurry and return waters through residential areas and across or under streets. At the time of review, the sites did not contain any homes and therefore would not have required relocations. Site E has been developed for single family homes since the time of consideration.

Site Alternative F consists of the area commonly known as Cedar Lake Marsh. The marsh properties are under the control of the Lake Heritage Park Foundation. The Foundation was very interested in accepting dewatered sediments as an amenity to the site since a number of marsh areas had been degraded due to dumping. The marsh managers identified a number of small locations consisting of a few acres each, and not containing sensitive habitats as disposal sites. The conclusions about site Alternative F were that the dredge slurry could not be placed directly on the site at the multiple identified locations and, therefore, would not serve as an SDF but only as an ultimate material disposal site. Multiple handling of the dewatered sediments would have been required for the ultimate placement of the sediments. Although an apparently attractive site initially, site Alternative F was eliminated from further consideration due to costs of multiple handlings for placement of materials in numerous very small areas.

Site Alternative G was owned by one landowner and would not have required relocation. Site topography would have severely limited layout and construction of a bermed SDF. The site was eliminated from consideration since the site was smaller than needed overall and contained drainage areas that may have required additional treatment to protect the natural areas in Cedar Lake Marsh.

Site Alternative H consisted of multiple parcels that had been acquired by one land developer with future plans for development. At the time of review, the sites did not contain any homes and, therefore, would not require relocations. The topography of the site was level and would allow for flexible layouts of bermed dewatering facilities. Soils investigations did not preclude construction of SDF facilities. Due to the proximity of the marsh site east of the Union Pacific Railroad (UPRR), pumping of slurry and return waters could be accomplished without traversing multiple streets or residential areas. Site Alternative I was a long distance from the proposed staging area and, although considered at an early stage, was eliminated from consideration due to pumping distance.

The town of Cedar Lake ultimately purchased 112 acres of agricultural property located just southwest of the lake as a proposed SDF site (Site H). The property is three miles northwest of Lowell, Indiana, within the Town of Cedar Lake.

The SDF site for both the NER Plan and LPP, lies in the west ½ of Section 3, Township 33N, Range 9W of the 2nd Principal Meridian, in West Creek Township, Lake County, Indiana, and is located on the Lowell 7.5' USGS topographic quadrangle map. The site is bordered on the west by Parrish Avenue and to the south by 155th Avenue. Agricultural areas border the SDF site to the north and east. Residential areas border the site on the south and west. The SDF site is directly adjacent to a private residence along the southern edge at 155th Avenue. Two railroad corridors are within the vicinity of the SDF site; the first runs north-south east of the SDF site, the second is west of the SDF site between Parrish and US 41.

The property is actively farmed and does not contain any structures. A large drainage ditch/stream flows through the southern quadrant of the property; two minor drainage ditches are located on the northern and eastern boundaries of the property. The drainage ditches flow east into Cedar Lake Marsh. The large ditch in the southern quadrant flows through the property and east across adjacent properties until it is ultimately discharged into Cedar Lake Marsh near the Howkinson property, which is owned by Lake County Parks. This ditch is covered in typical hydrophytic vegetation.

The SDF involves the excavation of on-site material for the construction of containment dikes, configuration of storage cells, and water clarification cells. Topsoil will be removed from the property and stockpiled for later use. Physically removed sediment will be transported from the lake to the SDF by hydraulic pumping. Solids generated during dredging activities will settle out within the SDF. The settling time will be accelerated by the addition of a cationic polymer to the physically removed material as it is hydraulically pumped to the SDF. Dewatering cells and decant structures will be constructed in the SDF to provide the required detention time for solids to settle. Upon completion of physical substrate restoration and dewatering activities, a protective cap/cover will be established over the physically removed material for final site closure consisting of re-placement of topsoil stripped from the site to create the SDF. The SDF will be stabilized with vegetation to control erosion of the physically removed material and protective cover. After completion of the project, recreational use of the site is planned, including ball fields and park land. Recreation features would be implemented by the non-Federal sponsor after USACE project completion. Therefore, recreation features are independent of the tentatively selected plan and do not impact project benefits.

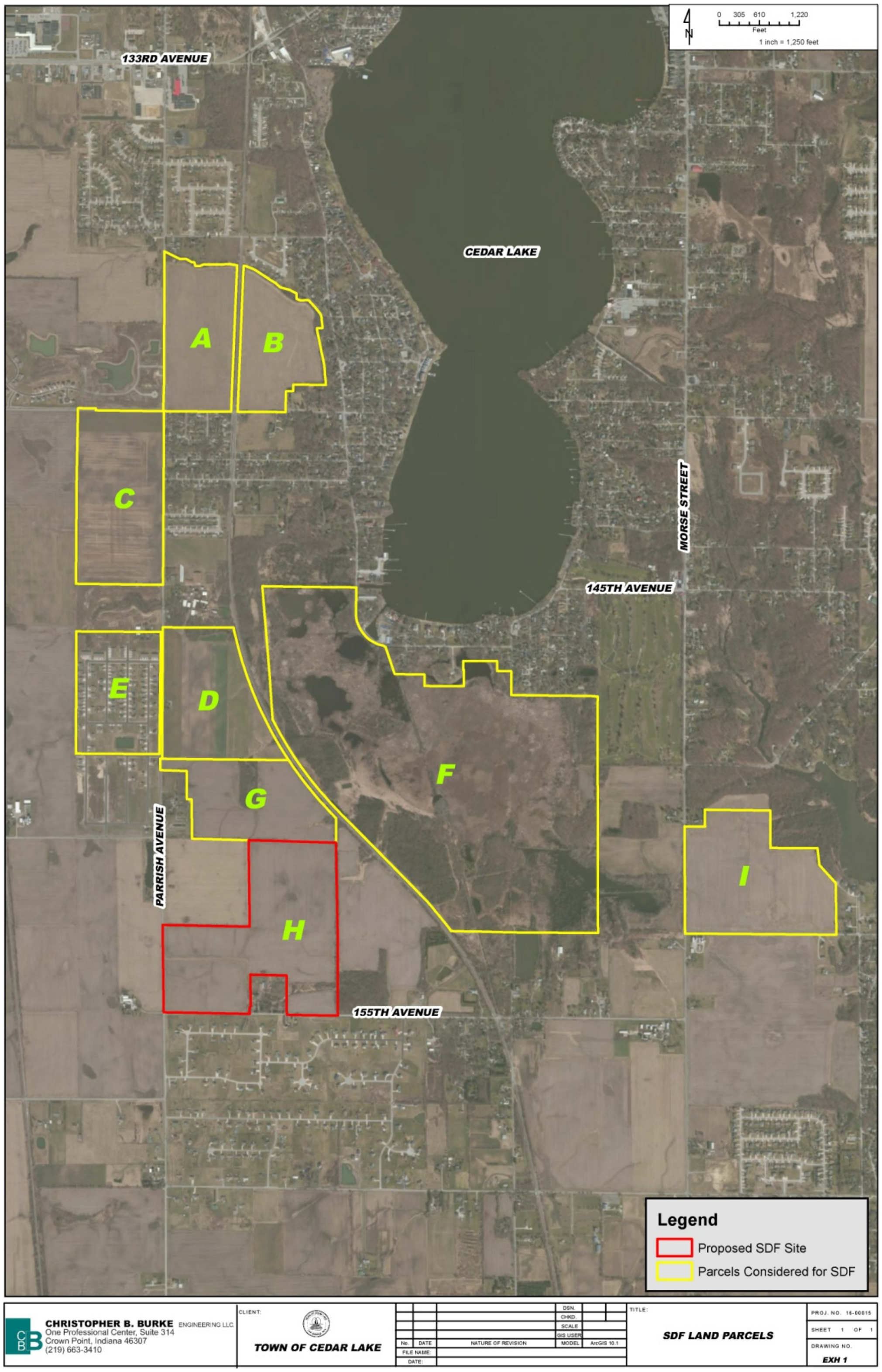

Figure 2: Proposed SDF Sites

Table 3: Physical Substrate Restoration Measures.

ID	Area (ac)	Depth (ft)	Volume (cu-yd)	Measure Description
MEASURE **A.1**	444	1.0	717,000	Area corresponds to the entire lake which contain silts and clays to a depth of 1-foot as shown in Figure 2-36, Textural Classification of Surficial Sediments in Cedar Lake, IU-SPEA Report 1984. This measure is meant to show the effect in regards to aerial extent differences.
MEASURE **A.2**	83	5.4	717,000	Dredge only areas that contain elevated levels of phosphorus > 700 mg/kg determined from interpolating 1998 Harza Sediment Samples. The volume of dredge material was set equal to Measure A.1 in order to show the effect in regards to aerial extent differences.
MEASURE **A.3**	83	2.7	358,000	Dredge only areas that contain elevated levels of phosphorus > 700 mg/kg determined from interpolating the 1998 Harza Sediment Samples. The depth of dredging was reduced by a half in comparison of Measure A.2 in order to show the effects in regards to depth differences.
MEASURE **A.4**	224	1.0	362,000	Dredge only areas that contain elevated levels of phosphorus > 500 mg/kg determined from interpolating the 1998 Harza Sediment Samples to a depth of 1-foot. The volume of dredge material is roughly equal in scale to Measure A.3 to show the effect of aerial extent and depth differences.
MEASURE **A.5**	61	2.7	265,000	Dredge only areas in the northern basin that contain elevated levels of phosphorus > 500 mg/kg determined from interpolating the 1998 Harza Sediment Samples to a depth equal to Measure A.3. This measure is meant to show the effect of concentrating dredging efforts on the northern portion where preliminary modeling suggested elevated levels of turbidity.
MEASURE **A.6**	444	Avg. ~ 11.5	8,240,000	Dredge entire lake down to glacial till. Estimated volume of 8,240,000 cy. Based on sediment depth survey performed by Indiana University in 1979 as shown in IU-SPEA Report 1984. This measure is meant to show the effect of removing all sediments that have accumulated in the lake and provides a baseline for eliminating internal nutrient recycling.
MEASURE **A.7**	163	1.0	263,000	Dredge portions of the central and southern basins that contain elevated available sediment phosphorus (ASP) concentrations > 100 mg/kg determined from interpolating 2008 ENSR Sediment Samples. This measure is meant to show the effect of concentrating dredging efforts on the central and southern portions where elevated levels of phosphorus were measured.
MEASURE **A.8**	87	1.0	140,000	Dredge portions of the southern basins that contain elevated available sediment phosphorus (ASP) concentrations > 100 mg/kg determined from interpolating 2008 ENSR Sediment Samples. This measure is meant to show the effect of concentrating dredging efforts solely on the southern portion where levels of phosphorus were measured to be greatest.

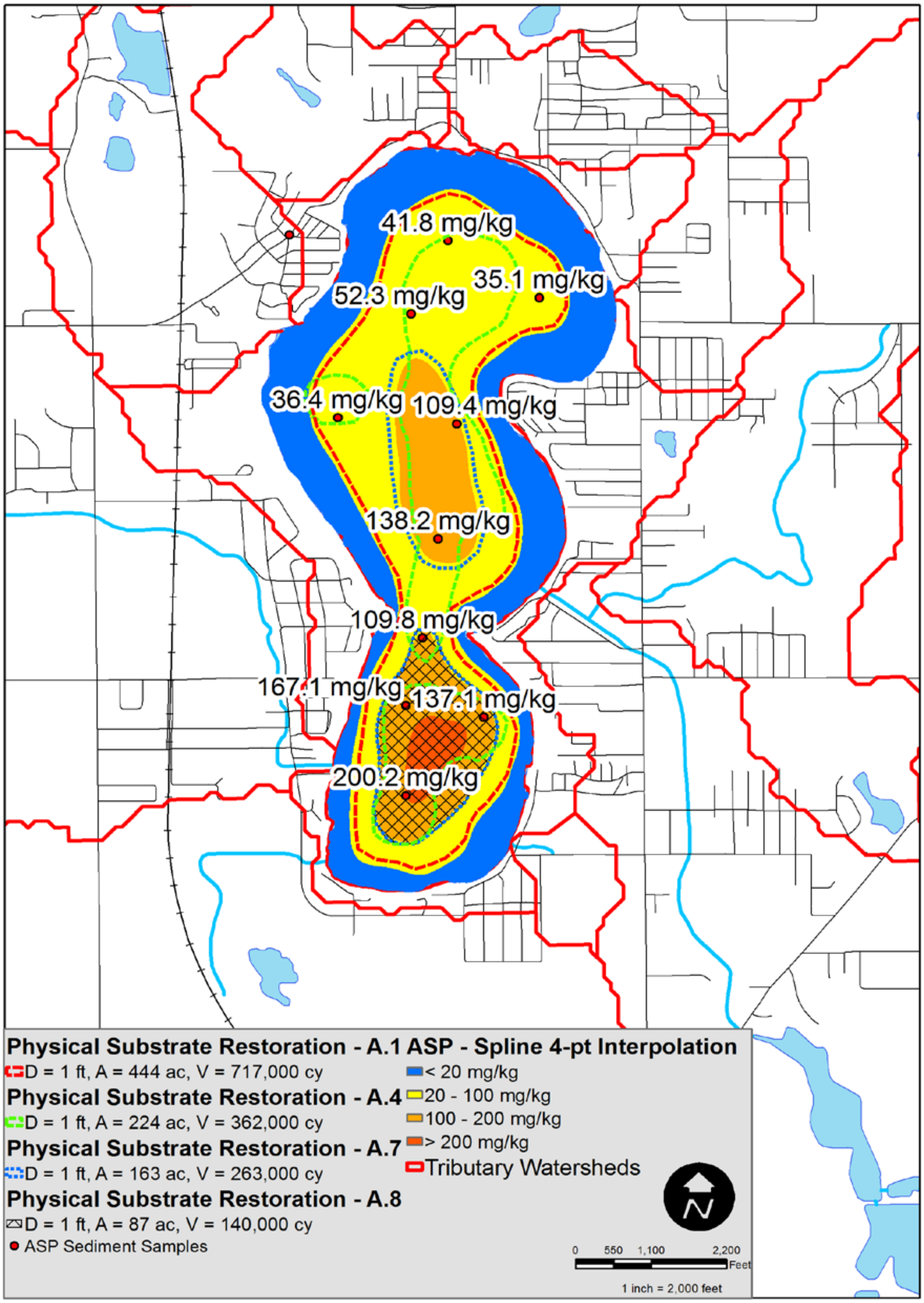

Figure 3: Physical Substrate Restoration Measures A.1, A.4, A.7 and A.8 Map.

3.2 Chemical Substrate Restoration

Sediments within Cedar Lake are not only physically unsuitable to this type of glacial lake, but contain high levels of nutrients that create conditions in the lake (i.e., turbidity) that preclude sunlight penetration which is needed by aquatic macrophytes for photosynthesis. Addressing the physical attributes of the sediments within the lake would allow aquatic macrophytes to become established, which are important for stabilizing sediments (e.g., roots) and providing cover for macroinvertebrates and juvenile fish species.

Measures under this category involve using Aluminum Sulfate (Alum) to reduce the internal nutrient loading caused by the interaction between fine-grained nutrient rich sediments and the water column. The release of phosphorus from bottom sediments to the water column has been shown to be the major contributor to water quality degradation in Cedar Lake. Studies have shown that lakes that experience high levels of phosphorus loadings from internal sediments can benefit from phosphorus inactivation. Iron, calcium, and aluminum have salts that can combine and sorb with inorganic phosphorus from the water column as part of a floc. In addition, these salts can solidify the top inch or two of the existing unsuitable sediments, which would provide a matrix for native plant roots and would reduce the release of fine-grained nutrient rich sediments into the water column. The introduction of alum to water forms an Aluminum hydroxide salt (the principle ingredient in common antacids such as Maalox), which binds with phosphorus to form an aluminum phosphate compound. All flocculation agents lose their effectiveness over time; therefore the long term effectiveness for an alum treatment in Cedar Lake was assessed as detailed in *Appendix H - Alum Treatment Analysis*.

As laid out in *Appendix H – Alum Treatment Analysis*, additional sediment sampling was performed across the lake to determine the magnitude and spatial distribution of available sediment phosphorus (ASP), which is the fraction of total phosphorus available to the water column and main contributor to lake eutrophication. A treatment analysis was performed based on the field measurement. Two different scales of chemical substrate restoration were formulated based on the alum dosage needed to stabilize up to a certain depth of sediment and the estimated long-term effectiveness of each treatment. Both scales assumed treatment of 400 acres, but with differing effective depths of stabilization and inert lake bottom based on the dosage. These depths are projected at either 10 cm or 20 cm with a residual level of available sediment phosphorus of less than 20 mg/kg. It has been shown through testing that alum can reduce internal loadings in the range of 80 to 100% when applied appropriately. Studies have shown that alum treatments are not harmful to macroinvertebrates and in some cases have actually increased their numbers. For modeling purposes, it was assumed that alum reduced the phosphorus release from bottom sediments by 80%.

Two alum dosage measures were formulated based on depth of sediment to be treated. ***Table 4*** below contains descriptions of the measures and the extent of treatment. ***Figure 4*** shows a layout map of the chemical substrate restoration measures.

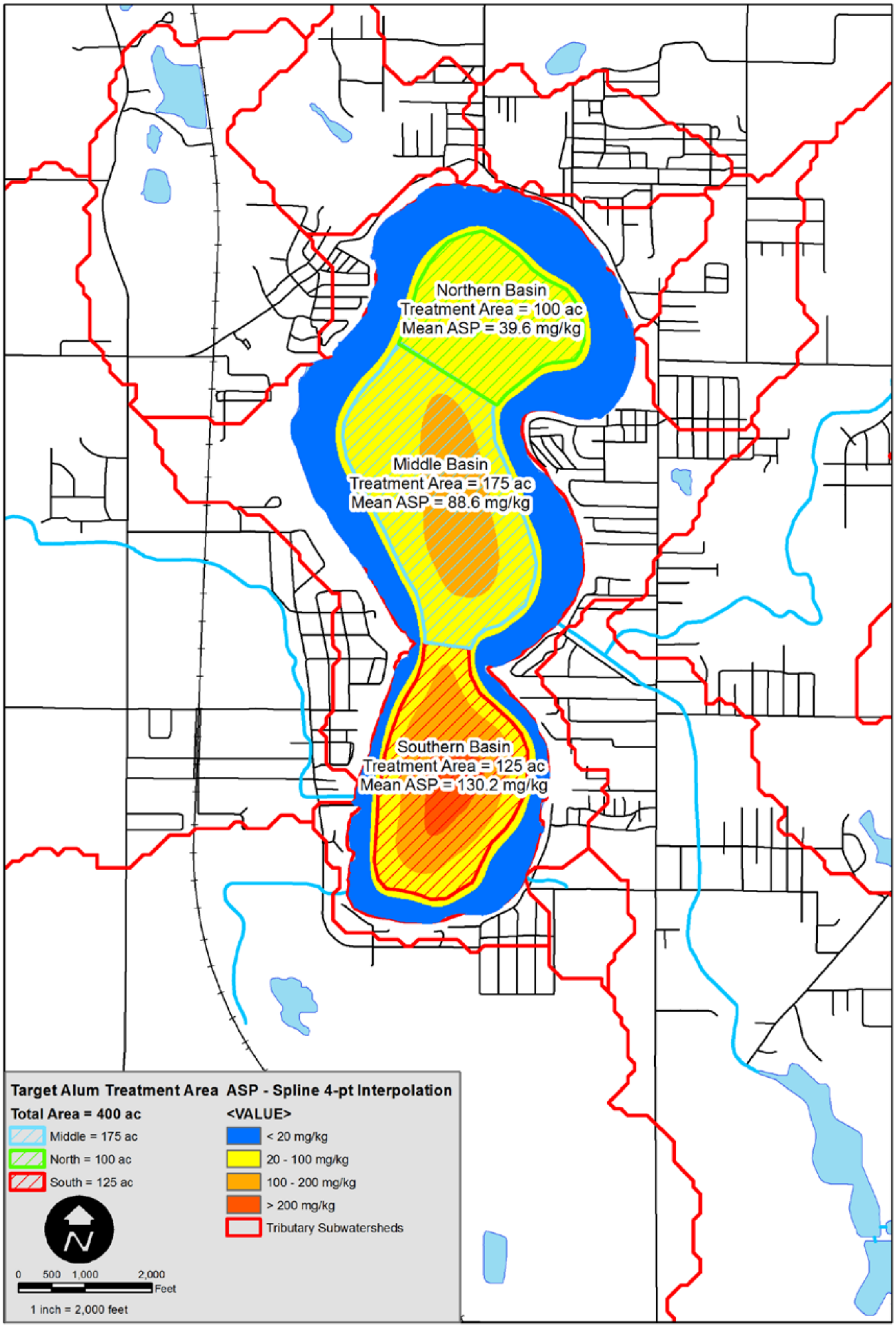

Figure 4: Chemical Substrate Restoration Measures B.1 and B.2 Map.

Table 4: Chemical Substrate Restoration Measures

ID	Area (acres)	Measure Description
MEASURE B.1	400	Apply alum treatment to areas that contain elevated levels of available sediment phosphorus (ASP) > 20 mg/kg determined from interpolating 2008 ENSR Sediment Samples. Alum dosage concentrations correspond to a treatment depth of 10 cm across entire lake.
MEASURE B.2	400	Apply alum treatment to areas that contain elevated levels of available sediment phosphorus (ASP) > 20 mg/kg determined from interpolating 2008 ENSR Sediment Samples. Alum dosage concentrations correspond to a treatment depth of 20 cm across entire lake.

3.3 Tributary Restoration

Cedar Lake has a small watershed size and thus the amount of surface runoff that drains into the lake is limited by drainage area. During the majority of the year, the lake acts as a source to the underlying aquifer. Due to the small drainage basin size and the loss of water to groundwater, the residence time for Cedar Lake is extremely long in the range of 1.5 to 2 years based on a water budget analysis. Any increased inflow to the lake could potentially reduce nutrient concentrations within the lake through dilution or by physically flushing fine-grained nutrient rich sediments out of the system. Only one stream was identified that could be rerouted to its historic channel which would flow into Cedar Lake, and that was Founders Creek.

Founders Creek historically drained a northeast area directly into Cedar Lake. In the late 1800s this tributary was rerouted to bypass the lake and enter Cedar Creek yards downstream of the outlet weir from Cedar Lake. This measure would involve rerouting Founders Creek back to its historic location where runoff and baseflow would once again drain directly back into the lake. The potential for reduced effectiveness due to the proximity of Founders Creek inlet to the Cedar Lake outlet was evaluated using the EFDC model. Since lake levels are typically below the elevation of the outlet weir, short-circuiting effects are not a concern and are only present when the lake overflows typically in the spring and late fall. ***Table 5*** below contains a description of the measure.

Table 5: Tributary Restoration Measure

ID	Measure Description
MEASURE C.1	Reroute Founders Creek back into Cedar Lake. Use the tributary loadings that were calculated using L-Thia for Founders Creek and route them into Cedar Lake just north of the Cedar Lake outlet.

3.4 Creation of Habitat Islands

Due to sedimentation within the lake, non-native and invasive fish species, and anthropogenic activities, physical habitat within Cedar Lake is nearly absent. The creation of habitat islands would provide habitat for fish, macroinvertebrates, waterfowl, shore birds, and migratory bird species.

Four scales of habitat islands were formulated and evaluated. Cedar Lake has a relatively long fetch length in the north-south direction due to its shape. Coupled with the fact that the primary wind direction is nearly along this same axis, wind induced forces play a dominant role in the hydrodynamic circulation and sediment resuspension in the lake. Creating habitat islands within the lake that effectively reduce fetch length may substantially reduce wind induced wave forces that cause resuspension of lake bottom sediments. Development of the type, size, and locations of habitat islands must take into consideration limits associated with the recreational use of the lake. Four habitat island scenarios were analyzed. ***Table 6*** contains a description of each of the habitat island measures and pertinent information. ***Figure 5*** shows a layout map of the habitat island measures.

Each of the measures were evaluated using the EFDC model. Results showed that habitat islands were not an effective way of lowering phosphorous concentrations in the water column. The habitat islands do not reduce the fetch length enough to eliminate sediment resuspension. Additionally it was determined that diffusion of phosphorus from bottom sediments to the water column is the main mechanism in transferring phosphorus to the water column, thus making these measures ineffective in reducing diffusion in Cedar Lake. Therefore, these measures were removed from further analysis.

Table 6: Creation of Habitat Islands Measures.

ID	Area (ac)	Elevation (ft above water)	Volume (cu-yd)	Measure Description
MEASURE D.1	1.7	1.0	34,000	Create two hard habitat islands across the narrow part of the lake between the central and south lobes allowing 200-ft separation for boat passage. Goal for habitat islands is to cut north-south traveling waves.
MEASURE D.2	1.7	1.0	N/A	Create two floating habitat islands in the same configuration as measure D.1. They would consist of wood or plastic structures filled with emergent vegetation anchored across the narrow part of the lake between the central and south lobes allowing 200-ft separation for boat passage. The wave break would not completely stop wind-induced waves, but rather dampen effects.
MEASURE D.3	31.7	Varies between 3.0 and 4.0	362,000	Dispose of dredged material in four in-lake disposal sites (i.e., habitat islands) located along the shoreline of Cedar Lake in areas currently undeveloped by residential housing. Habitat islands would be built above the water level, except for the wetland swale on the southern end of the lake where the Golf Course tributary drains.
MEASURE D.4	12.4	1.0	155,000	Create two habitat islands located near the narrow part of the lake between the central and south lobes. Additional dredged material would be disposed of outside the lake. Habitat islands would be built above the water level. Similar to the other habitat islands, the goal of creating strategically placed habitat islands made of dredged material is to reduce the wind induced wave forces within some parts of the lake.

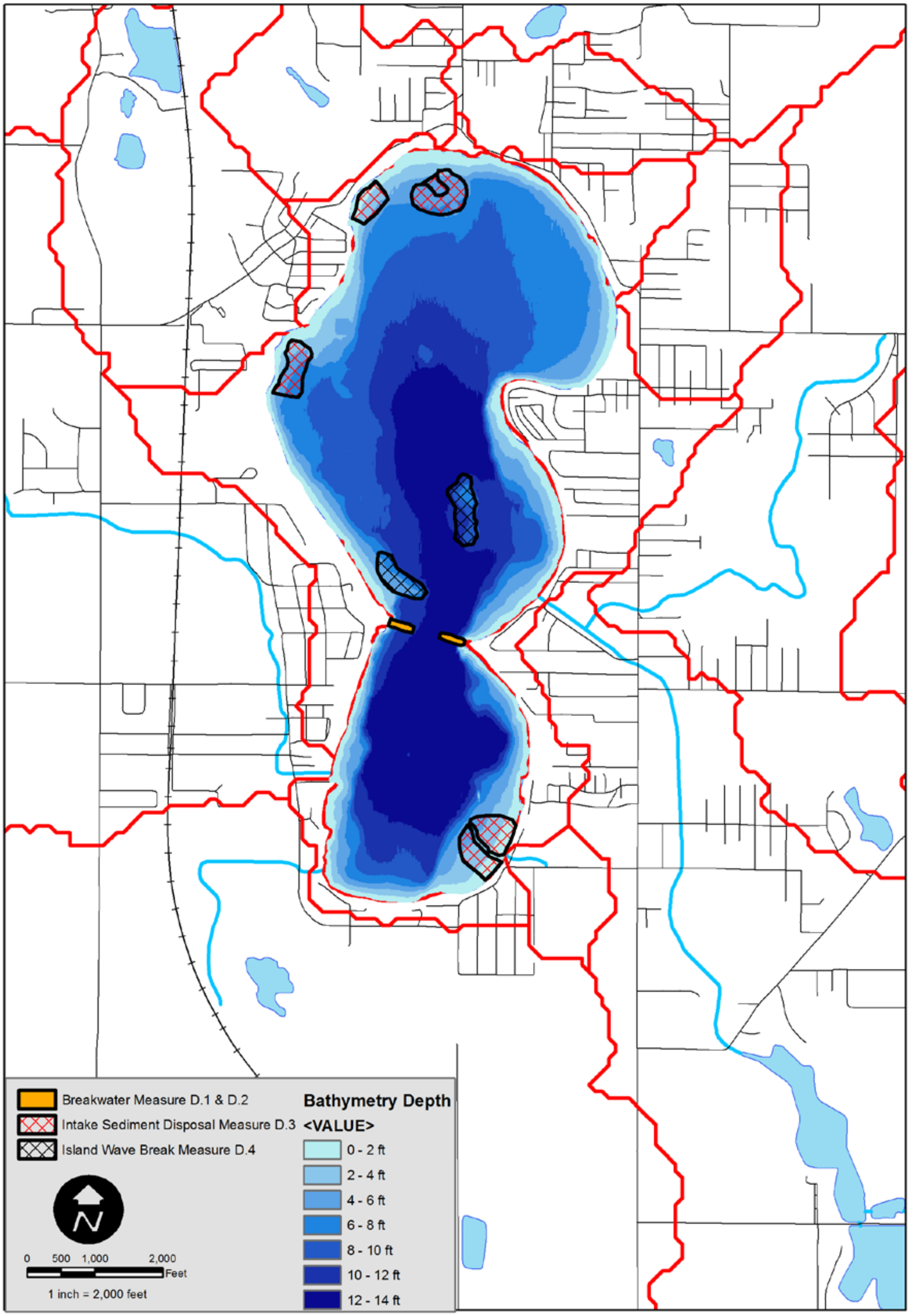

Figure 5: Creation of Habitat Islands Measures D.1 through D.4 Map.

3.5 Littoral Macrophyte Restoration

Currently Cedar Lake is absent of any appreciable aquatic vegetation (i.e., aquatic macrophytes). Causes for the lack of aquatic macrophytes are due to many factors including turbidity, high nutrients, wave action, and removal by humans. There are major ecosystem benefits in the establishment of emergent and submergent macrophytes that include: structural habitat for aquatic species, food sources, dissolved oxygen production, shoreline stabilization, and nutrient absorption.

Two types of aquatic macrophyte beds are possible depending on water depth. Emergent vegetation can be established in depths of water up to 1 foot while submergent vegetation can grow in deeper depths depending on water clarity. It was assumed that submergent vegetation could be established in areas up to 4 feet in depth. These depths were used in laying out areas for littoral macrophyte restoration.

Restoration of submergent and emergent vegetation to the littoral zone of Cedar Lake would provide spawning habitat for fishes such as Bowfin (*Amia calva*), Northern Pike (*Esox lucius*), and Yellow Perch (*Perca flavescens*) which either build nests or lay their eggs on or among submerged vegetation in shallow water. Later, the restored aquatic macrophytes would provide foraging habitat for juveniles of these species. Additionally, littoral zone vegetation provides habitat structure for aquatic macroinvertebrates such as Odonates (i.e. damselflies and dragonflies) to lay their eggs upon, support their emerging larvae, and provide perches for foraging adults. In addition, studies have shown that aquatic vegetation can uptake significant amounts of nutrients including nitrogen and phosphorus from the water column during the growing season. Based on research done by C.E. Boyd and others in the 1970s, the uptake of nitrogen and phosphorus for several species of emergent vegetation was determined (Dhote 2008). The emergent vegetation species recommended for Cedar Lake are thought to behave similar to common cattail, *Typha latifolia*, which was found to remove 1,000 kg/ac/yr of nitrogen and 160 kg/ac/yr of phosphorus. Since submergent vegetation is characteristically less dense than emergent vegetation, it is assumed that their nutrient removal rates are half as much or 500 kg/ac/yr of nitrogen and 80 kg/ac/yr of phosphorus. ***Table 7*** is a recommended plant list of emergent and submergent vegetation for establishment in Cedar Lake.

Based on bathymetry surveyed by the Chicago District in May 2005, areas of 0 to 1 foot and 1 to 4 feet of depth were established around the entire perimeter of the lake. Since aquatic vegetation is critical for aquatic habitat restoration throughout the lake, a large footprint area was established for establishment of aquatic vegetation. Native plant species selected for establishment can survive motorboats under slow idling speeds. No Wake Zones are necessary for establishment and survival of aquatic vegetation. ***Table 8*** contains a description of the littoral macrophyte restoration measure and pertinent information. ***Figure 6*** shows a layout map of the littoral macrophyte restoration measure.

Table 7: Recommended Emergent and Submergent Plant List.

Emergent Zone		Submergent Zone	
Species	**Common name**	**Species**	**Common name**
Acorus calamus	sweet flag	*Ceratophyllum demersum*	coontail
Alisma sp.	water plaintain	*Elodea canadensis*	common waterweed
Carex comosa	bristly sedge	*Potamogeton amplifolius*	large-leaved pondweed
Carex lacustris	lake sedge	*Potamogeton natans*	common pondweed
Carex lurida	bottlebrush sedge	*Potamogeton pectinatus*	sago pondweed
Eleocharis obtusa	spike rush	*Vallisneria americana*	eel grass
Iris virginica	blue flag iris	*Numphar advena*	yellow pond lily
Juncus effusus	common rush	*Nelumbo lutea*	lotus
Leersia orzyoides	rice cut grass		
Pontederia cordata	pickerel weed		
Sagittaria latifolia	common arrowhead		
Scirpus acutus	hard-stemmed bulrush		
Scirpus pungens	chairmaker's rush		
Scirpus validus	great bulrush		
Sparangium eurycarpum	bur reed		
Verbena hasta	blue vervain		
Zizania aquatica	wild rice		

Table 8: Restoration of Littoral Macrophytes Measure.

ID	Area (ac)	Measure Description
MEASURE **E.1**	Emergent = 35 ac Submergent = 95 ac	Establish aquatic emergent and submergent vegetation along the entire shoreline of Cedar Lake. In areas that are 1 ft of depth or less, emergent vegetation would be established with a phosphorus removal rate of 160 kg/ac/yr. In areas that are between 1 and 4 ft of depth, submergent vegetation would be established with a phosphorus removal rate of 80 kg/ac/yr.

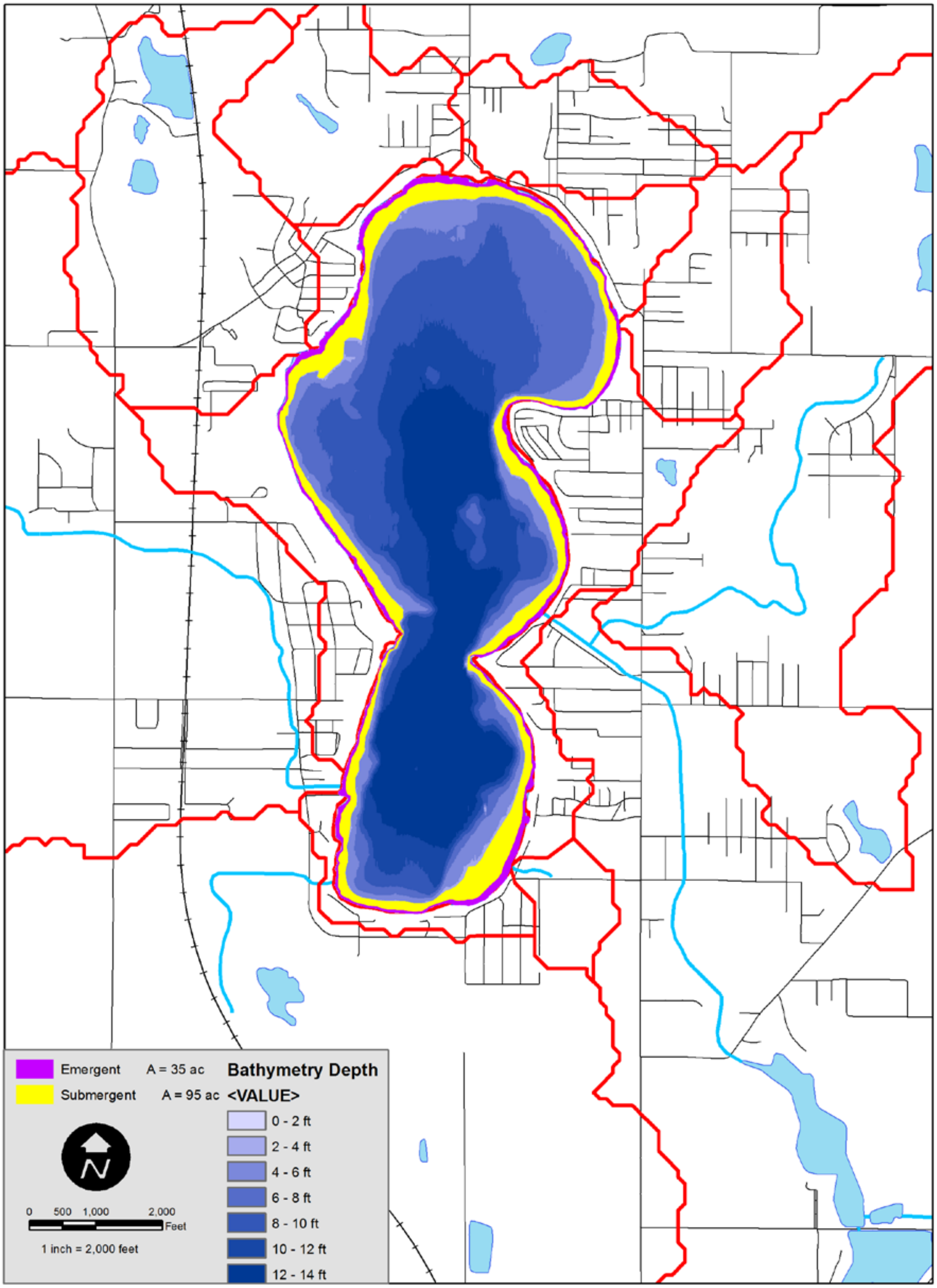

Figure 6: Littoral Macrophyte Restoration Measure E.1 Map.

3.6 Institutional Controls

Cedar Lake is a significant recreational lake that is used for passive and active uses. Many residents in the Town of Cedar Lake own and operate small recreational and fishing boats on Cedar Lake. As a result, waves induced by recreational boat propellers can force detachment of aquatic macroinvertebrates from lake bed substrates in turn impacting the aquatic macroinvertebrates colonizing the littoral zone. Recreational boat propellers can also pose a risk to aquatic plants. Reducing the effects of boat induced waves on aquatic macroinvertebrates and plants would benefit not only aquatic macroinvertebrates and aquatic vegetation, but also fish, waterfowl, and shorebirds. The levels at which restrictions to recreational boating are considered must take into account public support and the willingness for those to adhere to the restrictions. Two measures to reduce the effects of boat-induced waves on sediment resuspension, shoreline erosion and aquatic vegetation destruction were considered.

Cedar Lake currently utilizes an approximate constant 200 ft No Wake Zone around the entire perimeter of the lake. The marker buoys are set and maintained by the Cedar Lake Enhancement Association. Even though the current No Wake Zones provide some reduction in boat induced waves, additional No Wake Zones throughout the lake would further reduce resuspension of bottom sediments. Doubling the No Wake Zone to 400 ft would encompass all areas less than 4 ft of depth and the entire littoral zone restoration area.

Two scales of institutional controls were formulated and evaluated. Cedar Lake currently utilizes an approximate constant 200 ft No Wake Zone around the entire perimeter of the lake. Even though the current No Wake Zone provides some reduction in boat induced waves, additional No Wake Zones throughout the lake would further reduce resuspension of bottom sediment. Doubling the No Wake Zone to 400 ft would encompass all areas less than 4 ft of depth and the entire littoral zone restoration area.

Currently Cedar Lake does not have boat restrictions. Many lakes throughout the region have instituted length and horsepower restrictions. Boat induced wave forces are directly proportional to the size and horsepower of the craft. Limitations would further reduce resuspension of bottom sediments. Limiting all motor boat engines to less than 10 horsepower will substantially reduce the size of waves generated by boats. This option was modeled and only provided a small benefit over the 400 ft No Wake Zone.

Table 9 contains a description of each of the institutional control measures and pertinent information. *Figure 7* shows a layout map of the extended No Wake Zone.

Table 9: Institutional Control Measures.

ID	Area (ac)	Measure Description
MEASURE **F.1**	276 ac (35% of Cedar Lake)	Increase the No Wake Zone to 400 ft from the shoreline, thus doubling the current No Wake Zone on Cedar Lake. This increase will encompass all areas with depth less than 4 ft and areas were aquatic vegetation could be established.
MEASURE **F.2**	783 ac (100% of Cedar Lake)	Restrict motorboats to engines having less than 10 horsepower. Boat induced waves would be substantially reduced by the limitations across the lake.

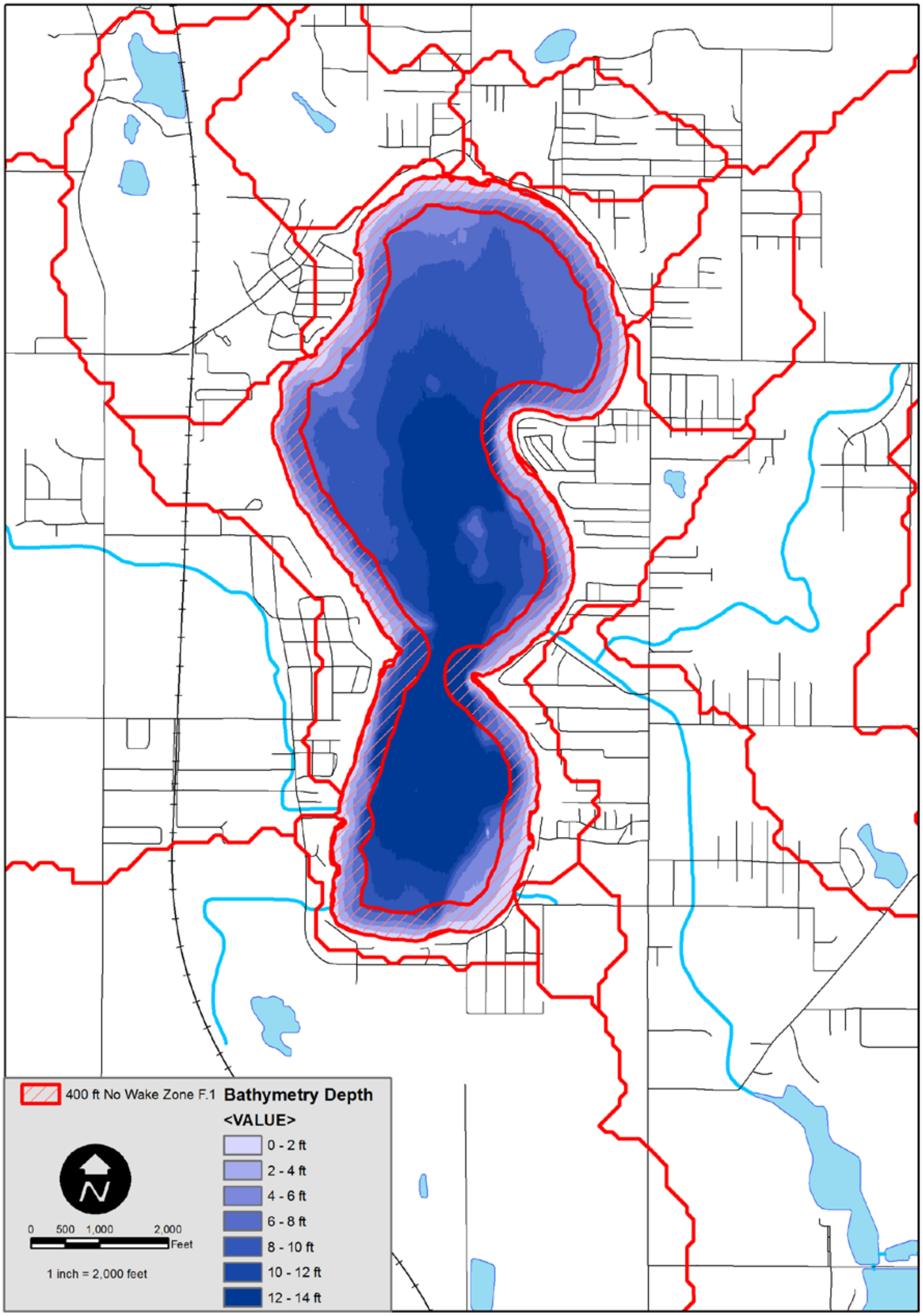

Figure 7: Institutional Control Measure F.1 Map.

3.7 Fish Community Management

The fish community of Cedar Lake was first sampled in 1964 and was found to be undesirable in terms of providing a sport fishery. In 1966, Rotenone was applied to the lake to eradicate all resident fish species in order to reestablish a desirable fishery. By 1974, undesirable species [e.g., Common Carp (*Cyprinus carpio*), Gizzard Shad (*Dorosoma cepedianum*), etc.] once again dominated the catch, and native glacial lake species [e.g., minnows, Iowa Darter (*Etheostoma exile*), etc.] were no longer present within the lake. In 1987, 4,400 hybrid Striped Bass (*Morone chrysops* x *Morone saxatilis*) were stocked in an effort to improve angling opportunities within the lake. Additional stockings of hybrid Striped Bass occurred in 1989-1993, 1995, and 2001. Subsequent fish surveys of Cedar Lake found that the survival of the stocked fish was good; however, a 2001 fish survey found only seven hybrid Striped Bass and over 5,000 non-native White Perch (*Morone americana)*. The stomach contents consisted of zooplankton alone, which also contributes to increases in algae, since zooplankton, which feed on phytoplankton, are heavily reduced by non-native White Perch.

Common Carp have been implicated in eutrophication of water bodies. The impact of Common Carp and White Perch is largely attributed to their benthic feeding activities (Welcomme 1984). These species increase phosphorus concentration (Breukelaar et al. 1994, Havens 1991, Brabrand et al. 1990, Lamarra 1975, Vanni and Findlay 1990), increase phytoplankton biomass, increase turbidity (Scheffer 1998) and reduce the abundance of submerged macrophytes (Crivelli 1983, Skubinna et al. 1995).

One important technique used to restore water quality in freshwater systems is fish community management. Fish community management can be aimed at increasing water clarity by manipulating the biomass (Perrow 1997) and structure of the fish community. This process has been conducted throughout Europe and North America during the past fifty years, many of which have been successful in improving water clarity and/or lowering algal biomass (Drenner and Hambright 1999).

Common Carp and young White Perch feed by sucking in sediment and straining the invertebrates in their gill rakers, thus resuspending sediments expunged from their gills. Experimental ponds stocked with Common Carp showed a positive relationship between fish biomass and suspended solids (Breukelaar et al. 1994, Lougheed et al. 1998). Meijer et al. (1990) found that a benthic fish density of 600 kg/ha in a shallow lake may reduce Secchi disk transparency to 0.4 m solely due to sediment resuspension. Also, Shapiro et al. (1975) present data which show that Common Carp release significant levels of phosphorus through excretion, where release rates are inversely proportional to fish size. Based on these experimental studies, it is assumed that non-native benthic fish removal would increase water clarity through both reductions in total suspended solids and reductions in algal density due to a decrease in water column phosphorus levels.

The expansion of macrophyte beds has also been observed following fish community management (Meijer et al. 1990, Ozimek et al. 1990, Hanson and Butler 1994, Meijer and Hosper 1997). This can be attributed to higher water clarity (Skubinna et al. 1995) and cessation of vegetation uprooting by foraging benthic fishes (Crivelli 1983). Reestablished macrophyte growth aids in stabilizing clear water conditions through competing with algae for nutrients and light (Perrow et al. 1997, Van Donk et al. 1993), providing refugia for zooplankton (Timms and

Moss 1984, Schriver et al. 1995), increasing sedimentation of suspended particles (James and Barko 1990), and suppressing algal growth by allelopathy (Wium-Anderson et al. 1982).

Although it was determined by the PDT that fish community management is crucial for the sustainable establishment of aquatic macrophytes and reduction of turbidity within Cedar Lake, it has been determined that the reduction of non-native fish species through the one-time application of Rotenone (i.e., piscicide) should be excluded from the NER Plan. Therefore, this measure, will not be implemented by the USACE, but by the non-Federal sponsor and the IDNR, as a pre-existing condition.

Fish community management involves a three step process involving target species reduction, predatory fish introduction, and community stabilization as laid out below:

a. Common Carp / White Perch reduction.

To estimate phosphorus release from these non-native, benthic fishes, Lamarra (1975) recommends between 0.4 and 0.8 $g/m^2/yr$ at 22 ºC based on his studies at Union Lake and Kuska Pond in Minnesota. The Cedar Lake water quality model should assume phosphorus release is at 0.6 $g/m^2/yr$ with the current Common Carp / White Perch population at 100%. This measure will seek to reduce these species populations by 75%; therefore, a corresponding 75% reduction (.45 $g/m^2/yr$) in phosphorus release could be assumed.

Abundance would be reduced through:

- annual physical harvest
- piscicide application
- preventing access to spawning grounds

b. Predatory fish introduction

Predatory fish would be introduced into Cedar Lake that could check the abundance of Common Carp and White Perch. These fish would need to the meet the following criteria: 1) native to Cedar Lake, 2) tolerant to poor water and habitat quality, 3) effective feeders. The following species meet these criteria:

- *Amia calva* (Bowfin)
- *Lepisosteus osseus* (Longnose Gar)
- *Pylodictis olivaris* (Flathead Catfish)
- *Micropterus salmoides* (Largemouth Bass)

c. Fish community stabilization

Once abundance reduction and balance of the Common Carp and White Perch populations have been achieved (3–5 years) and habitat and water quality improved, a native lake fish community may be reestablished. This would ensure food web and predatory / prey interactions would be stable. Historic collections preserved at the Field Museum of Natural History and the University of Michigan were queried for glacial lakes within the same geographic area of Cedar Lake. Based on these collections, the historic fish community most likely resembled the species listed in ***Table***

10. To achieve a certain percentage of the historic fish community structure, a reintroduction program would have to be implemented since a weir fragments the primary source of recolonization. *Table 11* is a list of species that could be procured from nearby glacial lakes such as Bass Lake, Lost Lake, Landenbaum Lake, Hartz Lake and Lake Maxinkuckee and introduced to Cedar Lake.

Table 12 contains a description of the fish community management measure and pertinent information used in evaluating the measure.

Table 10: Reconstructed fish community for Cedar Lake based on historic records

Scientific Name	Common Name	Scientific Name	Common Name
Amia calva	Bowfin	*Nocomis biuttatus*	Hornyhead Chub
Lepisosteus osseus	Longnose Gar	*Labidesthes sicculus*	Brook Silverside
Dorosoma cepedianum	Gizzard Shad	*Fundulus diaphanus*	Banded Killifish
Notemigonus crysoleucas	Golden Shiner	*Fundulus dispar*	Northern Starhead Topminnow
Pimephales notatus	Bluntnose Minnow	*Ambloplites rupestris*	Rockbass
Notropis volucellus	Mimic Shiner	*Pomoxis annularis*	White Crappie
Notropis heterodon	Blackchin Shiner	*Pomoxis nigromaculatus*	Black Crappie
Notropis heterolepis	Blacknose Shiner	*Lepomis gulosus*	Warmouth
Catostomus commersonii	White Sucker	*Lepomis gibbosus*	Pumpkinseed
Erimyzon sucetta	Lake Chubsucker	*Micropterus dolomieu*	Smallmouth Bass
Ameiurus nebulosus	Brown Bullhead	*Micropterus salmoides*	Largemouth Bass
Ameiurus natalis	Yellow Bullhead	*Sander vitreus*	Walleye
Noturus gyrinus	Tadpole Madtom	*Perca flavescens*	Yellow Perch
Pylodictis olivaris	Flathead Catfish	*Percina caprodes*	Logperch
Esox americanus	Grass Pickerel	*Etheostoma exile*	Iowa Darter
Esox lucius	Northern Pike	*Etheostoma microperca*	Least Darter
Umbra limi	Central Mudminnow	*Etheostoma nigrum*	Johnny Darter
Semotilus atromaculatus	Creek Chub		

Table 11: Recommended Native Glacial Lake Fish Species.

Species	Common name	Species	Common name
Amia calva	Bowfin	*Labidesthes sicculus*	Brook Silverside
Lepisosteus oculatus	Spotted Gar	*Fundulus diaphanus*	Banded Killifish
Lepisosteus osseus	Longnose Gar	*Fundulus dispar*	Northern Starhead Topminnow
Dorosoma cepedianum	Gizzard Shad	*Ambloplites rupestris*	Rockbass
Notemigonus crysoleucas	Golden Shiner	*Pomoxis annularis*	White Crappie
Pimephales notatus	Bluntnose Minnow	*Pomoxis nigromaculatus*	Black Crappie
Notropis volucellus	Mimic Shiner	*Lepomis gulosus*	Warmouth
Notropis heterodon	Blackchin Shiner	*Lepomis gibbosus*	Pumpkinseed
Notropis heterolepis	Blacknose Shiner	*Micropterus dolomieu*	Smallmouth Bass
Catostomus commersonii	White Sucker	*Micropterus salmoides*	Largemouth Bass
Erimyzon sucetta	Lake Chubsucker	*Sander vitreus*	Walleye
Ameiurus nebulosus	Brown Bullhead	*Perca flavescens*	Yellow Perch
Noturus gyrinus	Tadpole Madtom	*Percina caprodes*	Logperch
Pylodictis olivaris	Flathead Catfish	*Etheostoma exile*	Iowa Darter
Esox americanus	Grass Pickerel	*Etheostoma microperca*	Least Darter
Esox lucius	Northern Pike	*Etheostoma nigrum*	Johnny Darter
Umbra limi	Central Mudminnow		

Table 12: Fish Community Management Measure.

ID	Area (ac)	Measure Description
MEASURE **G.1**	167	Fish community management involves a three step process involving target species reduction, predatory fish introduction, and community stabilization. Common Carp and White Perch are the target species which are assumed to currently release 3.2 kg/ac/yr of phosphorus in the littoral zone encompassing 167 acres. The target eradication is 75% resulting in a final phosphorus loading of 0.8 kg/ac/yr. (Completed by the non-Federal sponsor)

4.0 Evaluation of Restoration Measures

An analysis of the costs and outputs of various restoration measures and combinations of restoration measures, known as alternatives, was performed for the Cedar Lake Aquatic Ecosystem Restoration Study. The overarching goals of this study are to improve, restore, and enhance the natural aquatic ecosystem of Cedar Lake. The justification for Federal investment in ecosystem restoration projects is based upon non-monetary units. Since ecosystem outputs are not assigned a monetary unit, multiple plans can be developed for recommendation and are identified through cost effectiveness and incremental cost analyses (CE/ICA). A cost effectiveness analysis identifies cost effective plans as those that no other plan achieves the same or more output for less cost. An incremental cost analysis takes the cost effective plans and identifies the increment of additional cost required for an additional output. Incremental cost effectiveness analysis aids decision makers in determining what levels of investment are required for various environmental outputs and their relative increments to help answer the question: Is it worth it? The results of CE/ICA analyses help decision makers with selection of an ecosystem restoration recommended plan.

Through CE/ICA analyses, the National Ecosystem Restoration (NER) Plan is determined. For ecosystem restoration projects, a plan that reasonably maximizes ecosystem restoration benefits compared to costs, consistent with the Federal objective is selected. The selected plan must be shown to be cost effective and justified to achieve the desired level of output. This plan shall be identified as the National Ecosystem Restoration (NER) Plan.

Several restoration measures were formulated to address the ecosystem degradation of Cedar Lake. A hydrodynamic, sediment transport, and water quality model was developed for Cedar Lake and used to assess each of the restoration measures and the benefits to the overall health of the lake (James 2007). The results of that analysis are detailed in *Appendix A - Hydrology and Hydraulics*. Restoration measures were formulated to address both internal and external (tributary) nutrient loadings, which have been determined to be the major cause of ecosystem degradation in Cedar Lake. Years of high nutrient loadings from agricultural and urban sources have caused the lake to become highly eutrophic. Elevated concentrations of phosphorus bound to bottom sediments and introduced by tributary loadings are the main cause of lake eutrophication, which cause the following ecosystem impairments: increased nuisance algae blooms, reduced water clarity, reduced native aquatic vegetation, oversaturation of dissolved oxygen, increased instances of fish kills, loss of desirable fish species, decreased social value, and decreased aesthetic value. A summarized list of restoration measures formulated to address eutrophication caused by both internal phosphorus recycling and tributary inputs are shown in ***Table 13***.

Table 13: Summary of Restoration Measures Evaluated

Measure /Scale	Type	Description
Baseline	No Action	No Action Plan as required
A.1	Physical Substrate Restoration	Physical removal of 717,000 cy of unsuitable sediments through dredging (i.e., dredge 444 ac across lake to depth of 1.0 ft)
A.2	Physical Substrate Restoration	Physical removal of 717,000 cy of unsuitable sediments through dredging (i.e., dredge 83 ac in deep areas to depth of 5.4 ft)
A.3	Physical Substrate Restoration	Physical removal of 358,000 cy of unsuitable sediments through dredging (i.e., dredge 83 ac in deep areas to depth of 2.7 ft)
A.4	Physical Substrate Restoration	Physical removal of 362,000 cy of unsuitable sediments through dredging (i.e., dredge 224 ac across lake to depth of 1.0 ft)
A.5	Physical Substrate Restoration	Physical removal of 265,000 cy of unsuitable sediments through dredging (i.e., dredge 61 ac in north basin to depth of 2.7 ft)
A.6	Physical Substrate Restoration	Physical removal of approximately 8,240,000 cy of unsuitable sediments through dredging (i.e., dredge 444 ac across lake down to glacial till)
A.7	Physical Substrate Restoration	Physical removal of 263,000 cy of unsuitable sediments through dredging (i.e., dredge 163 ac in central and south basins to depth of 1.0 ft)
A.8	Physical Substrate Restoration	Physical removal of 140,000 cy of unsuitable sediments through dredging (i.e., dredge 87 ac in south basin to depth of 1.0 ft)
B.1	Chemical Substrate Restoration	Stabilize 400 ac of lake bottom sediments with alum to a treatment depth of 10cm with target residual ASP levels of < 20 mg/kg across entire lake
B.2	Chemical Substrate Restoration	Stabilize 400 ac of lake bottom sediments with alum to a treatment depth of 20 cm with target residual ASP levels of < 20 mg/kg across entire lake
C.1	Tributary Restoration	Reroute Founders Creek back to Cedar Lake
/1 D.1	Habitat Islands	Insert a break water in the throat to the southern lobe
/1 D.2	Habitat Islands	Insert floating wave break in same area as D.1
/1 D.3	Habitat Islands	Create 4 islands within the lake
/1 D.4	Habitat Islands	Create 2 islands within the lake
E.1	Littoral Zone Restoration	Establish 35 ac emergent and 95 ac submergent aquatic vegetation within the littoral zone
F.1	Institutional Controls	Extend No Wake Zone from 200 to 400 ft from shoreline corresponding to approximately 35% of lake
F.2	Institutional Controls	Restrict motorboats to engines having less than 10 HP. No Wake Zone over entire lake
G.1	Fish Community Management	Eradicate 75% of target species with the lake and adjacent marsh (Completed by the non-Federal sponsor)

/1 Due to negligible habitat output in model results, all habitat island measures were removed from further analysis.

4.1 Evaluation of NED Costs

In order to compare restoration measures and alternatives, the costs and benefits of each measure are first determined. National Economic Development (NED) costs are used for the economic analysis of alternative plans and reflect the opportunity costs of direct or indirect resources consumed by project implementation. From an economic perspective, the real measure of cost is opportunity cost, i.e., the value of that which is foregone when a choice of a particular plan or measure is made. In order to capture the opportunity costs of proposed plans, NED costs include three types of costs: implementation costs, other direct costs, and associated costs. In addition to implementation costs for each restoration measure, interest foregone during construction was determined as another direct cost. It should be noted that NED costs are solely used for economic justification and differ from financial costs used in determining total project and associated cost sharing.

First NED costs include construction, lands, easements, rights-of-way, relocations and disposal areas (LERRDs), preconstruction engineering and design (PED), construction management, engineering during construction (EDC), and project management and associated contingencies. Interest during construction (IDC) is based on estimated implementation duration for each measure and compounded monthly using current discount rate. All NED costs were referenced to October 2009 price levels. Since the true economic cost of implementation can vary over time depending on restoration measure, first costs and IDC were distributed accumulated over the entire 50-year project life and discounted based on the FY2011 Federal discount rate of 4 1/8%. Costs used in the planning formulation would be discounted uniformly, and therefore would not change the outcome of the comparison to select a plan. Once all distributed costs were converted to present values, the annual equivalent cost of implementing each measure was determined. Annualized operations, maintenance, repair, replacement and rehabilitation (OMRR&R) costs were added to establish the total annual equivalent cost of each measure used in the cost effectiveness and incremental cost analyses. A summary of total NED costs for each measure is shown in ***Table 14***.

Table 14: Summary of NED Costs/1

Measure /Scale	Total First Cost /2	Annual Equivalent First Cost	IDC /3	Annualized IDC	Annual OMRR&R	Total Annualized Cost
Baseline	[redacted]	[redacted]			[redacted]	[redacted]
/4 A.1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
/5 A.2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
/6 A.3	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
/7 A.4	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
/8 A.5	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
/9 A.6	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
A.7	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
A.8	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
B.1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
B.2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
C.1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
E.1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
F.1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
/11 F.2	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
G.1	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

/1 Costs used in planning formulation would be escalated uniformly, and therefore would not change the outcome of the comparison to select a plan.
/2 Total first cost includes costs associated with implementation, contingencies, lands, easements, rights-of-way, relocations and disposal areas (LERRDs), preconstruction engineering and design (PED), construction management, engineering during construction (EDC), and project management referenced to October 2010 price level. Costs associated with project planning and feasibility study are sunk costs and are not included in total first costs.
/3 Interest During Construction (IDC) was compounded monthly using current Federal discount rate and estimated implementation duration for each measure
/4 Cost for Measure A.1 estimated by scaling A.4 based on total dredge volume.
/5 Cost for Measure A.2 estimated by scaling A.3 based on total dredge volume.
/6 Cost for Measure A.3 estimated by scaling components of A.7/A.8 based on total dredge volume.
/7 Cost for Measure A.4 estimated by scaling components of A.7/A.8 based on total dredge volume.
/8 Cost for Measure A.5 estimated by scaling A.3 based on total dredge volume.
/9 Cost for Measure A.6 estimated by scaling A.3 based on total dredge volume.
/10 OMRR&R for Measure B.1 includes cost for retreatment estimated at 25 years past first treatment.
/11 Cost for Measure F.2 estimated by scaling F.1 based on percentage of No Wake Zone area.

4.2 Evaluation of NER Output

The USACE objective in ecosystem restoration planning is to contribute to national ecosystem restoration (NER). Contributions to national ecosystem restoration (NER outputs) are increases in the net quantity and/or quality of desired ecosystem resources. Measurement of NER is based on changes in ecological resource quality as a function of improvement in habitat quality and/or quantity and expressed quantitatively in physical units or indexes. Ecosystem restoration plans shall be formulated and evaluated in terms of their net contributions to increases in ecosystem value (NER outputs), expressed in non-monetary units.

Habitat outputs for each restoration plan were estimated over the entire 50 year project life. In order to restore the aquatic ecosystem of Cedar Lake, both ecosystem function and structure must be addressed. The level of habitat suitability, which takes into account the function and structure of the ecosystem, is calculated by developing a habitat suitability index (HSI). The HSI is an algebraic function that uses various indicators of the quality of habitat function and structure. Several species-specific HSIs have been developed by the U.S. Fish and Wildlife Service. There are limitations to using a species-specific index when the goal is to restore the overall natural habitat because outputs are focused on one species and other species may be overlooked or negatively impacted. Unfortunately there is not an established HSI for lake habitats; therefore one was developed specifically for Cedar Lake. Total habitat outputs, in terms of habitat units (HUs) were calculated by multiplying the habitat suitability index by the area of habitat affected as shown in the following equation:

$$HU = Area \times HSI$$

where HU is a habitat unit of output, habitat area affected is expressed in units of acres, and HSI is the habitat suitability index encompassing habitat function and structure.

Ecosystem function describes the foundational processes of natural systems including nutrient cycles and energy fluxes. The natural ecosystem function has been severely degraded through nutrient eutrophication. To quantify the degree at which eutrophication occurs, the Carlson trophic state index (TSI) was used for Cedar Lake (Carlson 1977). The TSI quantifies the concept that changes in nutrient levels (measured by total phosphorus) causes changes in algal biomass (measured by chlorophyll a) which in turn causes changes in lake clarity (measured by Secchi disk transparency). The TSI was modeled for each restoration measure according to the following equation:

$$TSI = 14.42 \ln\left(P[\mu g / L]\right) + 4.15,$$

where P is the spatially averaged phosphorus concentration. Both average TSI and maximum TSI were used in the assessing the functional output of each measure. The average TSI score for baseline conditions and each restoration measure was computed by taking the TSI score based spatially depth-averaged phosphorus concentrations on a two hour interval over a nine-month period of record corresponding to ice-off conditions. The average TSI indicates the overall health of the lake over a season. The maximum TSI score is the maximum value computed throughout the entire season and indicates the range of functional degradation. The maximum TSI marks the level at which the habitat function is most degraded and marks the level at which many species cannot survive. The maximum TSI score can provide indication to the limits of the ecosystem function.

The theoretical scale of the Carlson TSI is from zero to infinity, but for calculating a ecosystem functional score, the range is defined to encompass the best and worst case scenarios. For Cedar Lake, the lowest TSI score that could possibly be achieved is 30, which marks the lowest end of eutrophication. This value could reasonably symbolize the state prior to human development. The highest TSI score that is assumed to be possible is 80, which marks a highly degraded hypereutrophic system. The total range of TSI scores for Cedar Lake is 50 points from 30 to 80. Both the average and maximum TSI values for the baseline and restoration measures will be normalized to this scale. Since the lower the TSI value, the better the health of the ecological function of the lake, the normalized values will be subtracted from one.

Ecosystem structure describes the composition of the habitat that is necessary for species to survive throughout their life cycle. There are several methods to measuring habitat structure within an ecosystem. The most common is to use a surrogate, such as species diversity to give an indication to the habitat structure present. There are several indices available for riparian, wetland, and stream ecosystems; however, there are few for lake systems. For Cedar Lake, habitat structure was measured using aquatic macrophyte and fish species diversity indices. The species richness, number of total species present, is measured and compared to the total number of species possible. The total number of species possible is determined by comparing to a similar-type reference ecosystem with pristine conditions. Since there are few pristine ecosystems left in this area, historic documentation is used when available to establish species composition during pre-settlement conditions. Based on research, there are a total of 38 native macrophyte species and 32 native fish species that could have survived in Cedar Lake during pre-settlement conditions. For each of the restoration measures, the species richness after implementation is determined by professional judgment of biologists familiar with the study area. The tolerance of each species is taken into account when predicting rebound of various species. It is assumed that when the ecosystem function is restored, ecosystem structure will also improve through natural recolonization. This phenomenon is more likely for aquatic macrophyte plant species than fish because more pathways for recolonization are present through existing seed banks, wind transport, and avian means. There is normally a time delay in natural recolonization, which should be taken into account.

As described above, the habitat suitability index derived for Cedar Lake takes into account both habitat function and habitat structure. This value is multiplied by the area affected to determine total habitat output in terms of habitat units. The HSI for Cedar Lake is shown in the equation below:

$$\text{HSI} = \text{SQRT}[(\text{Functional HSI}) \text{ x } (\text{Structural HSI})]$$

$$\text{HSI} = \sqrt{\left[1 - \frac{(AvgTSI - 30) + (MaxTSI - 30)}{2 \times (80 - 30)}\right] \times \left[\frac{\left(\frac{SR_{Macrophytes}}{Total_{Macrophytes}}\right) + \left(\frac{SR_{Fishes}}{Total_{Fishes}}\right)}{2}\right]} =$$

where HSI is the habitat suitability index, AvgTSI is the average trophic state index of the lake during ice-off conditions, MaxTSI is the maximum trophic state index of the lake during the year, $SR_{Macrophytes}$ is the number of macrophyte species present, $Total_{Macrophytes}$ is the total number of macrophyte species possible, SR_{Fishes} is the number of fish species present, and $Total_{Fishes}$ is the total number of fish species possible.

Habitat function and structure parameters along with total HUs were computed for the baseline and with project conditions over the 50-year life of the project as shown graphically in ***Figure 8*** below. The average annual habitat units (AAHUs) were then computed by averaging annual scores over the entire project life. A summary of habitat outputs for each measure is shown in ***Table 15*** below.

The future without project condition was assumed to be stable based upon recently adopted stormwater management ordinances, planned sewer system upgrades, and projected landuse changes. The Town of Cedar Lake has recently passed a new stormwater management ordinance, has invested in upland sediment control measures, and plans to substantially upgrade the surrounding sewer system to address remaining surcharges. These efforts along with a projected conversion of the basin landuse from agricultural to residential will reduce sediment and nutrient loadings to the lake. An analysis of past monitoring of Cedar Lake by the state of Indiana throughout the past three decades suggests that the lake had been improving, but has reached steady state conditions. Modeling results of baseline conditions showed that almost 90% of the phosphorus loading within the lake is due to internal recycling of bottom sediments. Due to a relatively small drainage area, Cedar Lake efficiently traps suspended sediments and dissolved nutrients from tributaries. Model results suggest that even with projected reductions in tributary loadings, the lake will maintain current eutrophication levels due to internal nutrient cycling.

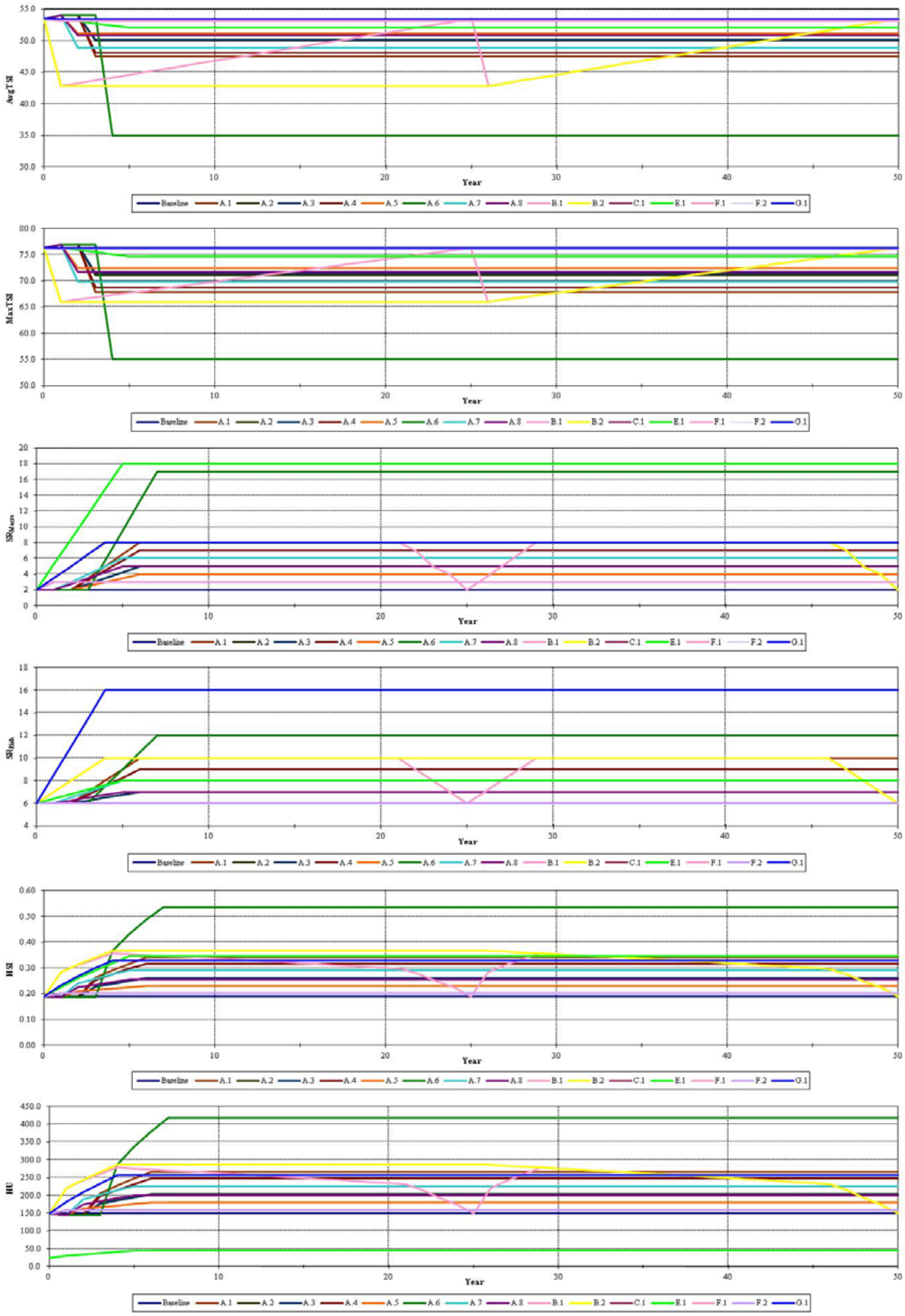

Figure 8: Graph of HSI and Habitat Outputs

Table 15: Summary of Habitat Outputs

Measure /Scale	Target AvgTSI	Target MaxTSI	/1 Target SR_{Macro}	/2 Target SR_{Fishes}	Target HSI	Target HU	Compute AAHUs	Incr. AAHUs
Baseline	53.5	76.3	2	6	.19	148.6	148.6	0.0
A.1	47.6	67.9	8	10	.34	266.1	256.7	108.1
A.2	50.0	71.1	5	7	.26	203.6	199.3	50.6
A.3	50.1	71.4	5	7	.26	202.6	198.3	49.7
A.4	48.1	68.7	7	9	.32	247.37	239.5	90.9
A.5	51.2	72.4	4	6	.23	180.0	177.9	29.3
A.6	/3 35.0	/3 55.0	17	12	.54	418.5	392.2	243.5
A.7	/4 48.9	/4 69.8	6	8	.29	226.4	221.8	73.2
A.8	/4 50.8	/4 71.7	5	7	.26	199.9	196.9	48.2
/5 B.1	42.8	66.0	8	10	.19	148.5	240.3	91.6
/6 B.2	42.8	66.0	8	10	.19	148.5	261.5	112.8
C.1	53.2	76.3	3	6	.20	157.2	157.1	8.4
/7 E.1	52.1	74.7	18	8	.35	45.1	43.9	43.9
F.1	53.1	76.2	3	6	.20	157.7	157.6	8.9
F.2	53.1	76.1	3	6	.20	158.0	157.8	9.2
G.1	53.4	76.3	8	16	.33	255.9	251.0	102.4

/1 Rate of macrophyte natural recolonization (when applicable) estimated at 5 years. Total number of native macrophyte species possible within Cedar Lake is 38.
/2 Rate of fish natural recolonization (when applicable) estimated at 5 years. Total number of native fish species possible within Cedar Lake is 32.
/3 AvgTSI and MaxTSI values estimated based on professional judgement.
/4 AvgTSI and MaxTSI values estimated based on model results of similar scaled dredge volumes and depths.
/5 Measure B.1 requires reapplication estimated at 25 years. HUs assumed to decrease at constant rate as treatment effectiveness diminishes.
/6 Measure B.2 estimated to last 50 years. HUs assumed to remain constant for 25 years after initial application and then assumed to decrease at constant rate as treatment effectiveness diminishes over remaining project life.
/7 Habitat area affected is 130 acres corresponding to zone of emergent and submergent vegetation.

4.3 Cost Effectiveness and Incremental Cost Analysis.

The cost effective and incremental cost analyses were performed using the newly certified U.S. Army Corps of Engineers Institute for Water Resources IWR-Planning Suite (IWR-PLAN) version 1.0.11.0 software (Skaggs 2006). The software generates a set of alternatives based on the types of measures and scales provided. The annualized costs and average annual habitat units for each of the measures are input for analyses. Two sets of plan dependencies were specified to ensure unrealistic combinations were not generated. Both littoral zone restoration and fish community management must be done in conjunction with either substrate restoration or nutrient inactivation. Substrate restoration measure A.6 was not included in the analysis because the cost of this measure is outside the scope of implementation. While including the other 14 measures with specified dependencies, the IWR-PLAN software generated 396 alternative plans. The cost effectiveness analysis determined that there were 59 cost effective plans and the incremental cost analysis determined that there are 10 "best buy" plans including the no action alternative. "Best Buys" provide the greatest increase in output for the least increases in cost. They have the lowest incremental costs per unit of output. Normally, a "best buy" plan is recommended for implementation. A summary of the "best buy" plans is shown *in **Table 16*** below.

Table 16: Summary of "Best Buy" Plans

	"Best Buy" Plan	Average Annual Output (AHHUs)	Average Annual Cost ($)	Cost per Output ($/AAHUs)	Inc. Cost ($)	Inc. Output (AAHUs)	Inc. Cost per Output
0	No Action	0.00	[redacted]	[redacted]	[redacted]	-	[redacted]
1	F1	8.93	[redacted]	[redacted]	[redacted]	8.93	[redacted]
2	B1,F1	100.55	[redacted]	[redacted]	[redacted]	91.62	[redacted]
3	B2,F1	121.78	[redacted]	[redacted]	[redacted]	21.23	[redacted]
4	B2,C1,F1	130.21	[redacted]	[redacted]	[redacted]	8.43	[redacted]
5	A8,B2,C1,E1,F1,G1	324.76	[redacted]	[redacted]	[redacted]	194.55	[redacted]
6	A7,B2,C1,E1,F1,G1	349.69	[redacted]	[redacted]	[redacted]	24.93	[redacted]
7	A7,B2,C1,E1,F2,G1	349.94	[redacted]	[redacted]	[redacted]	.25	[redacted]
8	A4,B2,C1,E1,F2,G1	367.63	[redacted]	[redacted]	[redacted]	17.69	[redacted]
9	A1,B2,C1,E1,F2,G1	384.88	[redacted]	[redacted]	[redacted]	17.25	[redacted]

A graphical summary of the CE/ICA results for all the plans generated by IWR-Plan is shown in ***Figure 9*** below. Additionally, a graphical representation of the incremental cost and outputs shown in the above table is shown in ***Figure 10.***

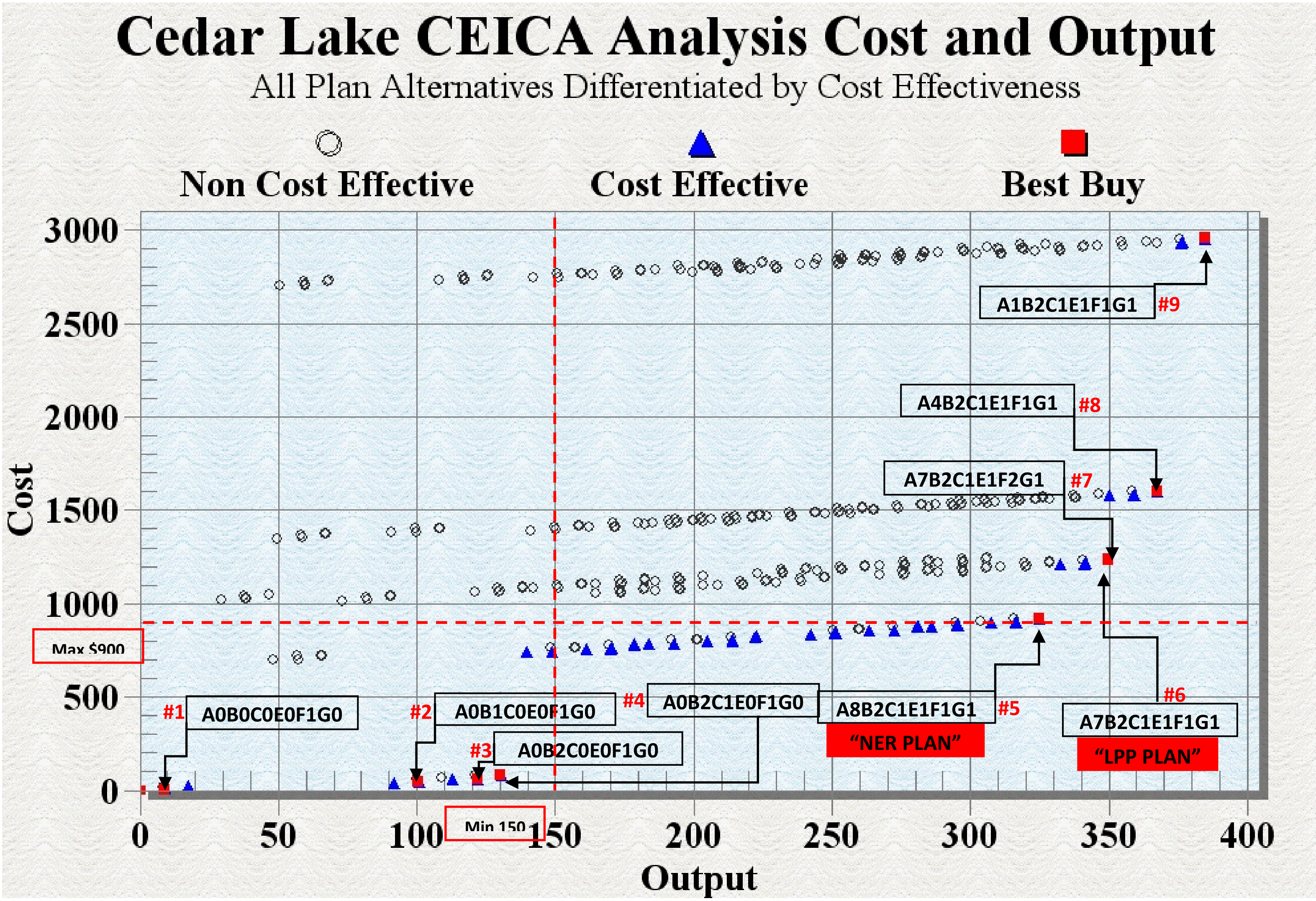

Figure 9: Cost and Output Results of Plans Generated by IWR-Plan

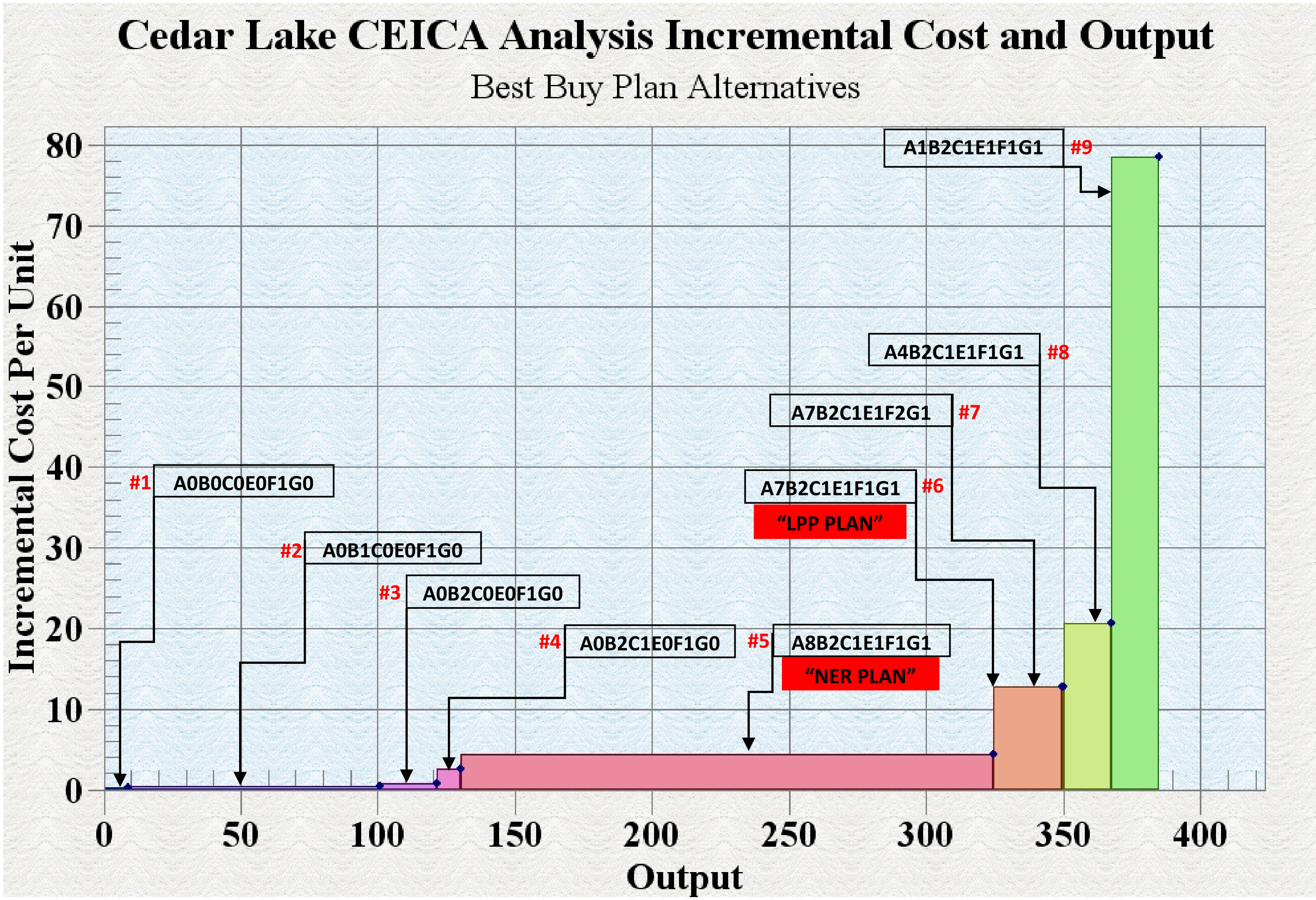

Figure 10: Incremental Cost and Output of "Best Buy" Plans

There are many ways decision makers can use the results of the CE/ICA analyses. The NER plan is selected by answering the question – is the next level of output worth it? To aid in answering these questions, guidelines are typically established to bracket the analyses. Decision making guidelines can include curve anomalies, output targets, output thresholds and cost affordability (USACE 1995).

For this analysis, a minimum threshold of outputs was set to ensure that the NER plan meets all project objectives. Specifically for Cedar Lake, it was determined that the NER Plan must achieve a minimum of 150 average annual habitat units (AAHUs) in order to meet all of the project objectives of restoring both the natural ecosystem function and habitat structure. Plans that have output less than 150 AAHUs would only address restoration of littoral currents & nutrient cycling, increase in spatial coverage of viable in-lake habitat, reestablishment of fish passage/colonization, and increase in biodiversity. Plans below 150 AAHUs would not address the eradication/control of non-native species. A plan unable to meet this objective would jeopardize the meeting of all other objectives, especially an increase in biodiversity at Cedar Lake. Additionally, plans providing less than 150 AAHUs would not provide any significant additional habitat output over the future without project condition which is expected to provide 148.6 AAHUs. Overall, plans not meeting this criterion would not address the holistic restoration of both physical habitat structure and biological functions.

Section 3065(c)(1) of WRDA 2007 authorizes the Secretary to plan, design and construct an aquatic ecosystem restoration project at Cedar Lake, Indiana. The WRDA language established a cap of $11,050,000 for any future appropriations of Federal funds for this project. Prior to WRDA 2007 authorization, the FS was appropriated $683,900 under Section 206 of WRDA 1996. A coordinated legal opinion determined that the $11,050,000 authorized by Section 3065 does not include amounts previously appropriated under Section 206 of WRDA 1996. Therefore, the total Federal costs (i.e., not including non-Federal costs) that may be expended for the planning, design and construction of a feasible project at Cedar Lake are $11,734,000, absent additional action by Congress.

Implementation guidance for this authority does not specify cost sharing requirements for FS costs. However, assuming that all costs would be cost-shared 65% Federal / 35% non-Federal, the total project cost (i.e., total Federal and non-Federal costs) is limited to approximately $18,050,000. Since total average annual costs includes interest during construction (IDC) and Operations, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R), an additional 10% above first costs was used to account for these NED costs. Using the FY11 Federal discount rate of 4 1/8 %, a maximum average annual cost threshold of approximately $900,000 was established for the CE-ICA analyses.

Among the identified "best buy" plans, natural breakpoints become apparent when there are large shifts in incremental costs per unit of output. For example, a natural breakpoint exists between Best Buy Plans 3 and 4 and between Best Buy Plans 6 and 7 with a large jump in incremental cost per unit of output. These natural breaks are shown more pronounced in *Figure 9*. As shown in ***Table 16***, the incremental costs per unit output are similar in magnitude between Best Buy Plans 4 through 7 with a nearly linearly increasing trend.

The NER Plan is selected by evaluating these cost-effectiveness results against established project-specific decision-making guidelines. The NER plan should be selected between the lower bound for outputs and upper bound for cost affordability. Based on a minimum output of 150

AAHUs and a maximum average annual cost of $900,000, only one "best buy" plan falls within this criteria (Best Buy Plan 5) as shown in ***Figure 8***. Best Buy Plan 5 is selected as the NER Plan because it is the most efficient plan that achieves project objectives.

A value engineering (VE) study was performed in 2009 and proposals outlined in the study were evaluated by the PDT in early 2013. It was found that the on-site waste-water treatment plant included in Alternative 5 as part of measure A.8 (physical substrate restoration) could be eliminated. Instead, suspended solids and phosphorus could be removed by gravity settling, along with the introduction of cationic polymer to speed the settling time (see *Appendix J – VE Study* for additional detail). These changes reduced the NER Plan (Alternative 5) cost estimate by approximately $[redacted].

The Town of Cedar Lake as the non-Federal sponsor requested that a more costly plan be considered for implementation. The non-Federal sponsor requested that Best Buy Plan 6 be identified as the Locally Preferred Plan (LPP). The LPP and NER Plans differ only by the scale of the physical substrate restoration measures. The LPP Plan includes 263,000 cy of sediment to be removed; this is a 123,000 cy increase (88%) over the NER Plan.

The non-Federal sponsor supports additional physical substrate restoration regardless of the increased incremental cost over the NER Plan. The Town of Cedar Lake and local organizations such as the Cedar Lake Enhancement Association (CLEA) have been working towards dredging Cedar Lake for over 40 years and would like to maximize assurance in achieving sustainable project outputs by removing as much unsuitable sediments from the lake as possible. Modeling analyses show that while additional physical substrate restoration produces added habitat output, the rate of habitat output per additional volume of material dredged reduces making habitat restoration through physical substrate restoration less efficient by volume. Incremental habitat output per unit volume of sediment removed reduces with the quantity of material dredged because sediments with the highest concentrations of nutrients are targeted for removal first. The additional material removed by larger dredging plans has lower nutrient concentrations, thus making the overall nutrient removal efficiency lower.

A comparison of NED economic costs and NER habitat outputs for the NER Plan and LPP are summarized in ***Table 17*** below.

Table 17: Summary of Economic Analysis for NER and LPP Plans

	NER Plan	LPP	Difference
Estimate of First Costs /1			
01 Lands & Damages			
LERRDs	[redacted]	[redacted]	[redacted]
06 Fish & Wildlife Facilities			
SDF	[redacted]	[redacted]	[redacted]
Dredging	[redacted]	[redacted]	[redacted]
SDF Closure	[redacted]	[redacted]	[redacted]
Reroute Founders Creek	[redacted]	[redacted]	[redacted]
Increase No Wake Zone	[redacted]	[redacted]	[redacted]
Alum Treatment	[redacted]	[redacted]	[redacted]
Establish Aquatic Vegetation	[redacted]	[redacted]	[redacted]
Fish Restocking	[redacted]	[redacted]	[redacted]
22 Planning & Feasibility Study /2	[redacted]	[redacted]	[redacted]
30 Planning, Engineering & Design	[redacted]	[redacted]	[redacted]
31 Construction Management	[redacted]	[redacted]	[redacted]
Total First Costs	[redacted]	[redacted]	[redacted]
Estimate of Annualized Costs			
Annualized First Costs /3	[redacted]	[redacted]	[redacted]
Annualized Interest During Construction	[redacted]	[redacted]	[redacted]
OMRR&R	[redacted]	[redacted]	[redacted]
Total Annualized Costs	[redacted]	[redacted]	[redacted]
Estimate of Benefits			
Habitat Output AAHUs	324.76	349.69	24.93
Cost Per Habitat Output	[redacted]	[redacted]	[redacted]
Incremental Cost Per Output	[redacted]	[redacted]	[redacted]

/1 Estimated project first costs are referenced to 1Q2016 (Oct 2016) price level and includes contingencies.
/2 Costs shared 65% Federal and 35% non-Federal except for FS costs where first $100,000 is 100% Federal and remaining costs are equally shared 50/50 between Federal and non-Federal.
/3 Annualization of costs based on FY14 Federal discount rate of 3 1/2%. Costs associated with-project planning and FS are sunk costs and are not included in the calculation of annualized first costs.

5.0 Description of Recommended Plan

The following section outlines the details of the selected NER Plan. In addition, the non-Federal sponsor requested that a larger plan be recommended for implementation. The non-Federal sponsor requests that more dredging be performed than which is included in the NER plan.

Projects may deviate from the NER Plan if requested by the non-Federal sponsor and approved by Assistant Secretary of the Army for Civil Works [ASA(CW)] and are identified as the Locally Preferred Plan (LPP). When the LPP is clearly of less scope and cost and meets the Administration’s policies for high-priority outputs, an exception for deviation is usually granted by ASA(CW). The LPP must have greater net benefits than smaller scale plans, and enough alternatives must be analyzed during the formulation and evaluation process to insure that net benefits do not maximize at a smaller scale than the sponsor’s preferred plan. If the sponsor prefers a plan more costly than the NER Plan and the increased scope of the plan is not sufficient to warrant full Federal participation, ASA(CW) may grant an exception as long as the sponsor pays the difference in cost between those plans and the locally preferred plan. The LPP, in this case, must have outputs similar in kind, and equal to or greater than the outputs of the Federal plan.

In this case the non-Federal sponsor is recommending a LPP that is more costly than the NER plan. The outputs are also greater than the outputs of the NER plan. The Town of Cedar Lake understands they must pay the difference in cost between the NER and LPP and that portion is not cost-shared. Details and the incremental benefits and costs of the LPP beyond the Federal plan are also provided.

5.1 National Ecosystem Restoration (NER) Plan

Through an evaluation of costs and outputs using cost effectiveness and incremental cost analyses, Best Buy Plan 5 was selected as the National Ecosystem Restoration (NER) Plan for Cedar Lake. This plan meets the evaluation criteria defined in Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G): completeness; effectiveness; efficiency; and acceptability (USWRC 1983).

The NER plan includes a combination of four restoration measures as summarized in ***Table 18***. This plan addresses both the functional and structural ecosystem impairments existing at Cedar Lake. The NER plan achieves all the project objectives within the authorized implementation cost limit. A map showing the layout of the NER Plan is shown in ***Figure 11***.

Table 18: Description of NER Plan

Measure /Scale	Type	Description
A.8	Physical Substrate Restoration	Mechanically dredge 87 ac in south basin to depth of 1.0 ft for a total of 140,000 cy. Extent of dredging corresponds to areas with available sediment phosphorus > 100 mg/kg based on sampling and analysis completed in April 2008. Dredged material will be hydraulically offloaded to a sediment dewatering facility (SDF) by slurrying using recycled effluent. Implementation costs include dredging, reslurrying, pumping, SDF construction, SDF closure and effluent treatment. Annual OMRR&R costs include maintenance of SDF site including mowing and fence repair.
B.2	Chemical Substrate Restoration	Dose 400 ac with alum and aluminate to a treatment depth of 20 cm. Area roughly corresponds to available sediment phosphorus (ASP) concentrations > 30 mg/kg. Target alum dose varies by location in lake, with target residual ASP < 20 mg/kg. Implementation costs include one lake treatment. Annual OMRR&R costs include periodic monitoring to determine effectiveness of the treatment used to determine retreatment schedule. Long term effectiveness of single treatment computed at least 50 years based on projected external loadings.
C.1	Tributary Restoration	Reroute Founders Creek back to Cedar Lake. Implementation costs based on provided stream centerline and typical channel and riparian cross-section. Annual OMRR&R costs include invasive species control on the approximate 2acre riparian area site.
E.1	Littoral Macrophyte Restoration	Establish 35 ac emergent and 95 ac submergent aquatic vegetation along the shoreline of the lake within the littoral zone. Implementation costs based on generated native species list. Annual OMRR&R costs include monitoring periodic invasive species control.
F.1	Institutional Controls	Increase No Wake Zone from 200 to 400 ft from shoreline corresponding to approximately 35% of lake. Implementation costs include adding additional marker buoys within the lake. Annual OMRR&R costs include removal of buoys prior to ice conditions and replacement of damaged markers.
G.1	Fish Community Management	Completely eradicate and/or significantly reduce (i.e., 75% of target species) Common Carp and White Perch within Cedar Lake and adjacent Cedar Lake Marsh. Implementation costs include one treatment of Rotenone and introduction of native fish species. Annual OMRR&R costs include periodic monitoring on an approximate 5-year cycle to determine species composition and assess the need for retreatment or restocking of native species. (Completed by non-Federal sponsor)

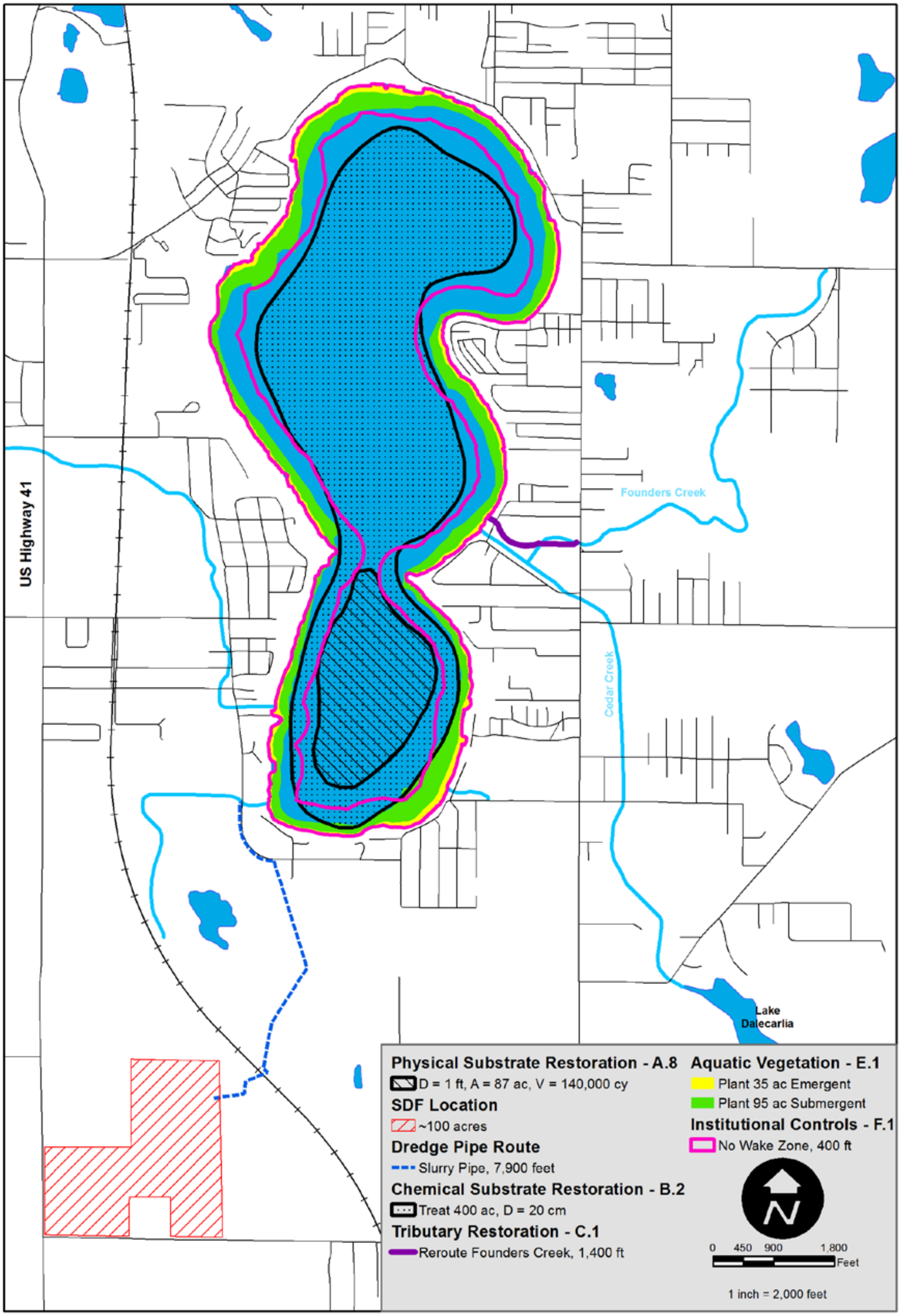

Figure 11: Layout Map of NER Plan

Implementation of the NER Plan would occur over multiple construction seasons and be properly sequenced in the following order to optimize desired output as listed below:

1.) *Physical substrate restoration* will then be implemented with initial activities being construction of the SDF and staging area followed by mechanical dredging and hydraulic offloading to occur over one construction season. It is recommended that dredging occur in the springtime so that algae propagules that sink to the bottom during winter can be removed along with sediment.

2.) *Chemical substrate restoration* will follow dredging by dosing the entire lake with alum including areas that have been dredged to ensure daylighted sediments are properly treated.

3.) *Institutional controls* will be implemented by extending No Wake Zones so that wave forces are reduced along the shoreline allowing aquatic vegetation to establish.

4.) *Littoral macrophyte restoration* would then follow given assurance that invasive benthic feeders were removed from the one-time application of Rotenone.

5.) Once aquatic vegetation had the ability to establish, the *fish community management* measure can be completed by stocking of native fish species.

6.) *Tributary restoration* can be implemented anytime during the construction process.

7.) *Fish community management* will be carried out by the non-Federal sponsor and the IDNR prior to the implementation of the components of the LPP. Management will entail a single application of Rotenone in the lake and connecting Cedar Lake Marsh. Stocking of native fish species will be delayed until components of the LPP have been implemented.

5.2 Locally Preferred Plan (LPP)

The Town of Cedar Lake as the non-Federal sponsor requested that a more costly plan be considered for implementation. The non-Federal sponsor requested that Best Buy Plan 6 be identified as the Locally Preferred Plan (LPP). The only difference between the LPP and the NER Plan is the scale of the physical substrate restoration measure. The LPP includes substrate restoration A.7 instead of A.8, which corresponds to 263,000 cy of sediment to be removed (or a 123,000 cy increase 88%) over the NER Plan. All of the other five components of the LPP are the same as those included in the NER Plan.

The LPP also includes fish community management which was determined by the PDT to be crucial for the sustainable establishment of aquatic macrophytes and reduction of turbidity within Cedar Lake. However, it has been determined that the reduction of non-native fish species through the one-time application of Rotenone (i.e., piscicide) should not be included in the NER Plan. Therefore, this measure will not be implemented by the USACE, but by the non-Federal sponsor and the IDNR prior to the implementation of the components of the LPP described below.

In regards to substrate restoration, the non-Federal sponsor supports additional physical substrate restoration regardless of the increased incremental cost over the NER Plan. The Town of Cedar Lake has been working towards dredging Cedar Lake for over 40 years and they feel this project is their only opportunity to remove as much fine-grained nutrient rich sediments from the lake as possible. Modeling analyses show that while additional sediment removal produces added habitat output, the rate of habitat output per additional volume of material dredged reduces making habitat restoration through substrate restoration less efficient by volume. Incremental habitat output per unit volume of sediment removed reduces with the quantity of material dredged because sediments with the highest concentrations of nutrients are targeted for removal first. The additional material removed by larger dredging plans has lower nutrient concentrations, thus making the overall nutrient removal efficiency lower.

Regardless of the inefficiency of additional physical substrate restoration over the NER Plan, habitat output is greater than the NER Plan, therefore a recommendation to the ASA(CW) to accept the LPP was made with the understanding that the non-Federal sponsor will pay the difference in cost between the NER Plan and the LPP Plan. The LPP policy waiver request was approved.

The LPP plan includes a combination of six restoration measures as summarized in ***Table 19***. The LPP Plan achieves all the project objectives and the Federal portion is within the authorized implementation limit. A map showing the layout of the LPP is shown in ***Figure 12***.

Table 19: Description of LPP Plan

Measure /Scale	Type	Description
A.7	Physical Substrate Restoration	Mechanically dredge 163 ac in the central and south basins to depth of 1.0 ft for a total of 263,000 cy. Extent of dredging corresponds to areas with available sediment phosphorus > 100 mg/kg based on sampling and analysis completed in April 2008. Dredged material will be hydraulically offloaded to a sediment dewatering facility (SDF) by slurrying using recycled effluent. Implementation costs include dredging, reslurrying, pumping, SDF construction, SDF closure and effluent treatment. Annual OMRR&R costs include maintenance of SDF site including mowing and fence repair.
B.2	Chemical Substrate Restoration	Dose 400 ac with alum and aluminate to a treatment depth of 20 cm. Area roughly corresponds to available sediment phosphorus (ASP) concentrations > 30 mg/kg. Target alum dose varies by location in lake, with target residual ASP < 20 mg/kg. Implementation costs include one lake treatment. Annual OMRR&R costs include periodic monitoring to determine effectiveness of the treatment used to determine retreatment schedule. Long term effectiveness of single treatment computed at least 50 years based on projected external loadings.
C.1	Tributary Restoration	Reroute Founders Creek back to Cedar Lake. Implementation costs based on a provided stream centerline and typical channel and riparian cross-section. Annual OMRR&R costs include invasive species control on the approximate 2-acre riparian area site.
E.1	Littoral Macrophyte Restoration	Establish 35 ac emergent and 95 ac submergent aquatic vegetation along the shoreline of the lake within the littoral zone. Implementation costs based on generated native species list. Annual OMRR&R costs include periodic invasive species control.
F.1	Institutional Controls	Increase ‘no–wake’ zone from 200 to 400 ft from shoreline corresponding to approximately 35% of lake. Implementation costs include adding additional marker buoys within the lake. Annual OMRR&R costs include removal of buoys prior to ice conditions and replacement of damaged markers.
G.1	Fish Community Management	Completely eradicate and/or significantly reduce (i.e., 75% of target species) Common Carp and White Perch within Cedar Lake and adjacent Cedar Lake Marsh. Implementation costs do not include the application of Rotenone, but do include the introduction of native fish species. Annual OMRR&R costs include periodic monitoring on an approximate 5-year cycle to determine species composition and assess the need for retreatment or restocking of native species. (Completed by non-Federal sponsor)

Implementation of the LPP Plan would occur in the same way as the NER Plan; over multiple construction seasons and properly sequenced to optimize desired output.

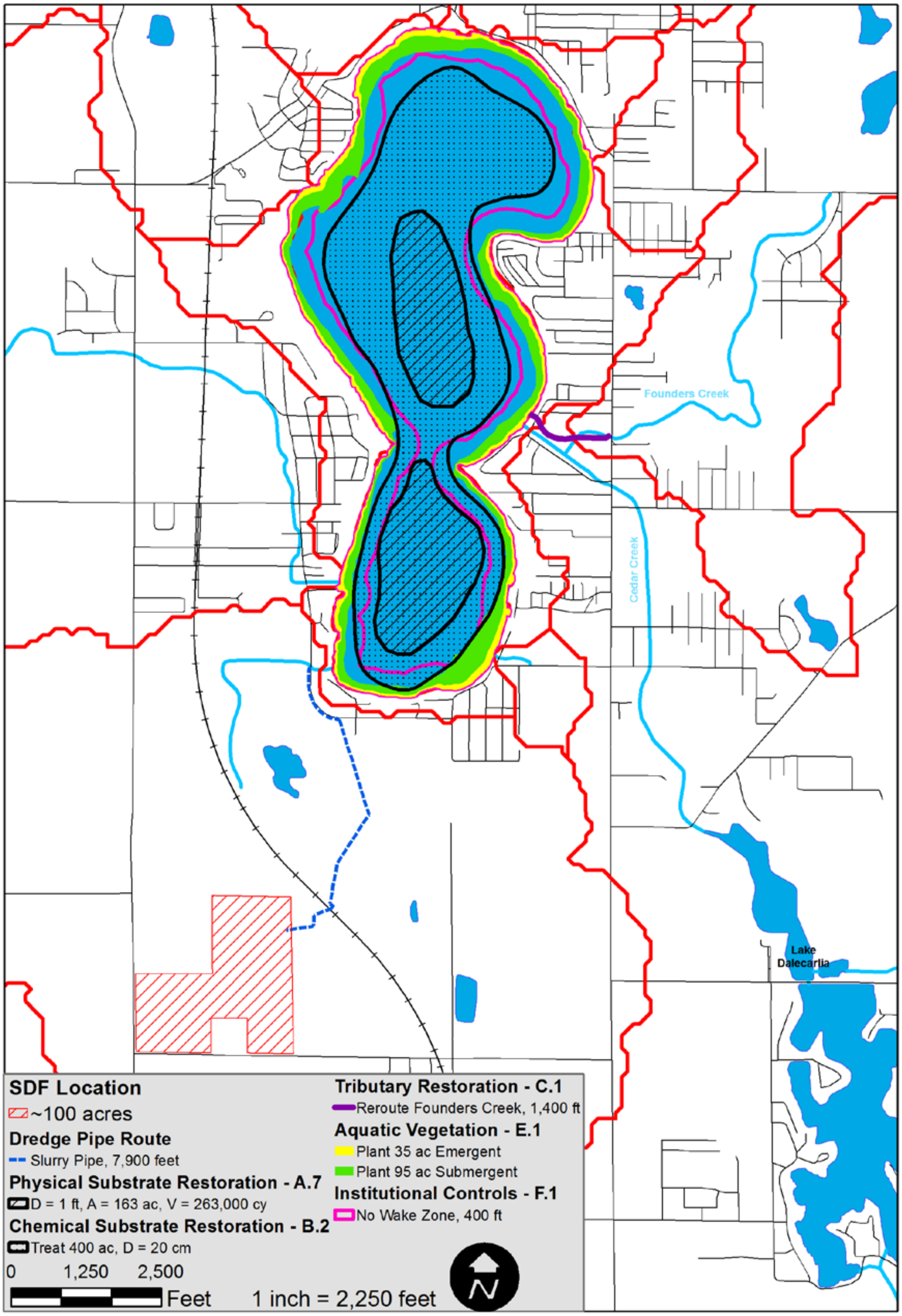

Figure 12: Layout Map of LPP versus NER Plan

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