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3/1/2011

TETRA TECH

Draft Final

Remedial Action Plan
for
Site 17 – Pettibone Creek

Naval Station Great Lakes
Great Lakes, Illinois

Naval Facilities Engineering Command Midwest

Contract Number N62467-04-D-0055

Contract Task Order 474

March 2011

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DRAFT FINAL
REMEDIAL ACTION PLAN
FOR
SITE 17 – PETTIBONE CREEK

NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:
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TABLE OF CONTENTS

SECTION **PAGE NO.**

LIST OF ACRONYMS vii

1.0 INTRODUCTION 1-1
1.1 PURPOSE AND SCOPE 1-1
1.2 FACILITY DESCRIPTION 1-1
1.3 REGULATORY SUMMARY 1-2
1.3.1 Naval Station Great Lakes 1-2
1.3.2 Site 17 – Pettibone Creek 1-2
1.4 REPORT ORGANIZATION 1-4

2.0 SITE SUMMARY 2-1
2.1 SITE SUMMARY 2-1
2.1.1 Physiography and Topography 2-1
2.1.2 Surface Water Hydrology 2-1
2.1.3 Geology 2-2
2.1.4 Hydrogeology 2-2
2.2 PREVIOUS INVESTIGATIONS 2-2
2.3 EXTENT OF CONTAMINATION 2-4
2.3.1 Nature and Extent 2-5
2.3.2 Human Health Risk Assessment 2-7
2.3.3 Ecological Risk Assessment 2-8
2.4 COCS BASED ON THE RESULTS OF PREVIOUS INVESTIGATIONS 2-11
2.5 DECEMBER 2008 INVESTIGATION 2-11
2.5.1 Investigation Summary 2-11
2.5.2 December 2008 Investigation Results and Conclusions 2-12
2.6 RESIDUAL RISK FROM NATIVE SEDIMENT INVESTIGATION COMPARED TO PREVIOUS RISK ASSESMENT 2-13
2.6.1 Residual Human Health Risks after Remedial Action 2-13
2.6.2 Residual Ecological Risks after Remedial Action 2-15

3.0 REMEDIAL ACTION WORK PLAN 3-1
3.1 DESCRIPTION OF THE REMEDIAL ACTION 3-1
3.2 PERFORMANCE STANDARDS 3-3
3.2.1 Stream Excavation 3-3
3.2.2 Dewatering and Processing 3-5
3.2.3 Post-Removal Sampling and Analysis 3-6
3.2.4 Disposal 3-6
3.2.5 Stream Backfilling/Restoration 3-7
3.2.6 Verification Sampling and Analysis 3-8
3.2.7 Erosion and Sediment Control 3-8
3.2.8 Stabilized Construction Entrance 3-9
3.2.9 Decontamination Pad 3-9
3.2.10 Dewatering Pad 3-9
3.2.11 Access Roads 3-10
3.2.12 Clearing 3-10
3.3 SEQUENCE OF RAP IMPLEMENTATION 3-10
3.4 STORMWATER POLLUTION PREVENTION 3-12

TABLE OF CONTENTS (Continued)

SECTION **PAGE NO.**

3.5 OTHER RAP IMPLEMENTATION REQUIREMENTS 3-12
3.5.1 Existing Stabilization Structures 3-12
3.5.2 Permits 3-12
3.5.3 Utilities 3-13
3.5.4 Traffic Control Plan 3-13
3.5.5 EMAC Contractor Requirements 3-14
3.6 IMPLEMENTATION 3-14

4.0 EROSION AND SEDIMENT CONTROL PLAN 4-1
4.1 PURPOSE 4-1
4.2 EROSION AND SEDIMENT CONTROL REQUIREMENTS 4-1
4.3 INSPECTION AND MAINTENANCE OF EROSION AND SEDIMENT CONTROLS 4-3
4.4 SITE RESTORATION 4-4
4.5 RESPONSE PROCEDURES FOR SPILL MITIGATION 4-5

5.0 VERIFICATION SAMPLING PLAN 5-1
5.1 PURPOSE 5-1
5.2 VERIFICATION SAMPLING OF SUPPORT FACILITIES 5-1

6.0 PETTIBONE CREEK STREAM RESTORATION ACTIVITIES 6-1
6.1 PURPOSE 6-1
6.2 DESCRIPTION OF THE SUPPLEMENTAL REMEDIAL ACTION 6-1
6.3 BASELINE FLOW ANAYSIS 6-2
6.4 POST CONSTRUCTION FLOW ANALYSIS 6-3
6.5 PROPOSED STREAM BANK STABILIZATION MEASURES 6-4
6.5.1 ERTEC Bank Stabilization System (BSS) 6-4
6.5.2 Rootwads 6-4
6.5.3 Log Vanes 6-5
6.5.4 J-Hook Vanes 6-6
6.5.5 LUNKERS 6-7
6.5.6 Soil Loss Calculation/Recommended Energy Dissipation Structure 6-8
6.5.7 Engineered Flood Plains 6-10

REFERENCES R-1

TABLE OF CONTENTS (Continued)

APPENDICES

A SITE PHOTOGRAPHS
B INVESTIGATON INFORMATION
C RESIDUAL RISK ASSESSMENT INFORMATION
D VOLUME CALCULATIONS
E SUPPLEMENTAL SPECIFICATIONS
F EROSION AND SEDIMENT CONTROL STANDARDS
G NAVAL STATION GREAT LAKES SPILL PROCEDURES
H SOIL SAMPLING SOP
I PETTIBONE NORTH BRANCH PHOTOGRAPHS, MARCH 2011
J HEC-RAS ANALYSIS - PRE-CONSTRUCTION FLOWS
K DESIGN FLOW CALCULATIONS
L HEC-RAS ANALYSIS - POST CONSTRUCTION FLOWS
M ERTEC BANK STABILIZATION REFERENCE DOCUMENTS
N ROOTWAD TECHNICAL GUIDANCE DOCUMENT
O LUNKERS TECHNICAL GUIDANCE DOCUMENT
P SOIL LOSS/BASIN SIZING CALCULATIONS
Q THE CROSS-VANE, W-WEIR AND J-HOOK VANE STRUCTURES…THEIR DESCRIPTION, DESIGN AND APPLICATION FOR STREAM STABILIZATION AND RIVER RESTORATION

TABLES

NUMBER

2-1 Summary of Human Health Risks Potential Current and Future Land Use Scenarios
2-2 Summary of Ecological Risks
2-3 December 2008 Investigation Data Summary Table
2-4 Comparison of 2001 and 2008 Sample Results
2-5 Summary of Potential Human Health Risk Reduction for Contact with Sediment in the North Branch
2-6 Potential Ecological Risk Reduction for Pettibone Creek
2-7 Comparison of 2008 Native Sediment Data to Benthic Invertebrate PRGs at Pettibone Creek
2-8 Comparison of 2008 Native Sediment Data to Piscivorous Bird PRGs at Pettibone Creek
3-1 Work Assignment Responsibility Chart
5-1 Verification Samples
6-1 Pettibone Creek Remedial Action Summary

FIGURES

NUMBER

1-1 Site Vicinity Map
1-2 Pettibone Creek and Storm Sewer Outfall Locations
2-1 2001 RI Sediment Samples
2-2 2008 Investigation Locations and Results
2-3 Extent of Contamination
3-1 Extent of Excavation
3-2 Typical Stream Excavation
3-3 Traffic Plan
4-1 Erosion and Sediment Control Devices
4-2 Erosion and Sediment Control Devices
4-3 Erosion and Sediment Control Plan
5-1 Verification Sampling Plan
6-1 Pettibone Creek Photograph Locations
6-2 Pettibone Creek Contours

DRAWINGS

NUMBER

C-1 Overall Site Plan
C-2 Site Plan (Sheet 1/2)
C-3 Site Plan (Sheet 2/2)
C-4 Engineered Flood Plain A - Proposed Grading and Sections
C-5 Engineered Flood Plain B - Proposed Grading and Sections
C-6 Engineered Flood Plain C - Proposed Grading and Sections
C-7 Construction Details

LIST OF ACRONYMS

µg/kg	micrograms per kilogram
ASTs	Above ground storage tanks
bgs	Below ground surface
BSS	Bank Stabilization System
CTE	Central Tendency Exposure
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CLEAN	Comprehensive Long-term Environmental Action Navy
cm	centimeters
COC	Chemical of concern
COPC	Chemicals of potential concern
CTO	Contract Task Order
DRO	Diesel Range Organics
E&S Manual	Illinois Procedures and Standards for Urban Soil Erosion and Sediment Control
EEQ	Ecological Effects Quotients
EMAC	Environmental Multiple Award Contract
EPC	Exposure point concentrations
ERA	Ecological Risk Assessment
FEMA	Federal Emergency Management Administration
FS	Feasibility Study
ft	Feet
GPS	Global positioning system
GRO	Gasoline Range Organics
HDPE	High-density polyethylene
HHRA	Human Health Risk Assessment
HI	Hazard Index
IAS	Initial Assessment Study
Illinois DOT	Illinois Department of Transportation
Illinois EPA	Illinois Environmental Protection Agency
ILCR	Incremental Lifetime Cancer Risk
IR	Installation Restoration
LDPE	Low density polyethylene
LOAEL	Lowest Observable Adverse Effect Level
LUNKERS	Little Underwater Neighborhood Keepers Encompassing Rheotaxic Salmonids

NAVFAC	Naval Facilities Engineering Command
MSDS	Material Safety Data Sheet
msl	mean sea level
NSGL	Naval Station Great Lakes
NCP	National Oil and Hazardous Substance Pollution contingency Plan
NCRS	North Chicago Refiners and Smelters
NEPA	National Environmental Policy Act
OICC	Officer in Charge of Construction
OHWM	Ordinary High Water Mark
PAH	Polynuclear Aromatic Hydrocarbon
PCB	polychlorinated biphenyl
ppm	parts per million
PRG	Preliminary Remediation Goals
PWD	Public Works Department
QAPP	Quality Assurance Project Plan
RA	Risk Assessment
RAP	Remedial Action Plan
RBC	Risk-Based Concentration
RAO	Remedial Action Objective
RME	Reasonable Maximum Exposure
RI	Remedial Investigation
SARA	Superfund Amendments and Reauthorization Act
SOP	Standard Operating Procedure
SVOC	Semivolatile Organic Compound
TACO	Tiered Approach to Corrective Action Objectives
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VOC	Volatile Organic Compound

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this document is to present the Remedial Action Plan (RAP) for Site 17 – Pettibone Creek at Naval Station Great Lakes located in Great Lakes, Illinois. This RAP includes the excavation and off-site disposal of contaminated sediment located within the North Branch of Pettibone Creek and stream restoration and the installation of stream bank stabilization features. The RAP was prepared for the United States Navy, Naval Facilities Engineering Command (NAVFAC) Midwest, by Tetra Tech under Contract Task Order (CTO) 474 of the Comprehensive Long-Term Environmental Action Navy (CLEAN) IV Contract Number N62467-04-D-0055.

Work will be performed under the Navy's Installation Restoration (IR) Program, which includes the following five distinct phases of work:

- Phase 1 - Preliminary Assessment [formerly known as the Initial Assessment Study (IAS)]
- Phase 2 - Remedial Investigation (RI) / Risk Assessment (RA)
- Phase 3 - Feasibility Study (FS), Proposed Plan, and Record of Decision
- Phase 4 - Remedial Action Plan (also known as the RAP)
- Phase 5 - RAP implementation

This RAP was prepared under Phase 4 (remedial design) and defines activities associated with corrective measures to be conducted to address contaminated sediments within Pettibone Creek upstream of the Boat Basin. Contaminated sediment in the Boat Basin will be addressed separately.

1.2 FACILITY DESCRIPTION

Naval Station Great Lakes covers 1,202 acres of Lake County, which is located in northeastern Illinois, north of the City of Chicago along the western shore of Lake Michigan. Lake County extends from the Wisconsin border south to Cook County and west to McHenry County. The Naval Station fronts 1.5 miles of Lake Michigan shoreline, and has provided facilities and support to training activities and a variety of military commands since 1911 and includes the Navy’s only boot camp (Figure 1-1). A variety of land uses currently surround Naval Station Great Lakes, including urbanized and industrial areas to the north, industrial use to the west, and a mixture of public use land and residential neighborhoods to the south.

1.3 REGULATORY SUMMARY

1.3.1 Naval Station Great Lakes

During the IAS performed in 1986, the Navy identified 14 potentially contaminated areas where hazardous material may have been released to the environment at the Naval Station (Rogers, Golden, & Halpern and BCM Eastern Inc., 1986). In addition, many sampling events have been conducted since the 1970s within the industrialized (non-Navy property) areas upstream of Naval Station Great Lakes. To investigate these areas within and upstream of the Naval Station, the Navy developed a team of representatives from the Illinois Environmental Protection Agency (Illinois EPA), Naval Facilities Engineering Command Southeast and its consultant Tetra Tech, and the Naval Station Great Lakes Environmental Department. The investigations were conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and its governing regulations, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300, and the National Environmental Policy Act (NEPA). This RAP is limited to the North Branch of Pettibone Creek within Site 17, located within Naval Station Great Lakes, east of Sheridan Road (Figure 1-1).

1.3.2 Site 17 – Pettibone Creek

Site 17 – Pettibone Creek has two major branches. The North Branch originates in the City of North Chicago near Commonwealth Avenue, flows south under Martin Luther King Jr. Drive and a parking area, resurfaces north of Sheridan Road, flows beneath Sheridan Road, resurfaces on Naval Station Great Lakes property, and flows south and east through Naval Station Great Lakes until it enters the Boat Basin, then discharges to Lake Michigan. The South Branch originates in a residential area southwest of Naval Station Great Lakes, flows northward through the Shore Acres Golf Course Country Club property, and enters Naval Station Great Lakes near the intersection of G and 3rd Streets. Flow continues northward on Naval Station Great Lakes property where it joins with flow from the North Branch. North Branch Pettibone Creek ranges between 15 and 30 feet in width and several inches to 2 feet in depth. Storm sewers collect stormwater from a large section of the City of North Chicago and from Naval Station Great Lakes and discharge it to Pettibone Creek (Illinois EPA, 1995). Because of the industrial and urban nature of this watershed, Pettibone Creek is subject to flash flooding and associated erosive forces during storm events. As a result, Pettibone Creek has severe erosion and sedimentation problems. Figure 1-2 presents Pettibone Creek within the limits of Naval Station Great Lakes property along with storm drain locations that discharge to Pettibone Creek. Photographs of sections of Pettibone Creek are included in Appendix A.

Because Site 17 is a stream that collects runoff from urban and industrialized areas both within and adjacent to Naval Station Great Lakes property, Site 17 has been receiving urban and industrial area stormwater runoff since the development of this portion of Lake County. Therefore, early investigation of Site 17 included studies of abandoned industrial facilities in the City of North Chicago, located upstream of Naval Station Great Lakes. These facilities [Fansteel, North Chicago Refiners and Smelters (NCRS), and Vacant Lot] were turn-of-the-century manufacturing facilities that produced tantalum mill products, non-ferrous metals, and zinc oxide. The United States Environmental Protection Agency (USEPA) Region 5 investigated these facilities for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and metals contamination. These former industrial areas are identified on Figure 1-1. Due to the contamination found upstream of Naval Station Great Lakes and the types of industrial activities performed on Naval Station Great Lakes property, the RAP for Site 17 – Pettibone Creek and the associated activities associated with this RAP will be performed in accordance with the CERCLA program. A summary of the environmental investigations performed for Pettibone Creek is provided in Section 2.0.

This RAP is consistent with Navy policy on the handling of contaminated sediments, because implementation of this RAP will occur only after the upgradient contamination areas and potential sources to the proposed remediation area have been controlled. Although it is likely that contamination will continue to be deposited in the form of sediment within the limits of Pettibone Creek, with the remediation of off-base contamination areas, future contamination is expected to be associated with urban land use only and not industrial activities and spills.

Additionally, the following recommendations are presented which, if enacted, could improve the quality of Pettibone Creek but are out of the scope of this RAP not addressed herein:

1) Conduct a video camera inspection of existing stormwater culverts emptying into Pettibone Creek. By identifying culverts that are inactive and/or damaged, a formalized repair/replacement program could be established to address defective culverts. Reducing inflows of storm water by repairing defective culverts may reduce impacts to the stability of existing, steep slopes prevalent along the banks of Pettibone Creek.

2) Additional stormwater retention features and other Best Management Practices could be installed at the inlets of the stormwater piping/systems that discharge into Pettibone Creek to reduce the peak flows associated with storm events thus reducing the velocities and flows impacting Pettibone Creek.

3) Stormwater outfall sampling could be conducted to evaluate potential contamination and to provide additional data relating to further risk-based decision making.

4) Install energy reduction measures (e.g., riprap aprons) at the outfall of existing culverts. By reducing the energy of stormwater flows through the use of energy dissipating structures such as riprap aprons, degradation and erosion of the stream banks via stormwater flows may be reduced.

5) Discontinue the practice of installing rock/debris along the banks of Pettibone Creek at locations where excessive erosion has occurred or is observable. Installing such measures contribute to downstream erosion and stream bank degradation.

1.4 REPORT ORGANIZATION

This report contains the following:

- Section 2.0 summarizes site characteristics including site description, summary of environmental investigations conducted within North Branch Pettibone Creek, and the nature and extent of contamination within North Branch Pettibone Creek.

- Section 3.0 presents the RAP for removing sediment from North Branch Pettibone Creek and for restoration of the disturbed areas of the creek.

- Section 4.0 presents erosion and sediment control features proposed for the RAP described in Section 3.0.

- Section 5.0 presents the verification sampling and analysis plan.

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SITE VICINITY MAP
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

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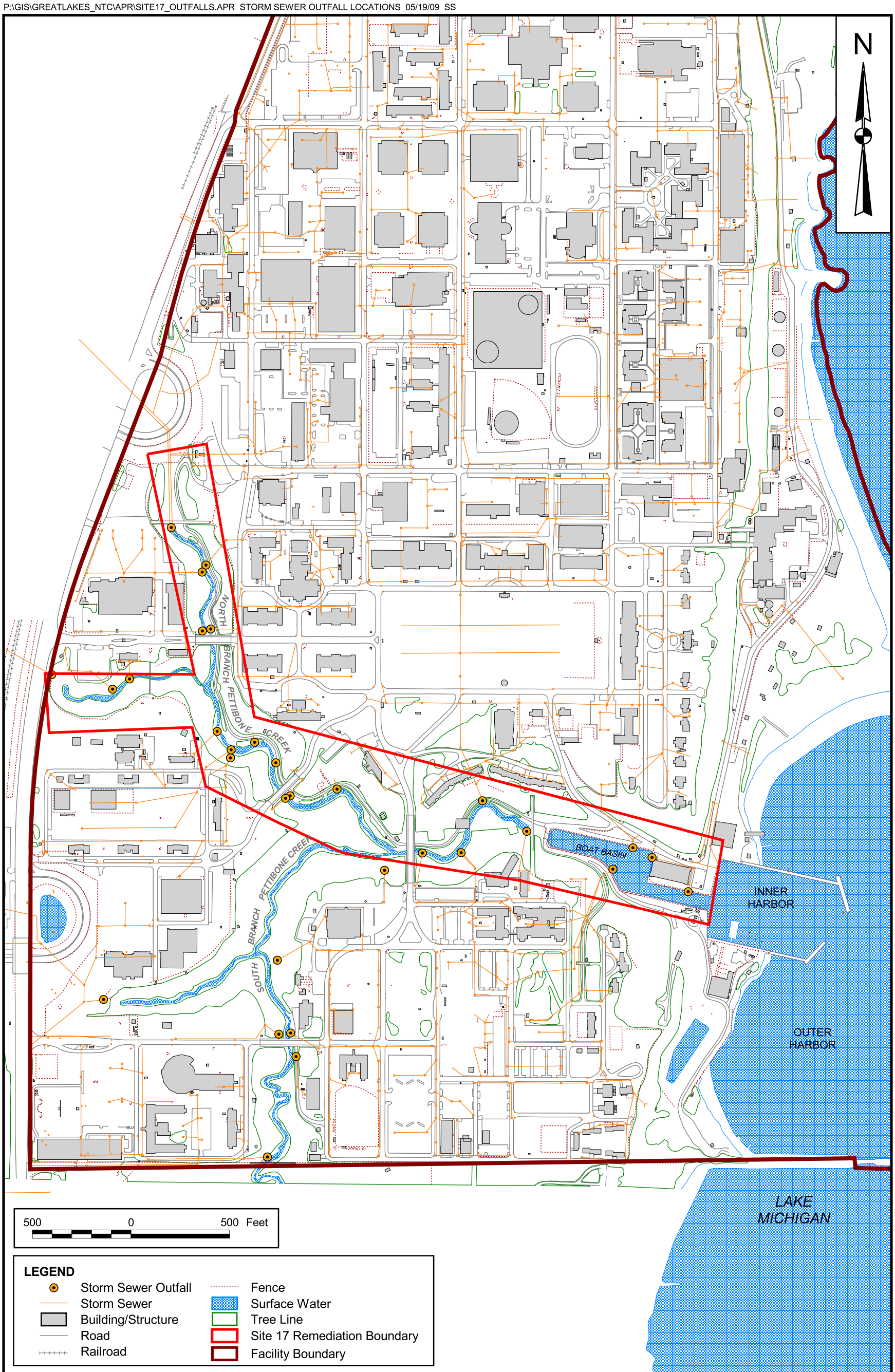

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PETTIBONE CREEK AND STORM SEWER OUTFALL LOCATIONS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

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2.0 SITE SUMMARY

2.1 SITE SUMMARY

A general description of Site 17 - Pettibone Creek is provided in Section 1.0. The following sections describe the physical conditions of the Site. These descriptions were excerpted from the Site 17 RI (TtNUS, 2003) and FS (TtNUS, 2005). This section also presents a summary of previous investigations that have been conducted along Pettibone Creek and a comparison to the results from the December 2008 investigation. The comparison also includes the calculation of the residual risk to human health and the ecological environment if removal of contaminated brown/tan sediment was conducted and the native blue/gray native clay soil identified in the December 2008 investigation remained in the North Branch of Pettibone Creek. The Risk Evaluation of Remedial Alternatives (RERA) performed by the Navy can be found in Appendix C.

2.1.1 Physiography and Topography

Most of Naval Station Great Lakes is situated on a plateau along the Lake Michigan shoreline. Site 17 is a stream valley with steeply eroded slopes. The vegetation consists of elm (*Ulmus spp*.), mixed oaks (*Quercus spp*.), sugar maple (*Acer saccharum*), silver maple (*Acer saccharinum*), boxelder (*Acer negundo*) and ash (*Fraxinus spp*.). Shrubs include blueberry (*Vaccinium spp*.), huckleberry (*Gaylussacia spp*.), blackberry (*Rubus spp*.), and immature trees of the overstory as well as willow (*Salix spp*.), red osier dogwood (*Cornus stolonifera*), sassafras (*Sassafras albidum*), and black oak (*Quercus velutina*). There are also shrubs, including raspberry and blackberry bushes along the banks, and vegetative cover including wild grape vines and perennial weeds. The principle mammals in the area include groundhogs, raccoons, squirrels, opossums, rabbits, chipmunks, and deer (TtNUS, 2001).

The topography of Site 17 includes a moderately steep stream gradient and banks and hillsides with 30- to 60-percent slopes that form the ravine through which Pettibone Creek flows. Site 17 elevations vary from approximately 650 feet above mean sea level (msl) at the tops of the Pettibone Creek hillsides to approximately 577 feet above msl at the Boat Basin where the Pettibone Creek discharges to Lake Michigan (TtNUS, 2003).

2.1.2 Surface Water Hydrology

Site 17 includes Pettibone Creek, the steep banks and hillsides adjacent to Pettibone Creek, and the Boat Basin through which Pettibone Creek flows prior to discharging to Lake Michigan. In general, flow in Pettibone Creek is eastward, with flow from both the North and South Branches joining within the limits of the Naval Station Great Lakes property. As discussed in Section 1.0, the North Branch conveys flow from

urban and industrialized areas north of Naval Station Great Lakes, and the South Branch conveys flow from residential and public use areas south of Naval Station Great Lakes.

2.1.3 Geology

The coastal geomorphology for Naval Station Great Lakes is characterized as a bluff coast, with bluffs consisting of gray to brown glacial till interbedded with glacial-like sediments of clay, silt, sand, and sandy outwash. Silt and clay are the dominant bluff materials. The average grain-size distribution of the gracial till is 10 percent sand, 42 percent silt, and 48 percent clay. In general, only 10 to 15 percent of eroded bluff materials are coarse enough to provide beach sediments (TtNUS, 2003). Bluff heights relative to mean lake level are variable, but generally in the range of 70 to 90 feet, and bluff slopes range from 25 degrees to nearly vertical. These bluffs are incised by “V”-shaped ravines occupied by streams such as Pettibone Creek that drain the western uplands eastward to Lake Michigan (TtNUS, 2003).

2.1.4 Hydrogeology

The Pettibone Creek watershed, one of five Lake Michigan watersheds in Lake County, Illinois, drains an area of 4.2 square miles, and the creek consists of North and South Branches, each with minor tributary branches. The hydrology of the watershed is well established, and the creek flows through well-defined ravines within Naval Station Great Lakes. The creek is characterized by moderately steep stream bed gradients and banks with 30 to 60 percent slopes (TtNUS, 2003).

There is very little floodplain area along Pettibone Creek because of the steeply sloped banks. The North branch of the creek has a short time of concentration (i.e., time it takes a unit of water to run the water course) because the source of water is primarily from an urban area with low infiltration rates and fast runoff rates during storms. As a result, Pettibone Creek is susceptible to flash floods characterized by high channel velocities and great erosive potential. The Illinois State Water Survey calculated the average flow rate of Pettibone Creek to be less than 10 cubic feet per second (cfs), which greatly increases during periods of precipitation (TtNUS, 2003).

2.2 PREVIOUS INVESTIGATIONS

This section provides a brief summary of the historical upstream non-Naval Station and Naval Station contaminant releases that have potentially impacted Pettibone Creek as reported in the FS (TtNUS, 2005). This section also summarizes the investigations conducted within Pettibone Creek. Additional details regarding the source areas and releases are provided in Section 2.2 of the Site 17 RI/RA (TtNUS, 2003).

Industries located along the North Branch Pettibone Creek upstream of Naval Station Great Lakes include the NCRS (also known as R. Lavin) facility and Fansteel (see Figure 1-1). Discharges from these industries, in combination with discharges from several storm sewers collecting water/runoff from a large section of the City of North Chicago, have contributed to elevated concentrations of contaminants in Pettibone Creek and Boat Basin sediments according to the Illinois EPA (Illinois EPA, 1995) and USEPA (USEPA, 2002a, 2002b, and 2002c). In addition, the Navy identified potential areas where hazardous materials may have been released to the environment at Naval Station Great Lakes in the IAS (Rogers, Golden, & Halpern and BCM Eastern Inc., 1996). The IAS identified 14 potentially contaminated sites along with potential sources such as surface runoff or fallout from engine exhaust from nearby roadways, historical pesticide usage and VOCs detected in groundwater samples from monitoring wells. The following table provides a brief overview of environmental studies conducted within Pettibone Creek and the Boat Basin from 1970 to 2001.

Date	Conducted by	Comments
1970 - 1971	Illinois EPA	PCBs and pesticides found in samples
1975	USEPA	Inner Harbor sediment samples polluted with toxic metals
May 1980	USEPA Contractor	Contaminated sediment samples
April 1988	STS Consultants Ltd. for the Navy	USEPA did not approve open water disposal of sediments
July 1988	Jacobs Engineering	Copper and lead had elevated concentrations in the sediment samples
April 1989	STS Consultants Ltd. for the Navy	Highest concentrations at the Boat Basin bend to join a channel to the Inner Harbor
June 1990	Illinois EPA	Elevated concentrations of zinc, copper, and lead in sediments downstream of the NCRS facility
1991	Illinois EPA	Surface water samples were contaminated with VOCs and SVOCs
Nov. 1991	Illinois EPA	Metals and SVOCs were present at concentrations three times greater than background concentrations
Aug. 1992	Halliburton NUS for the Navy	Contaminants present in Pettibone Creek and Boat Basin sediments
Sept. 1992	Illinois EPA	Elevated concentrations of inorganics, chlorinated solvents, polynuclear aromatic hydrocarbons (PAHs), pesticides, and PCBs were detected in soil and sediment samples
April 1994	Illinois EPA	VOCs, SVOCs, pesticides, and metals detected in sediment samples
1995	Illinois EPA	Significant metals contamination in sediment samples. Illinois EPA identified many potential sources that were part of upstream facilities.
1997	Ecology and Environment, Inc. for USEPA	Contaminants detected in soil samples from the Vacant Lot site and sediment samples. Off-site active industrial discharge and stormwater drainage into Pettibone Creek represent potential sources of contamination.
2000	Contractor for Fansteel Inc.	Contaminants detected in sediment samples

Date	Conducted by	Comments
October 2000	TN & Associates for USEPA Region 5	Results of downstream sampling suggested that contaminants are migrating downstream from the NCRS/City of North Chicago discharge into Pettibone Creek
September 2001	Tetra Tech	PAHs, pesticides, PCBs, and metals detected in sediment samples; VOCs and metals detected in surface water samples

The most recent field investigation, discussed in the Site 17 FS, was the RI/RA performed in September 2001. Activities consisted of surface water and sediment sampling within Pettibone Creek, including the collection and analysis of six surface water samples and 38 sediment samples. The sediment samples were collected from depth ranges of 0 to 4 centimeters (cm) and 14 of the 38 sediment locations was collected at a depth of 1 foot. These samples were analyzed for PAHs, pesticides, PCBs, and metals due to the detections of PAHs, pesticides, PCBs, and metals in off-site, upstream samples, collected during previous environmental investigations of Pettibone Creek. A select number of these samples were also analyzed for VOCs and SVOCs.

In addition, sediment samples were collected from 12 locations in the Boat Basin. At each location, four samples were collected from the following depth intervals: 0 to 4 cm, 4 cm to 3 feet, 3 to 6 feet, and 6 to 10 feet. The general trend within the Boat Basin was that the sediment at the surface is “cleaner” than the sediment at depth (i.e., concentrations of pesticides, PCBs, and metals in deeper sediment samples were greater than surface sediment samples). The difference in concentration with depth may reflect decreases in contaminant loading over time; sediments have accumulated, undisturbed in the Boat Basin over an extended period (approximately 30 years since the last dredging). Concentrations of most pesticides, PCBs, and metals in the at-depth samples (> 3 feet) from the Boat Basin also exceed concentrations for sediment samples collected within Pettibone Creek. The following section summarizes the findings of this investigation.

2.3 EXTENT OF CONTAMINATION

This section summarizes the nature and extent of contamination, the human health risk assessment (HHRA), and the ecological risk assessment (ERA) within Site 17, as identified in the RI/RA and FS. Because this RAP is limited to the North Branch of Pettibone Creek, the following discussion is limited to the portion of Pettibone Creek located upstream of the Boat Basin along the North Branch to the culverts where Pettibone Creek surfaces on Naval Station Great Lakes property (see Figure 1-1). More detailed information is available in Section 4.0 of the RI/RA report (TtNUS, 2003).

2.3.1 Nature and Extent

VOCs were not significant site-related contaminants at Site 17. Maximum concentrations of chlorinated solvents and toluene were detected in the sample collected at the upstream boundary of Site 17.

PAHs were the predominant SVOCs detected in sediment samples collected at Site 17. In general, concentrations of PAHs were greatest in surface sediment samples and typically decreased with depth. Average concentrations detected in samples from North Branch of Pettibone Creek and the Boat Basin [typically less than 5,000 micrograms per kilogram (µg/kg)] generally exceeded average concentrations in the South Branch Pettibone Creek (typically less than 1,000 µg/kg). PAHs were not detected in Site 17 surface water samples. PAH concentrations in sediment samples have increased compared to historical data, and this is believed to be caused by the widespread use of petroleum products in our modern industrialized society.

In addition, it is possible that the PAHs that are the primary COCs could be attributed to background. The Illinois EPA TACO Concentrations of Polynuclear Aromatic Hydrocarbon Chemicals in Background Soils (Illinois EPA, 2000) listed in 35 Illinois Administration Code 742 Appendix A Table H of TACO provide background criteria of PAHs in Metropolitan Statistical Area. The table below compares the maximum and average concentrations of the COCs from the September 2001 investigation to the Metropolitan Statistical Area background PAHs as determined by Illinois EPA. Most of the PAHs retained as COCs in the NAVFAC HHRA are below background criteria, which indicate they could be attributed to background. The maximum PAH result was observed in the samples that were located near the culverts where North Branch Pettibone Creek discharges onto NSGL property. The results from these samples were an order of magnitude higher than the other samples in Pettibone Creek.

COC (µg/kg)	Maximum Result from Remedial Investigation	Average Result from Remedial Investigation	Background PAHs in surface soil in Illinois within MSA
Benzo(a)anthracene	11000	1304	1800
Benzo(a)pyrene	11000	1294	2100
Benzo(b)fluoranthene	12000	1362	2100
Dibenzo(a,h)anthracene	6300	740	1700
Indeno(1,2,3-cd)pyrene	5800	658	1600

Pesticides, PCBs, and metals exhibit a different extent profile than PAHs in sediment. In general, concentrations of pesticides, PCBs, and metals were lower in surface sediment samples and increased with depth. Pesticides were detected in sediment samples collected at Site 17 at concentrations that reflect the widespread and historical use of chemicals for pesticide control.

PCBs were detected in less than 50 percent of the sediment samples analyzed. Average concentrations of Aroclor-1248, -1254, and -1260 in at-depth samples in the Boat Basin (240 µg/kg, 1400 µg/kg, and 300 µg/kg, respectively) were greater than those reported for the surface sediment samples and sediment samples from Pettibone Creek by a factor of two or more. Previous PCB data suggest that significant possible upstream sources may have contributed to the sediment contamination. In addition, PCB contamination of sediments may have occurred due to storage by Naval Station Great Lakes of out-of-service transformers (some filled with PCB-containing oil) at various locations within the Naval Station. Past investigations at these storage locations indicated limited soil contamination exceeding federal and state cleanup guidelines. However, there is no cleanup documentation available for the PCB-contaminated soil.

Copper, lead, and zinc were identified as significant environmental contaminants in sediment samples collected upstream of Site 17 during past environmental investigations. Concentrations detected in off-site upstream samples were often two to three times greater than concentrations in Site 17 sediment samples. Although overland runoff and stormwater discharges may contribute pollutants to the watershed, the analytical results available for the Site 17 area do not suggest that a significant point source(s) from Naval Station Great Lakes is impacting the surface water/sediment quality of Pettibone Creek or the Boat Basin. Several metals (e.g., copper, lead, mercury, selenium, silver, and zinc) were detected in sediments in the Boat Basin and the North Branch Pettibone Creek at average concentrations an order of magnitude greater than background sediment concentrations reported in Tiered Approach to Corrective Action Objectives (TACO) (Illinois EPA, 2000). In contrast, most analytical results reported for the South Branch Pettibone Creek are similar to background sediment concentrations reported in TACO. The analytical data suggest that the primary source of contamination is historical discharge and stormwater discharge within the Pettibone Creek watershed, particularly because contaminant concentrations in deeper sediment samples from the Boat Basin were greater than concentrations in surface sediment samples. These differences in concentration with depth may reflect decreases in contaminant loading over time (i.e., sediments have accumulated over the past 30 years since the last dredging; however, the most recent sediments deposited into the Boat Basin are generally “cleaner”).

The potential sources of background sediment contamination still remain in the stormwater sewer systems and surface water runoff from industrial facilities into Pettibone Creek. However, these industrial facilities (R. Lavin & Sons and Fansteel) that have contributed to historical contamination in Pettibone Creek have filed petitions for bankruptcy and ceased operations. Pettibone Creek may continue to receive a variety of wastes from upstream industries, road runoff, storm sewers, and runoff/discharges from local residential properties. Several of the potential sources (industrial sites) have been cleaned up, and it is expected that additional releases to the creek should not be as significant as they were in the past. Nevertheless, there will continue to be runoff from the surrounding urban area into Pettibone Creek

and the upstream outfalls are still permitted under the state National Pollutant Discharge Elimination System program.

Lastly, as discussed above, because the source of PAHs in sediment includes runoff from roads and parking lots, the sediment may become recontaminated with PAHs. Therefore, the potential for recontamination of the sediment with PAHs and/or other chemicals from runoff and/or residual contamination at the upstream sites is likely.

The available analytical data from investigations performed prior to the 2001 RI/RA are presented in the RI/RA and FS. The 2001 RI/RA sample locations are identified on Figure 2-1. The results from the 2001 RI used to delineate the extent of excavation for this RAP are presented in Table B-1 in Appendix B.1.

2.3.2 Human Health Risk Assessment

A HHRA was conducted to determine whether contamination in surface water, contaminated sediment, and fish in Pettibone Creek and the Boat Basin poses health risks to potential receptors (adolescent and adult recreational users) under current and/or foreseeable future site conditions. The results of the HHRA are presented in Section 6.0 of the RI/RA Report (TtNUS, 2003) and summarized in this section.

Chemicals of potential concern (COPCs) were identified by comparing maximum concentrations of constituents detected in Site 17 samples to USEPA Region 9 risk-based Preliminary Remediation Goals (PRGs), Illinois EPA remediation objectives for residential land use, and USEPA Region 3 Risk-Based Concentrations (RBCs) for fish ingestion. Risks to construction workers and under industrial land use scenarios were acceptable. Under current/future land use, quantitative estimates of non-carcinogenic and carcinogenic risks [Hazard Indices (HIs) and Incremental Lifetime Cancer Risks (ILCRs), respectively] were developed for adult and adolescent recreational users hypothetically exposed to COPCs in surface water, surface sediment, and fish tissue (estimated from chemical concentrations in sediment). The results of the risk assessment are discussed below and presented in Table 2-1.

Risks from Exposure to Contaminated Sediment: HIs for adult and adolescent recreational users in Pettibone Creek (2E-03 and 3E-02, respectively) and the Boat Basin (3E-02 and 3E-02, respectively) were less than the regulatory goal of unity (1.0). The ILCR for the adolescent recreational user exposed to sediment in the South Branch Pettibone Creek was less than 1E-06. The ILCR for the adult recreational user exposed to sediment in the South Branch Pettibone Creek (2E-06) was within the USEPA risk management range of 1E-06 to 1E-04. ILCRs for adult and adolescent recreational users for exposure to surface sediment in the North Branch Pettibone Creek (7E-06 and 3E-06, respectively) and the Boat Basin (8E-06 and 3E-06, respectively) were within the USEPA risk management range. ILCRs greater than 1E-06 were mainly the result of exposure to PAHs.

Risks from Exposure to Surface Water: HIs for adult (7E-02) and adolescent (7E-02) recreational users from exposure to COPCs in Pettibone Creek and the Boat Basin were less than unity. The ILCR for adult (2E-06) recreational users exposed to surface water was within the USEPA risk management range. The ILCR for adolescent (1E-06) recreational users exposed to surface water was equal to the USEPA and Illinois EPA risk goal of 1E-06.

Summary of Human Health Risks: No significant potential health hazards are associated with exposure to COPCs in surface water and surface sediment under the recreational land use scenarios. The quantitative risk evaluation indicated that non-carcinogenic HIs were less than unity (1.0) for adult and adolescent recreational users. Carcinogenic risks were less than or within the USEPA's risk management range of 1E-06 to 1E-04.

The HIs and ILCRs estimated for recreational fisherman consuming fish contaminated with PCBs and pesticides exceeded USEPA benchmarks. Potential health hazards are associated with the ingestion of fish based on estimated (modeled) fish tissue concentrations, sediment concentrations, and bioaccumulation factors. This risk to recreational fisherman was consistent with the Illinois EPA fish advisories for Lake Michigan.

2.3.3 Ecological Risk Assessment

An ERA was also performed as part of the RI/RA at Site 17. The goal of the ERA for Site 17 was to determine whether adverse ecological impacts are possible as a result of exposure to chemicals. The screening-level ERA relied on environmental chemistry data; biological sampling or testing was not conducted for the RI/RA. The screening-level ERA methodology used at Naval Station Great Lakes followed the guidance presented in the Final Guidelines for Ecological Risk Assessment (USEPA, 1998), Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA, 1997), and Navy Policy for Conducting Ecological Risk Assessments (U.S. Navy, 1999), and Quality Assurance Project Plan (TtNUS, 2001) prepared for this project. The results of the ERA, as summarized below, were excerpted from Section 7.0 of the RI/RA report (TtNUS, 2003).

Several chemicals detected in surface water and/or sediment were initially retained as ecological COPCs because their concentrations exceeded screening levels or because they were bioaccumulative chemicals with Ecological Effects Quotients (EEQs) greater than 1 based on conservative exposure scenarios. These chemicals were then re-evaluated in Step 3a of the ERA to determine which chemicals had the greatest potential for causing risks to ecological receptors and should be retained as chemicals of concern (COCs) for further discussion/evaluation. The two primary ecological endpoints evaluated were aquatic organisms (i.e., fish and invertebrates) and mammals and birds that consume invertebrates

and/or fish. Different lists of chemicals were retained as COCs for these different endpoints. Also, different lists of COCs were retained for each of the areas (i.e., the North Branch Pettibone Creek, the South Branch Pettibone Creek, and the Boat Basin).

Table 2-2 lists the chemicals retained as ecological COCs for each of the endpoints in each of the areas. No chemicals detected in surface water were retained as COCs for risks to aquatic organisms. A few of the chemicals detected in surface water were included in the food-chain model; however, exposure via drinking water was insignificant because chemical concentrations in surface water were much lower than concentrations in sediment. Consequently, no chemicals in surface water were retained as COCs for either of the primary endpoints. Therefore, although some of the pesticides (4,4'-DDE and 4,4'-DDT) and metals were retained as COCs for the food-chain model, it was because of concentrations in sediment not surface water. However, because Pettibone Creek and the Boat Basin do not support large fish populations, the piscivorous exposure route is not expected to be significant. Additionally, exposure of terrestrial wildlife to contaminants in sediment (and surface water) via dermal contact is unlikely to represent a major exposure pathway because fur, feathers, and chitinous exoskeletons are expected to minimize transfer of contaminants across dermal tissue.

No chemicals were retained as COCs for sediment in the South Branch Pettibone Creek for aquatic receptors or mammals/birds. With the exception of a few sporadic elevated detections, chemical concentrations in the South Branch are relatively low and may represent a good background/reference location.

PAHs, several pesticides, and several metals in sediment samples were retained as COCs for risks to aquatic receptors in the North Branch Pettibone Creek because they were detected in several samples at concentrations that exceeded alternate benchmarks. The alternate benchmarks are literature-based upper-effects levels used in the Step 3a refinement of the COPC list. The alternate benchmarks are less conservative than the screening benchmarks used in the initial COPC selection and were used to determine the ecological risk-drivers at Site 17. Also, two pesticides (4,4'-DDE and 4,4'-DDT) were retained as COCs because they may cause risks to piscivorous birds; however, as discussed above, Pettibone Creek and the Boat Basin do not support large fish populations, and the piscivorous exposure route is not expected to be significant. Most of the elevated concentrations of these chemicals were detected in the most upstream sample, which indicates that the predominant source of these chemicals appears to be outside of Naval Station Great Lakes. In addition, the concentrations of pesticides are indicative of those associated with typical applications of these pesticides. Therefore, although these chemicals were retained as COCs, the fact that they may not be site related was factored into the risk management decisions.

PAHs, several pesticides and PCBs, and several metals were retained as COCs for risks to aquatic receptors in the Boat Basin because they were detected in several sediment samples at concentrations that exceeded alternate benchmarks. Also, one pesticide (4,4'-DDE) was retained as a COC because it may cause risks to piscivorous birds. In addition, the concentrations of pesticides are indicative of those associated with typical applications of the pesticide. Therefore, although these chemicals were retained as COCs, the fact that they may not be site-related was factored into the risk management decisions.

In summary, several chemicals were retained as COCs in the North Branch Pettibone Creek and the Boat Basin because they were detected in several samples at concentrations that exceeded alternate benchmarks, indicating that there may be potential risks to aquatic receptors from these chemicals. However, because these potential risks are based on literature values, there is uncertainty in the conclusions. Also, because of the large amount of soil eroding into the creek, physical stressors as well as chemical stressors may be adding to the risks to aquatic organisms.

Finally, pesticides were selected as COCs in the North Branch Pettibone Creek and Boat Basin because they may cause a risk to piscivorous birds that consume fish from the area. The risks are based on predicted fish tissue concentrations estimated from sediment concentrations that incorporate the assumed percent lipids of the fish and site-specific total organic carbon (TOC) concentration of the sediment. The sediment in Pettibone Creek and the Boat Basin is very sandy with little TOC; therefore, the predicted fish tissue concentrations of pesticides are much greater than the pesticide concentrations in sediment samples. The literature values used to make these predictions may not be representative of actual site conditions. In addition, although the elevated pesticide detections are located in several samples along the creek and Boat Basin, the samples were biased toward depositional areas that are expected to have greater chemical concentrations than other areas of the creek.

Based on the evaluation in Section 8 of the RI/RA (Fish Tissue Uncertainty Analysis Evaluation with Historical Data), it appears that risks to piscivorous birds and mammals are overestimated, although the amount of overestimation cannot be quantified with the existing data. There is uncertainty in the risk to the piscivorous birds because it is unknown if they will obtain a significant portion of their diet from Pettibone Creek and the Boat Basin. Pettibone Creek and the Boat Basin do not support large fish opulations and the piscivorous exposure route is not expected to be significant. For these reasons, there is considerable uncertainty in concluding that there are potential risks to piscivorous birds from contaminated sediment.

In conclusion, PAH, PCB, and metal data indicate potential risks to aquatic organisms and piscivorous birds exposed to the contaminated sediment in the North Branch Pettibone Creek and Boat Basin. The potential risks are based on literature data.

2.4 COCS BASED ON THE RESULTS OF PREVIOUS INVESTIGATIONS

Based on the results of previous investigations and the original HHRA and ERA (TtNUS, 2003), the chemicals that were previously retained as COCs are as follows:

- PAHs (benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, ideno(1,2,3-cd)pyrene)
- Pesticides/PCBs (4,4-DDT, Aroclor 1254)
- Inorganics (arsenic, cadmium, chromium, copper, mercury, thallium)

For additional discussion on the selection of the original COCs and screening criteria utilized for that selection process, refer to the Site 17 Feasibility Study (TtNUS, 2005). Figure 2-3 presents the 2001 and 2008 sediment sampling locations along North Branch Pettibone Creek, and indicates locations where sediment concentrations exceeded screening criteria and identifies the extent of contamination within the North Branch Pettibone Creek.

2.5 DECEMBER 2008 INVESTIGATION

The purpose of the December 2008 investigation within the North Branch Pettibone Creek was to determine whether the contamination detected in sediment extends to underlying native stream bed soil and to determine the sediment layer thickness at each sampling location. The results of this investigation were not used to update the HHRA and ERA presented in the RI/RA and FS, rather the results were used to further delineate the vertical extent of contamination within North Branch Pettibone Creek. Using the data from this investigation, a HHRA and ERA were conducted to determine the residual risk related to the samples of native stream bed soil using the same parameters as in the original RI/RA. The results of this HHRA and ERA are presented in Section 2.6.

2.5.1 Investigation Summary

Additional field activities for Site 17 - Pettibone Creek were performed from December 8 to December 9, 2008. The activities consisted of collecting native stream bed soil samples located beneath the accumulated Pettibone Creek sediments. The sampling event was conducted to meet the following objectives:

- Characterize the nature and extent of contamination within the native Pettibone Creek stream bed soil.
- Further (vertically) delineate contaminated sediment in Pettibone Creek.
- Develop a physical description of the native stream bed soil.

During the investigation, 10 native stream bed soil samples were collected from locations near historical sample locations. The samples were located in the field using coordinates and a global positioning system (GPS) unit. After sample locations were identified, the sample team collected samples with a hand auger. Samples were collected below the non-native loose sediment deposit (between 0.25 to 2 feet below ground surface (bgs) in the native stream bed soil. Native soil is typically gray clay and silt in contrast to the overlying sediment, which is typically brown fine- to course-grained sand with some silt that is prone to movement during storm events. December 2008 sample locations and results are presented on Figure 2-2. Collected samples were packaged and shipped in coolers via air courier (i.e., Federal Express) to Empirical Laboratories in Nashville, Tennessee. Each collected sample was analyzed for specific metals (copper, lead, mercury, and zinc), PAHs, pesticides, and PCBs. Table 2-3 presents a summary of the December 2008 analytical results in the form of a frequency of detection table. A full data printout (Table B.2) and a summary of detected concentrations with screening criteria (Table B-2) are provided in Appendix B. A Tetra Tech geologist collected the samples and developed the field logs, and a Tetra Tech licensed Professional Geologist reviewed the field logs and sampling documentation. The documentation associated with the December 2008 investigation (field notes, sample logs, chain-of-custodies, and data validation letters) is provided in Appendix B.3 and B.4.

2.5.2 December 2008 Investigation Results and Conclusions

Analytical Results - As indicated in Table 2-3, several constituents were detected in stream bed soil at concentrations greater than one or more screening values. These parameters included benzo(a)pyrene, pyrene, 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, total DDT Positive Detections, copper, lead, mercury, and zinc. The concentrations of these parameters are presented in Appendix B.2 on Table B-2 and in Table 2-3. As summarized in Table 2-4 concentrations of contaminants in non-native sediment deposits are much higher than concentrations in native stream bed soil. This evaluation indicates that the removal of sediment will reduce risks to human health and ecological receptors.

Sediment Thickness Results - At each of the 10 sampling locations, non-native sediment deposit thickness above the native stream bed soil was measured. This measurement is reported in the form of the underlying soil sample depth interval in Tables B-1 and B-2 in Appendix B.2. These sample depths indicate the depth below the surface of the non-native sediment deposit, at the time of the sampling event, to the top of the underlying soil (e.g., an underlying sample depth interval of 1.0 to 1.5 feet indicates that the top of the underlying soil is 1.0 foot below the sediment surface, so the thickness of the non-native sediment deposit is recorded as 1.0 foot). The transition from the overlying non-native sediment deposit to the underlying native stream bed soil was evident by the change in soil color and type. The following table presents the sediment thickness at each sample location.

Sediment Depth Measurements

Sample	Depth (ft)	Sample	Depth (ft)
NTC17PCSD40	1.0	NTC17PCSD45	0.25
NTC17PCSD41	0.5	NTC17PCSD46	1.0
NTC17PCSD42	0.25	NTC17PCSD47	2.0
NTC17PCSD43	1.0	NTC17PCSD48	2.5
NTC17PCSD44	0.25	NTC17PCSD49	0.75

The results of the sediment depth evaluation indicate that, on average, there is approximately 1 foot of non-native sediment deposit above the underlying native stream bed soil. However, it should be noted that sediment thicknesses vary significantly within the North Branch of Pettibone Creek at the Naval Station, and thicknesses may change with each runoff-producing storm event. Site visits indicate that depositional areas in the creek can accumulate up to 3 to 4 feet of sediment above the native stream bed soil. Conversely, where steam velocities are high, little to no sediment is found above the native stream bed soil.

2.6 RESIDUAL RISK FROM NATIVE SEDIMENT INVESTIGATION COMPARED TO PREVIOUS RISK ASSESMENT

2.6.1 Residual Human Health Risks after Remedial Action

Using the data from the December 2008 investigation, the Navy and Marine Corps Public Health Center conducted a HHRA evaluation for Site 17 – North Branch Pettibone Creek (Navy HHRA) to compare the post-action residual risk (represented by chemical concentrations in native sediment) to current levels of risk (represented by chemical concentrations in surface sediment) to determine the efficacy of the proposed remediation actions (see Appendix C, NAVFAC, 2011). The purpose of this study was to complete a human health risk evaluation to determine the level of risk reduction expected to be achieved by completing the removal action for Site 17.

In order to keep the results of this evaluation comparable to the original HHRA presented within the RI/RA (TtNUS, 2003), most of the assumptions made in the original RI/RA were also used in this evaluation. The same receptors (adult and adolescent recreational users), risk assumptions, and parameters were evaluated in this risk calculation as were evaluated in the original HHRA. Tables 4.1 and 4.2 in Appendix C of the NAVFAC report (2011) list these receptors and parameters. One exception was that updated screening levels were utilized, in addition to updated information in the assessment of chemicals assumed to be carcinogenic via a mutagenic mode of action, and the derivation of exposure point concentrations (EPCs).

Table 2.1 in the NAVFAC report (2011; Appendix C) shows the COCs based on this native sediment investigation. The number of COCs retained (i.e., exceeded screening criteria) in the native sediment investigation is lower than the number of COCs identified in the original contaminated sediment HHRA (TtNUS, 2003). The only chemicals retained as COCs in the Navy native sediment investigation are the following:

- PAHs (benzo(a)pyrene, benzo(a)anthracene, benzo(b)fluoranthene, ideno(1,2,3-c,d)pyrene, chrysene, dibenzo(a,h)anthracene)

Total cancer risk calculations were performed for North Branch Pettibone Creek based on these native sediment results to compare to the results in the original TtNUS HHRA (2003). The study conducted by the Navy and Marine Corps Public Health Center found that the ILCRs would decrease to 1E-07 in both adult and adolescent recreational users (from the original ILCRs of 8E-06 and 3E-06, respectively). The complete results of this study are included in Tables 7.1 and 7.2 in Attachment 1 of the evaluation (Appendix C).

No adverse non-carcinogenic health effects are anticipated for these receptors at North Branch Pettibone Creek from exposure to native sediment.

Reasonable Maximum Exposure (RME) Cancer Risks from Exposure to Native Sediment: RME ILCRs for adult and adolescent recreational users for exposure to native sediment in the North Branch Pettibone Creek (2.7E-07 and 9.3E-08, respectively) were below the USEPA risk management range of 1E-04 to 1E-06 and below the Illinois EPA risk goal of 1E-06.

Central Tendency Exposure (CTE) Cancer Risks from Exposure to Native Sediment: CTE ILCRs for adult and adolescent recreational users for exposure to native sediment in the North Branch Pettibone Creek (7.7E-09 and 1.3E-08, respectively) were below the USEPA risk management range of 1E-04 to 1E-06 and below the Illinois EPA risk goal of 1E-06.

Summary of Human Health Risks: Table 2-5 summarizes the findings in the Navy and Marine Corps Public Health Center HHRA evaluation in comparison to the risk calculations in the original HHRA (i.e. contaminated sediment). No significant potential health hazards are associated with exposure to COCs in native sediment under the recreational land use scenarios. Carcinogenic risks were all less than USEPA's risk management range of 1E-06 to 1E-04 and the Illinois EPA risk goal of 1E-06 and all native sediment total cancer risks are lower than contaminated (i.e., non-native) sediment total cancer risks.

The Navy and Marine Corps evaluation concluded that the estimated residual risks associated with exposure to the COCs in native sediment from Pettibone Creek for both the adult and adolescent recreational users were less than or within USEPA target levels and were less than the risks calculated in the original RI/RA conducted by Tetra Tech (TtNUS, 2003). Therefore, the Navy concluded that the proposed removal action will sufficiently accomplish risk reduction.

In addition, it is possible that the PAHs that are the primary COCs could be attributed to background. The Illinois EPA TACO Concentrations of Polynuclear Aromatic Hydrocarbon Chemicals in Background Soils (Illinois EPA, 2000) listed in 35 Illinois Administration Code 742 Appendix A Table H of TACO provide background criteria of PAHs in Metropolitan Statistical Area. The table below compares the maximum concentrations of the COCs from the 2008 Investigation to the Metropolitan Statistical Area background PAHs as determined by Illinois EPA. The PAHs retained as COCs in the NAVFAC HHRA are below background criteria, which indicate they could be attributed to background.

COC (µg/kg)	Maximum Result from 2008 Investigation	Background PAHs in surface soil in Illinois within MSA
BENZO(A)ANTHRACENE	260	1800
BENZO(A)PYRENE	200	2100
BENZO(B)FLUORANTHENE	240	2000
DIBENZO(A,H)ANTHRACENE	27	420
INDENO(1,2,3-CD)PYRENE	100	1600

2.6.2 Residual Ecological Risks after Remedial Action

Similar to the evaluation of residual risk for human health, this section presents a summary of the ecological risk evaluation to determine the level of risk reduction expected to be achieved by completing the proposed removal action for Site 17. The proposed remedy will address the following site-specific remedial action objective (RAO): reduce ecological risk associated with: (1) benthic invertebrate exposure to contaminated sediments, (2) exposure of piscivorous birds to contaminated sediment via ingestion of fish and aquatic organisms.

In order to evaluate risk reduction for benthic invertebrates and to make accurate comparison to the 2003 RI/RA, the post remediation EEQs were calculated using the screening criteria selected in Table 7-2 of the RI report and the maximum concentrations from the 2008 native sediment data. The potential reduction in risk for the benthic invertebrate endpoint resulting from completion of the proposed removal action is presented in Table 2-6. Additionally, concentrations of COCs from the 2008 native sediment data were compared to the PRGs developed and approved for use by representatives of the Navy and Illinois EPA in the FS (TtNUS, 2005). This comparison is presented in Table 2-7. There were very few

PRG exceedances in the native sediment, which indicates that there is low potential risk to the populations of benthic invertebrates in Pettibone Creek.

To evaluate risks to piscivorous birds, food-web modeling was conducted to calculate chronic daily intake using the native sediment data, which was then used to calculate EEQ using both the no observed adverse effects level and lowest observed adverse effects level. Two pesticides (DDE and DDT) present an EEQ greater than 1, associated with exposure to native sediment from the North Branch of Pettibone Creek (see Table 2-8). Additionally, mean concentrations of COCs for the piscivorous bird endpoint from the 2008 native sediment data were compared to the PRGs developed and approved for use by representatives of the Navy and Illinois EPA in the FS (TtNUS, 2005) (see Table 2-8). The means for both DDE and DDT from the 2008 native sediment data did not exceed the PRGs. This indicates that there is no potential risk to the piscivorous bird endpoint from exposure to native sediment in Pettibone Creek.

In summary, the proposed removal action of surface sediment in the North Branch will result in a significant risk reduction for benthic invertebrates and piscivorous birds. Furthermore, stream restoration efforts following the removal action will result in habitat improvement over time, allowing accretion of sediment over existing native sediment.

TABLE 2-1

SUMMARY OF HUMAN HEALTH RISKS
POTENTIAL CURRENT AND FUTURE LAND USE SCENARIOS
SITE 17 – PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Receptor	Medium of Concern	Exposure Route	Total ILCR	
			RME	CTE
North Branch Pettibone Creek				
Adolescent Recreational User	Sediment	Incidental Ingestion and Dermal Contact	2.6E-06	4.1E-07
Adult Recreational User	Sediment	Incidental Ingestion and Dermal Contact	6.9E-06	2.2E-07
South Branch Pettibone Creek				
Adolescent Recreational User	Sediment	Incidental Ingestion and Dermal Contact	5.4E-07	7.9E-08
Adult Recreational User	Sediment	Incidental Ingestion and Dermal Contact	1.6E-06	4.5E-08
Boat Basin				
Adolescent Recreational User	Surface Water	Dermal Contact	9.7E-07	2.3E-07
	Sediment	Incidental Ingestion and Dermal Contact	3.0E-06	4.7E-07
Adult Recreational User	Surface Water	Dermal Contact	1.8E-06	1.3E-07
	Sediment	Incidental Ingestion and Dermal Contact	8.1E-06	2.6E-07
	Fish Tissue	Ingestion	1.8E-04	2.1E-05

Receptor	Medium of Concern	Exposure Route	Total HI	
			RME	CTE
North Branch Pettibone Creek				
Adolescent Recreational User	Sediment	Incidental Ingestion and Dermal Contact	3.0E-02	6.0E-03
Adult Recreational User	Sediment	Incidental Ingestion and Dermal Contact	2.7E-02	4.1E-03
South Branch Pettibone Creek				
Adolescent Recreational User	Sediment	Incidental Ingestion and Dermal Contact (1)	4.4E-03	1.1E-03
Adult Recreational User	Sediment	Incidental Ingestion and Dermal Contact	2.7E-03	6.6E-04
Boat Basin				
Adolescent Recreational User	Surface Water	Dermal Contact	6.9E-02	1.6E-02
	Sediment	Incidental Ingestion and Dermal Contact	3.2E-02	5.9E-03
Adult Recreational User	Surface Water	Dermal Contact	6.9E-02	1.6E-02
	Sediment	Incidental Ingestion and Dermal Contact	3.1E-02	4.2E-03
	Fish Tissue	Ingestion	6.6E+00	2.6E+00

TABLE 2-1

SUMMARY OF HUMAN HEALTH RISKS
POTENTIAL CURRENT AND FUTURE LAND USE SCENARIOS
SITE 17 – PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

1 Not evaluated for dermal contact because thallium was the only non-carcinogen selected as a COPC, see Section 6.2.4.1 of Site 17 RI/RA (TtNUS, 2003).

Details of the HHRA assumptions and computations are provided in Section 6 of the Site 17 RI/RA (TtNUS, 2003).

CTE - Central Tendency Exposure.
ILCR - Incremental Lifetime Cancer Risk.
RME - Reasonable Maximum Exposure.
HI - Hazard Index.

TABLE 2-2

SUMMARY OF ECOLOGICAL RISKS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Receptor[1]	Exposure Route[2]	Chemical of Concern	EEQ[3]
North Branch Pettibone Creek			
Benthic Invertebrates and Fish	Direct contact, Ingestion of sediment, Ingestion of prey	PAHs	2.3 to 1,364
		4,4'-DDT	1,800
		4,4'-DDE	105
		4,4'-DDD	85
		Endosulfan II	80
		Copper	30
		Lead	10
		Mercury	24
		Zinc	18.0
Piscivorous Birds	Direct contact, Ingestion of sediment, Ingestion of prey	4,4'-DDT	43
		4,4'-DDE	94
Boat Basin			
Benthic Invertebrates and Fish	Direct contact, Ingestion of sediment, Ingestion of prey	PAHs	3.5 to 62
		4,4'-DDT	120
		4,4'-DDE	115
		4,4'-DDD	155
		Endosulfan I	58
		Endosulfan II	80
		Aroclor-1254	11
		Aroclor-1260	54
		Copper	18
		Lead	9.3
		Zinc	17
Piscivorous Birds	Direct contact, Ingestion of sediment, Ingestion of prey	4,4'-DDE	60

1- Risks to carnivorous mammals were also evaluated; however, no COCs were retained for this receptor.
2- COCs were detected in sediment. Surface water was also evaluated as a medium of concern; however, no chemicals were retained as COCs.
3- The LOAEL EEQ using the average concentration and average exposure assumptions is shown for piscivorous birds because this EEQ was used in the final risk determination.
EEQ = Ecological Effect Quotient.
PAHs = Polynuclear Aromatic Hydrocarbons.
COCs = Chemicals of Concern.
LOAEL = Lowest Observable Adverse Effect Level.

TABLE 2-3

DECEMBER 2008 INVESTIGATION DATA SUMMARY TABLE
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Parameter	Frequency of Detection	Minimum Result	Maximum Result	Location / Sample Number of Maximum Detect	Minimum Non-Detect	Maximum Non-Detect	TACO BACKGROUND SOIL WITHIN METROPOLITAN	ILLINOIS EPA UNSIEVED STREAM SEDIMENT BACKGROUND	ILLINOIS TACO ROUTE SPECIFIC VALUES FOR SOIL INGESTION	REGION 9 RESIDENTIAL SOIL PRG	REGION 9 INDUSTRIAL SOIL PRG	ECOLOGICAL SEDIMENT	MINIMUM CRITERION
							Value / Exceeds	Value / Exceeds	Value / Exceeds	Value / Exceeds	Value / Exceeds	Value / Exceeds	Value / Exceeds
Polynuclear Aromatic Hydrocarbons (ug/kg)													
2-METHYLNAPHTHALENE	9/10	2.3 J	20	NTC17PCSD47	4	4	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	368 / 0	368 / 0
ACENAPHTHENE	5/10	1.9 J	11	NTC17PCSD42 NTC17PCSD44	3.8	4	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	186 / 0	186 / 0
ANTHRACENE	6/10	3 J	71	NTC17PCSD42	3.8	4	NC / 0	NC / 0	23000000 / 0	22000000 / 0	100000000 / 0	85 / 0	85 / 0
BENZO(A)ANTHRACENE	5/10	33	260	NTC17PCSD44	3.8	4	NC / 0	NC / 0	900 / 0	620 / 0	2900 /0	287 / 0	287 / 0
BENZO(A)PYRENE	5/10	24	200	NTC17PCSD42	3.8	4	NC / 0	NC / 0	**90 / 2**	**62 / 2**	290 / 0	**73 / 2**	**62 / 2**
BENZO(B)FLUORANTHENE	5/10	20	240	NTC17PCSD42	3.8	4	NC / 0	NC / 0	900 / 0	620 / 0	2900 / 0	886 / 0	620 / 0
BENZO(G,H,I)PERYLENE	10/10	1.8 J	120	NTC17PCSD42			NC / 0	NC / 0	3100000 / 0	56000 / 0	54000000 / 0	170 / 0	170 / 0
BENZO(K)FLUORANTHENE	5/10	6.4	64	NTC17PCSD42	3.8	4	NC / 0	NC / 0	9000 / 0	6200 / 0	29000 / 0	8860 / 0	6200 / 0
CHRYSENE	5/10	29	200 J	NTC17PCSD44	3.8	4	NC / 0	NC / 0	88000 / 0	62000 / 0	290000 / 0	400 / 0	400 / 0
DIBENZO(A,H)ANTHRACENE	4/10	4.2 J	27 J	NTC17PCSD42	3.8	4	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	60 / 0	60 / 0
FLUORANTHENE	9/10	3.1 J	620 J	NTC17PCSD44	3.8	3.8	NC / 0	NC / 0	3100000 / 0	2300000 / 0	30000000 / 0	2790 / 0	2790 / 0
FLUORENE	6/10	2.8 J	19	NTC17PCSD44	3.8	4	NC / 0	NC / 0	3100000 / 0	2600000 / 0	33000000 / 0	35 / 0	35 / 0
HIGH MOLECULAR WEIGHT PAHS	10/10	4.4	2192	NTC17PCSD44			NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	**1700 / 2**	**1700 / 2**
INDENO(1,2,3-CD)PYRENE	4/10	17	100	NTC17PCSD42	3.8	4	NC / 0	NC / 0	900 / 0	620 / 0	2900 / 0	2500 / 0	620 / 0
LOW MOLECULAR WEIGHT PAHS	10/10	3.9	425.8	NTC17PCSD44			NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	552 / 0	552 / 0
NAPHTHALENE	3/10	4.8	6.5	NTC17PCSD42	3.8	4.4	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	340 / 0	340 / 0
PHENANTHRENE	10/10	3.9 J	320 J	NTC17PCSD44			NC / 0	NC / 0	3100000 / 0	56000 / 0	54000000 / 0	810 / 0	810 / 0
PYRENE	7/10	4.4	460 J	NTC17PCSD44	3.8	4	NC / 0	NC / 0	2300000 / 0	2300000 / 0	54000000 / 0	**350 / 2**	**350 / 2**
BAP EQUIVALENT-HALFND	5/10	31.593	283.81	NTC17PCSD42	3.8	4	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0
BAP EQUIVALENT-POS	5/10	29.393	283.81	NTC17PCSD42	3.8	4	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0
TOTAL PAHS	10/10	13.2	2617.8	NTC17PCSD44			NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	4000 / 0	4000 / 0
Pesticides/PCBs (ug/kg)													
4,4'-DDD	6/10	2.1 J	19 J	NTC17PCSD49	0.76	0.83	NC / 0	NC / 0	3000 / 0	2400 / 0	17000 / 0	**2 / 6**	**2 / 6**
4,4'-DDE	6/10	0.92 J	68 J	NTC17PCSD49	0.76	0.83	NC / 0	NC / 0	2000 / 0	1700 / 0	12000 / 0	**2 / 4**	**2 / 4**
4,4'-DDT	5/10	1.4 J	19 J	NTC17PCSD49	0.76	0.83	NC / 0	NC / 0	2000 / 0	1700 / 0	12000 / 0	**1 / 5**	**1 / 5**
AROCLOR-1260	1/10	7.2 J	7.2 J	NTC17PCSD48	19	22	NC / 0	NC / 0	1000 / 0	220 / 0	1000 / 0	**5 / 1**	**5 / 1**
ENDRIN	2/10	1.5 J	2 J	NTC17PCSD49	0.76	0.84	NC / 0	NC / 0	23000 / 0	18000 / 0	260000 / 0	19 / 0	19 / 0
GAMMA-BHC (LINDANE)	1/10	0.25 J	0.25 J	NTC17PCSD44	0.38	0.44	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	0.39 / 0	0.39 / 0
TOTAL AROCLOR	1/10	7.2	7.2	NTC17PCSD48	19	22	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	50 / 0	50 / 0
TOTAL DDT POS	6/10	6.4	106	NTC17PCSD49	0	0.78	NC / 0	NC / 0	NC / 0	NC / 0	NC / 0	**7 / 5**	**7 / 5**
Inorganics (mg/kg)													
COPPER	10/10	16.3	167	NTC17PCSD48			**19.6 / 7**	**38 / 2**	2900 / 0	2900 / 0	76000 / 0	**16 / 10**	**16 / 10**
LEAD	10/10	8.9	103	NTC17PCSD48			**36 / 2**	**28 / 3**	400 / 0	400 / 0	750 / 0	**31 / 3**	**28 / 3**
MERCURY	5/10	0.018	0.061	NTC17PCSD42	0.014	0.017	**0.06 / 1**	0.07 / 0	23 / 0	23 / 0	610 / 0	0.2 / 0	**0.06 / 1**
ZINC	10/10	43.2	1070	NTC17PCSD48			**95 / 4**	**80 / 5**	23000 / 0	23000 / 0	100000 / 0	**120 / 2**	**80 / 5**

Notes:
The location identification is identical to the sample number.
The column labled "Value / Exceeds" indicates the screening value for the identified criteria and the number of exceedances of that screening level.
Black shading indicates that screening value has been exceeded.

Associated Samples:

NTC17PCSD40	NTC17PCSD45	(ug/kg) - micrograms per kilogram
NTC17PCSD41	NTC17PCSD46	(mg/kg) - Milligrams per kilogram
NTC17PCSD42	NTC17PCSD47	TACO - Tiered Approach to Corrective Action Objectives
NTC17PCSD43	NTC17PCSD48	EPA - Environmental Protection Agency
NTC17PCSD44	NTC17PCSD49	PRG - Preliminary Remediation Goals
		POS - Positive Detections

TABLE 2-4

COMPARISON OF 2001 AND 2008 SAMPLE RESULTS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Sample Number Sample Date Sediment/Soil description Sample Interval (in ft bgs)	Minimum Screening Value (See Table 2-3)	NTC17PCSD01 9/24/2001 Sediment - Dk Brown F-M SAND 0-0.13	NTC17PCSD01 9/24/2001 Sediment - Brown F-C SAND 1-1	NTC17PCSD49 12/9/2008 Native Soil - Brown CLAY with silt/sand 0.75-1.25	NTC17PCSD03 9/24/2001 Sediment - Ol. Gray F-SAND and SILT 0-0.13	NTC17PCSD48 12/9/2008 Native Soil - Gray CLAY little silt t-sand 2.5-3.0	NTC17PCSD08 9/24/2001 Sediment - Ol. Gray F - SAND and SILT 0-0.13	NTC17PCSD08 9/24/2001 Sediment - Ol. Gray F - SAND and SILT 1-1	NTC17PCSD47 12/9/2008 Native Soil - Gray Silty CLAY 2.0-2.5
Semivolatile Organics (ug/kg)									
2-METHYLNAPHTHALENE	368	ND	ND	3.3 J	ND	7.6	ND	ND	20
ACENAPHTHENE	186	ND	ND	1.9 J	ND	4.8	ND	ND	3.8 U
ANTHRACENE	85	**4000**	**1600**	7.8	**410**	20	73 J	**800**	3.8 U
BENZALDEHYDE	NVP	ND	ND	NA	ND	NA	ND	ND	NA
BENZO(A)ANTHRACENE	287	**11000**	**4100**	37	**1400**	33	**430**	**2800**	3.8 U
BENZO(A)PYRENE	62	**11000**	**4000**	37	**1500**	24	**470**	**2900**	3.8 U
BENZO(B)FLUORANTHENE	620	**12000**	**4100**	34	**1500**	20	510	**3200**	3.8 U
BENZO(G,H,I)PERYLENE	170	**7500 J**	**2600**	21	**1200**	12	**420**	**2300**	3.2 J
BENZO(K)FLUORANTHENE	6200	ND	ND	10	ND	6.4	ND	ND	3.8 U
CAPROLACTAM	NVP	ND	ND	NA	ND	NA	ND	ND	NA
CARBAZOLE	NVP	ND	ND	NA	ND	NA	ND	ND	NA
CHRYSENE	400	**12000**	**4200**	39	**1500**	29	**470**	**3000**	3.8 U
DIBENZO(A,H)ANTHRACENE	60	ND	ND	4.2 J	ND	4 U	ND	ND	3.8 U
FLUORANTHENE	2790	**33000**	**13000**	82	**4600**	69	1100	**8200**	5.7
FLUORENE	35	**2400 J**	**840**	2.8 J	**320 J**	9.7	**74 J**	**450**	3.8 U
INDENO(1,2,3-CD)PYRENE	620	**5800 J**	**1600**	17	**680**	4 U	370	**1600**	3.8 U
NAPHTHALENE	340	ND	ND	4.4 U	ND	4 U	ND	ND	6.2
PHENANTHRENE	810	**24000**	**8500**	52	**2600**	78	630	**4600**	24
PYRENE	350	**27000**	**9700**	68	**3400**	59	**940**	**6100**	3.8 U
TOTAL PAHS	4000	**156000**	**56670**	417	**20009**	372.5	**5757**	**37970**	59.1
Pesticides/PCBs (ug/kg)									
4,4'-DDD	2	**25 J**	**3.8**	**19 J**	**63**	**3.8 J**	**4.7**	**14**	0.76 UJ
4,4'-DDE	2	**36 J**	**8.5**	**68 J**	**110**	1.2 J	**11**	**22**	0.76 UJ
4,4'-DDT	1	**32 J**	**9.5**	**19 J**	**190**	**1.4 J**	**7.5**	**15**	0.76 UJ
TOTAL DDT	7	**93**	**21.8**	**106**	**363**	**6.4**	**23.2**	**51**	0.76 U
AROCLOR-1254	NVP	300 J	92	22 UJ	200	20 UJ	40 U	45 U	19 UJ
AROCLOR-1260	5	39 UR	36 U	22 UJ	**150**	7.2 J	40 U	45 U	19 UJ
ENDRIN	16	ND	ND	**2 J**	ND	0.8 UJ	ND	ND	0.76 UJ
GAMMA-BHC (LINDANE)	0.39	ND	ND	0.44 UJ	ND	0.4 UJ	ND	ND	0.38 UJ
TOTAL PCBS	NVP	300	92	NC	350	NC	40	45	NC
ENDOSULFAN I	NVP	2 U	1.8 U	0.44 UJ	21 U	0.4 UJ	2 U	2.3 U	0.38 UJ
ENDOSULFAN II	NVP	**12 J**	**2.8**	0.89 UJ	**4.1 J**	0.8 UJ	**0.55 J**	**0.9 J**	0.76 UJ
TOTAL AROCLOR (Detected)	50	**300 J**	**92**	NC	**350**	7.2	ND	ND	19 U
Inorganics (mg/kg)									
COPPER	16	**368**	**370**	**31.4**	**222**	**167**	**43.1**	**55.8**	22.6
LEAD	28	**322 J**	**187**	**36.6**	**213**	**103**	**73.0**	**71.9**	11.2
MERCURY	0.06	**0.94 J**	**0.31**	0.017 U	**0.25**	0.018	0.05	**0.12**	0.015 U
ZINC	80	**1140 J**	**2620**	**97.3**	**774**	**1070**	**192**	**171**	51

TABLE 2-4

COMPARISON OF 2001 AND 2008 SAMPLE RESULTS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Sample Number Sample Date Sediment/Soil description Sample Interval (in ft bgs)	Minimum Screening Value (See Table 2-3)	NTC17PCSD11 9/23/2001 Sediment - Brown F-M SAND 0-0.13	NTC17PCSD11 9/23/2001 Sediment - Brown F-M SAND 1-1	NTC17PCSD46 12/9/2008 Native Soil - Gray CLAY little silt, sand, gravel 1.0-1.5	NTC17PCSD13 9/23/2001 Sediment - Brown F-M SAND 0-0.13	NTC17PCSD45 12/9/2008 Native Soil - Gray CLAY little silt 0.25-0.75	NTC17PCSD14 9/23/2001 Sediment - Brown F-M SAND 0-0.13	NTC17PCSD14 9/23/2001 Sediment - Brown/Gray M-C SAND with gravel/clay 1-1	NTC17PCSD44 12/9/2008 Native Soil - Brown SAND/SILT/CLAY 0.25-0.75
Semivolatile Organics (ug/kg)									
2-METHYLNAPHTHALENE	368	ND	ND	5.1	ND	7.5	ND	ND	5
ACENAPHTHENE	186	ND	ND	3.8 U	ND	3.9 U	ND	Nd	11
ANTHRACENE	85	**1100**	**310**	3.8 U	**600**	3.9 U	**110 J**	**290**	66
BENZALDEHYDE	NVP	ND	ND	NA	ND	NA	370 U	ND	NA
BENZO(A)ANTHRACENE	287	**2900**	**950**	3.8 U	**2000**	3.9 U	**440**	**500**	260
BENZO(A)PYRENE	62	**2700**	**1200**	3.8 U	**1900**	3.9 U	**410**	**410**	**180**
BENZO(B)FLUORANTHENE	620	**2800**	**1000**	3.8 U	**1900**	3.9 U	440	380	200 J
BENZO(G,H,I)PERYLENE	170	**1500**	**1100**	4.4	**1300**	3.8 J	**260**	**230**	100
BENZO(K)FLUORANTHENE	6200	ND	ND	3.8 U	ND	3.9 U	ND	ND	58
CAPROLACTAM	NVP	ND	ND	NA	ND	NA	370 U	ND	NA
CARBAZOLE	NVP	ND	ND	NA	ND	NA	**720**	ND	NA
CHRYSENE	400	**2900**	**950**	3.8 U	**1900**	3.9 U	**430**	**430**	200 J
DIBENZO(A,H)ANTHRACENE	60	ND	ND	3.8 U	ND	3.9 U	ND	ND	26
FLUORANTHENE	2790	**8400**	**2700**	3.8 U	**5200**	7.6	1200	1300	620 J
FLUORENE	35	**850**	**160**	3.8 U	**280 J**	3.9 U	**80 J**	**150 J**	19
INDENO(1,2,3-CD)PYRENE	620	**1500**	**590**	3.8 U	**920**	3.9 U	170	140 J	88
NAPHTHALENE	340	ND	ND	3.8 U	ND	3.9 U	ND	ND	4.8
PHENANTHRENE	810	**6400**	**1800**	16	**3100**	18	720	**1000**	320 J
PYRENE	350	**6600**	**2100**	3.8 U	**4200**	7.7	**930**	**1000**	**460 J**
TOTAL PAHS	4000	**39250**	**13420**	25.5	**24400**	44.6	**5466**	**6060**	2617.8
Pesticides/PCBs (ug/kg)									
4,4'-DDD	2	**58**	**76**	0.76 UJ	**100**	0.78 UJ	**100**	**180**	**2.1 J**
4,4'-DDE	2	**110**	**160**	0.76 UJ	**110**	0.78 UJ	**150**	**200**	**14 J**
4,4'-DDT	1	**170**	**190**	0.76 UJ	**150**	0.78 UJ	**190**	**190**	**13 J**
TOTAL DDT	7	**338**	**426**	0.76 U	**360**	0.78 U	**440**	**570**	**29.1**
AROCLOR-1254	NVP	37 U	**790**	19 UJ	140	20 UJ	200	40 U	21 UJ
AROCLOR-1260	5	**46**	40 U	19 UJ	**41**	20 UJ	**43**	40 U	21 UJ
ENDRIN	16	ND	ND	0.76 UJ	ND	0.78 UJ	ND	ND	1.5 J
GAMMA-BHC (LINDANE)	0.39	ND	ND	0.38 UJ	ND	0.39 UJ	ND	ND	0.25 J
TOTAL PCBS	NVP	46	790	NC	181	NC	243	40	NC
ENDOSULFAN I	NVP	19 U	41 U	0.38 UJ	18 U	0.39 UJ	38 U	41 U	0.42 UJ
ENDOSULFAN II	NVP	19 U	41 U	0.76 UJ	18 U	0.78 UJ	38 U	41 U	0.27 U
TOTAL AROCLOR (Detected)	50	46	ND	19 U	**181**	20 U	**243**	ND	21 U
Inorganics (mg/kg)									
COPPER	16	**123**	**182**	**19.4**	**197**	**53.5**	**123**	**268**	**32.1**
LEAD	28	**120**	**154**	9.6	**155**	24	**108**	**177**	20.6
MERCURY	0.06	**0.45**	**0.14**	0.014 U	**0.22**	0.015 U	**4.7**	**0.1**	0.038
ZINC	80	**570**	**1260**	43.9	**856**	**230**	**810**	**2180**	**81.3 J**

TABLE 2-4

COMPARISON OF 2001 AND 2008 SAMPLE RESULTS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Sample Number Sample Date Sediment/Soil description Sample Interval (in ft bgs)	Minimum Screening Value (See Table 2-3)	NTC17PCSD17 9/22/2001 Sediment - Brown M-C SAND/GRAVEL 0-0.13	NTC17PCSD17 9/22/2001 Sediment - Brown F-Gravelly SAND 1-1	NTC17PCSD43 12/9/2008 Native Soil - Gray CLAY little silt 1.0-1.5	NTC17PCSD19 9/22/2001 Sediment - Ol. Gray SILT and F-SAND 0-0.13	NTC17PCSD42 12/9/2008 Native Soil - Brown SAND/SILT/CLAY 0.25-0.75	NTC17PCSD21 9/22/2001 Sediment - Brown F-C SAND 0-0.13	NTC17PCSD41 12/8/2008 Native Soil - Gray SILT little clay/sand 0.5-1.0
Semivolatile Organics (ug/kg)								
2-METHYLNAPHTHALENE	368	ND	ND	4.2	ND	7.2	ND	2.3 J
ACENAPHTHENE	186	ND	ND	3.5 J	ND	11	ND	4 U
ANTHRACENE	85	**160**	**87**	12	**290**	71	**120**	3 J
BENZALDEHYDE	NVP	ND	ND	NA	ND	NA	360 U	NA
BENZO(A)ANTHRACENE	287	**530**	**340**	67	**760**	220	**380**	4 U
BENZO(A)PYRENE	62	**500**	**300**	62	**790**	**200**	**330**	4 U
BENZO(B)FLUORANTHENE	620	510	310	74	**790**	240	340	4 U
BENZO(G,H,I)PERYLENE	170	**320**	**200**	38	**540 J**	120	**230**	5.5
BENZO(K)FLUORANTHENE	6200	ND	ND	20	ND	64	ND	4 U
CAPROLACTAM	NVP	ND	ND	NA	ND	NA	360 U	NA
CARBAZOLE	NVP	ND	ND	NA	ND	NA	75 J	NA
CHRYSENE	400	**490**	330	56	**740**	170	350	4 U
DIBENZO(A,H)ANTHRACENE	60	ND	ND	8.1	ND	27 J	ND	4 U
FLUORANTHENE	2790	1300	900	150	2000 J	550	940	9.3
FLUORENE	35	**40 J**	**73 J**	6.3	**120 J**	18	**77**	2.9 J
INDENO(1,2,3-CD)PYRENE	620	180	130	30	320 J	100	140	4 U
NAPHTHALENE	340	ND	ND	4.1 U	ND	6.5	ND	4 U
PHENANTHRENE	810	590	610	110	**1300**	310	500	18
PYRENE	350	**980**	**720**	130	**1500**	**440**	**720**	4 U
TOTAL PAHS	4000	**5920**	**4180**	771.1	**9590**	2554.7	**4345**	41
Pesticides/PCBs (ug/kg)								
4,4'-DDD	2	**30**	**59**	0.83 UJ	**170**	**2.4 J**	**51**	**13 J**
4,4'-DDE	2	**46**	**150**	0.83 UJ	**210**	**8.4 J**	**42**	**7.4 J**
4,4'-DDT	1	**110**	**160**	0.83 UJ	**230**	**5 J**	**62**	**3.9 J**
TOTAL DDT	7	**186**	**369**	0 U	**610**	**15.8**	**155**	**24.3**
AROCLOR-1254	NVP	69	37 U	21 UJ	440	21 UJ	56	20 UJ
AROCLOR-1260	5	36 U	**51**	21 UJ	**110**	21 UJ	36 U	20 UJ
ENDRIN	16	ND	ND	0.83 UJ	ND	0.84 UJ	ND	0.8 UJ
GAMMA-BHC (LINDANE)	0.39	ND	ND	0.41 UJ	ND	0.42 UJ	ND	0.4 UJ
TOTAL PCBS	NVP	69	51	NC	550	NC	56	NC
ENDOSULFAN I	NVP	9.3 U	38 U	0.41 UJ	42 U	0.42 UJ	9.2 U	0.4 UJ
ENDOSULFAN II	NVP	**1.8 J**	38 U	0.83 UJ	42 U	0.84 UJ	**1.1 J**	0.8 UJ
TOTAL AROCLOR (Detected)	50	**69**	**51**	21 U	**550**	21 U	**56**	20 U
Inorganics (mg/kg)								
COPPER	16	**206**	**138**	**22**	**118**	**18.1**	**79.6**	**23.9**
LEAD	28	**135**	**77.1**	9.9	**109**	**33.6**	**45.5**	11.4
MERCURY	0.06	**0.08**	**0.1**	0.023	**0.61**	**0.061**	**0.06**	0.028
ZINC	80	**1210**	**799**	44.3 J	**377 J**	**99.3 J**	**362**	45.3

TABLE 2-4

COMPARISON OF 2001 AND 2008 SAMPLE RESULTS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Sample Number Sample Date Sediment/Soil description Sample Interval (in ft bgs)	Minimum Screening Value (See Table 2-3)	NTC17PCSD23 9/22/2001 Sediment - Brown F - SAND 0-0.13	NTC17PCSD23 9/22/2001 Sediment - Brown F-Gravelly SAND 1-1	NTC17PCSD40 12/8/2008 Native Soil - Gray SILT little clay/sand 1.0-1.5
Semivolatile Organics (ug/kg)				
2-METHYLNAPHTHALENE	368	ND	ND	4 U
ACENAPHTHENE	186	ND	ND	4 U
ANTHRACENE	85	**150**	**390**	4 U
BENZALDEHYDE	NVP	420 U	ND	NA
BENZO(A)ANTHRACENE	287	**470**	**790**	4 U
BENZO(A)PYRENE	62	**470**	**770**	4 U
BENZO(B)FLUORANTHENE	620	450	**730**	4 U
BENZO(G,H,I)PERYLENE	170	85 U	**460**	1.8 J
BENZO(K)FLUORANTHENE	6200	ND	ND	4 U
CAPROLACTAM	NVP	420 U	ND	NA
CARBAZOLE	NVP	250 J	ND	NA
CHRYSENE	400	**450**	**730**	4 U
DIBENZO(A,H)ANTHRACENE	60	ND	ND	4 U
FLUORANTHENE	2790	1300	2400	3.1 J
FLUORENE	35	**76 J**	**240**	4 U
INDENO(1,2,3-CD)PYRENE	620	230	300	4 U
NAPHTHALENE	340	ND	ND	4 U
PHENANTHRENE	810	730	**1900**	3.9 J
PYRENE	350	**1000**	**1800**	4.4
TOTAL PAHS	4000	**5586**	**10920**	13.2
Pesticides/PCBs (ug/kg)				
4,4'-DDD	2	**89**	**45**	**6.1 J**
4,4'-DDE	2	**91**	**40**	0.92 J
4,4'-DDT	1	**81**	**90**	0.79 UJ
TOTAL DDT	7	**261**	**175**	**7.02**
AROCLOR-1254	NVP	42 U	39 U	20 UJ
AROCLOR-1260	5	42 U	39 U	20 UJ
ENDRIN	16	ND	ND	0.79 UJ
GAMMA-BHC (LINDANE)	0.39	ND	ND	0.4 UJ
TOTAL PCBS	NVP	42	39	NC
ENDOSULFAN I	NVP	22 U	10 U	0.4 UJ
ENDOSULFAN II	NVP	22 U	10 U	0.79 UJ
TOTAL AROCLOR (Detected)	50	ND	ND	NC
Inorganics (mg/kg)				
COPPER	16	**50.3**	**167**	**16.3**
LEAD	28	**57.6**	**159**	8.9
MERCURY	0.06	**0.09**	**0.15**	0.016 U
ZINC	80	**279**	**1240**	43.2

NVP - No screening value provided
J - Estimated concentration
U - Contaminant not detected at indicated Concentration
ND - Contaminated not detected
NC - Value not calculated
NA - Contaminant not analyzed

(ug/kg) - micrograms per kilogram
(mg/kg) - Milligrams per kilogram
PCB - Polychlorinated biphenyl
PAH - Polynuclear aromatic hydrocarbon
ft bgs - Feet below ground surface

Notes:
Black shading indicates exceedance of minimum screening value.
Gray shading indicates December 2008 sample.

TABLE 2-5

SUMMARY OF POTENTIAL HUMAN HEALTH RISK REDUCTION FOR CONTACT WITH SEDIMENT IN THE NORTH BRANCH
SITE 17 - PETTIBONE CREEK
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Receptor	ILCR for Contaminated (Non-Native) Sediment	ILCR for Native Sediment
Adult Recreational User	8.0E-06	4.0E-07
Adolescent Recreational User	3.0E-06	3.0E-05

RI-RA HHRA – Remedial Investigation Risk Assessment Human Health Risk Assessment

ILCR – Incremental lifetime cancer risk

HI – Hazard index

NA – Not applicable. HIs were not calculated because only potentially carcinogenic chemicals exceeded screening values.

TABLE 2-6

POTENTIAL ECOLOGICAL RISK REDUCTION FOR PETTIBONE CREEK
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Receptor	Chemicals of Concern	RI/RA ERA EEQ[1]	Expected Post Remediation EEQ
Benthic invertebrates	PAHs	2.3 to 1,364	0.03 to 2.5
	4,4'-DDT	1800	19
	4,4'-DDE	105	34
	4,4'-DDD	85	9.5
	Endosulfan II	80	NC
	Copper	30	10.5
	Lead	10	3.2
	Mercury	24	0.3
	Zinc	18	9.1
Piscivorous Birds	4,4'-DDT	43	1.1
	4,4'-DDE	94	11.7

RI RA ERA - Remedial Investigation-Risk Assessment Ecological Risk Assessment
NC - Not calculated. This chemical was not detected in 2008

1 EEQ – Environmental Effects Quotient calculated by dividing chemical concentration or chronic daily intake by appropriate sediment benchmarks/toxicity reference values. Benthic Invertebrate EEQs calculated using Screening Values from RI Table 7-2 and maximum sediment concentrations. Piscivorous Bird EEQs are calculated using mean sediment concentrations, average inputs, and using the Lowest Observable Adverse Effect Level (LOAEL).

TABLE 2-7

COMPARISON OF 2008 NATIVE SEDIMENT DATA TO BENTHIC INVERTEBRATE PRGS AT PETTIBONE CREEK
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Chemicals of Concern	PRGs[1]	Number of Sample Stations Exceeding PRGs	Sample Station Exceeding PRGs	Concentration Exceeding PRGs
Organics (ug/kg)				
PAHs	640-35,000	0	None	None
4,4'-DDD	20	0	None	None
4,4'-DDE	15	1	NTC17PCSD49	68
4,4'-DDT	7	2	NTC17PCSD49 NTC17PCSD44	19 13
Endosulfan II	0.5	0	Not Detected	None
Inorganics (mg/kg)				
Copper	149	1	NTC17PCSD48	167
Lead	128	0	None	
Mercury	1.06	0	None	
Zinc	459	1	NTC17PCSD48	1070

1 PRGs from Table 2-6 of FS (TtNUS, 2005)

PRG - Preliminary Remediation Goals
PAH - Polynuclear aromatic hydrocarbon
ug/kg - micrograms per kilogram
mg/kg- milligrams per kilogram

TABLE 2-8

COMPARISON OF 2008 NATIVE SEDIMENT TO PISCIVOROUS BIRD PRGS AT PETTIBONE CREEK
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Chemicals of Concern	PRGs (ug/kg)	Mean 2008 Native Sediment (ug/kg)
4,4'-DDE	16	10.3
4,4'-DDT	75	4.6

PRG - Preliminary Remediation Goals
ug/kg - micrograms per kilogram

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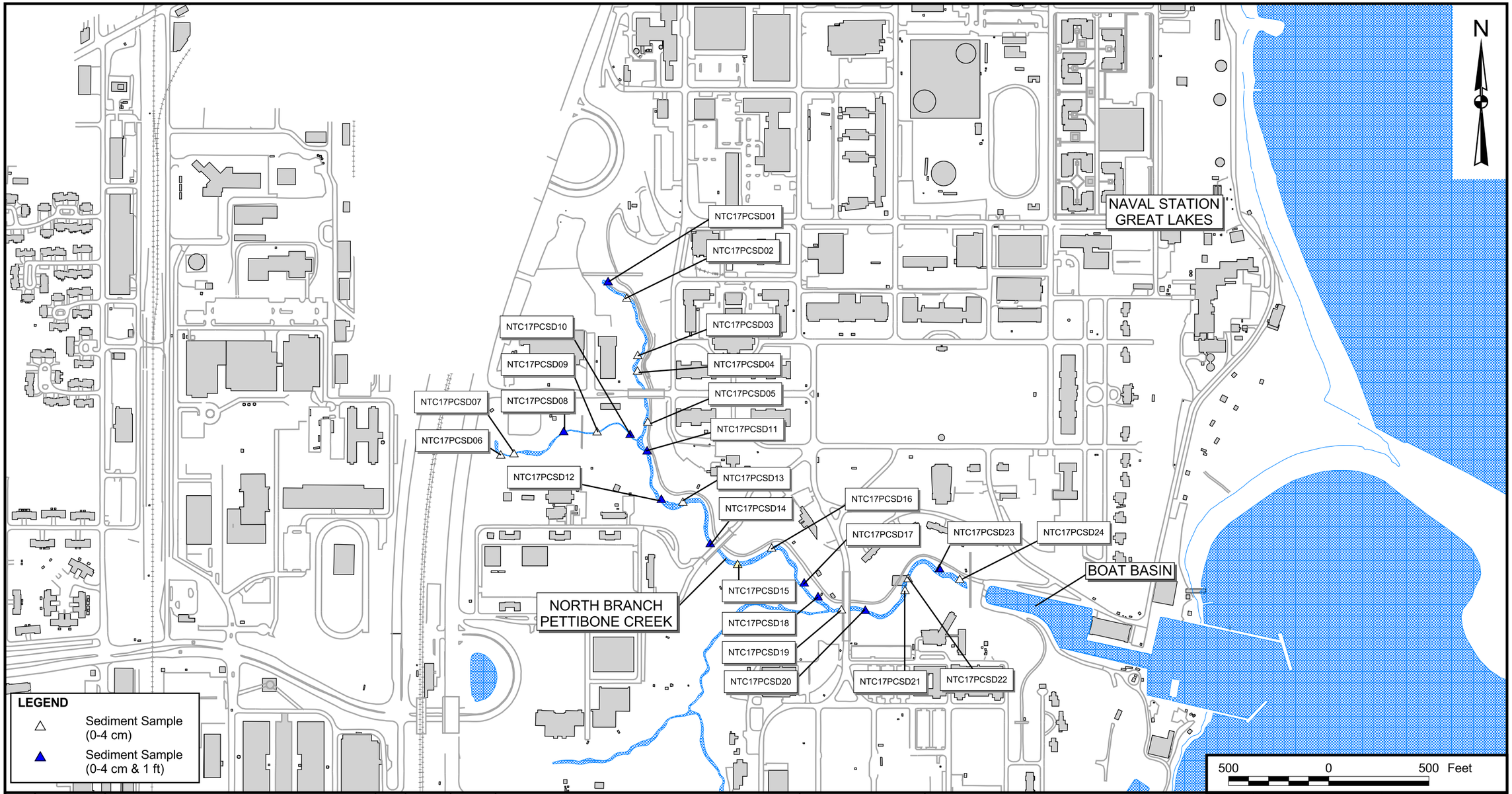

NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY S. STROZ	DATE 02/26/08
CHECKED BY T. SMITH	DATE 05/20/09
COST/SCHEDULE-AREA	
SCALE AS NOTED	

Tetra Tech NUS, Inc.

2001 RI SEDIMENT SAMPLES
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER 01021	OWNER NUMBER 0747
APPROVED BY RFD	5/15/09
APPROVED BY	DATE —
DRAWING NO. FIGURE 2-1	REV 0

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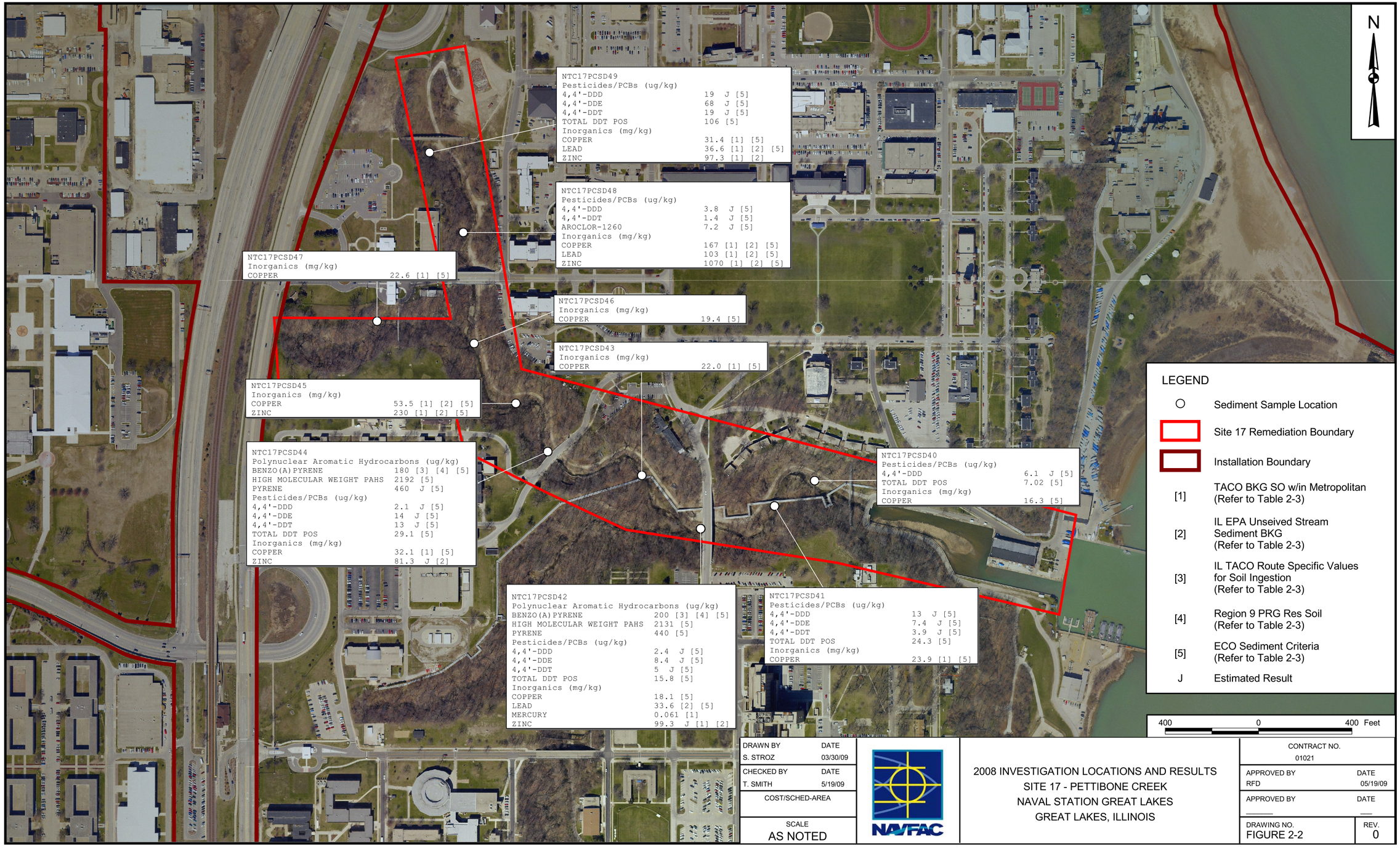


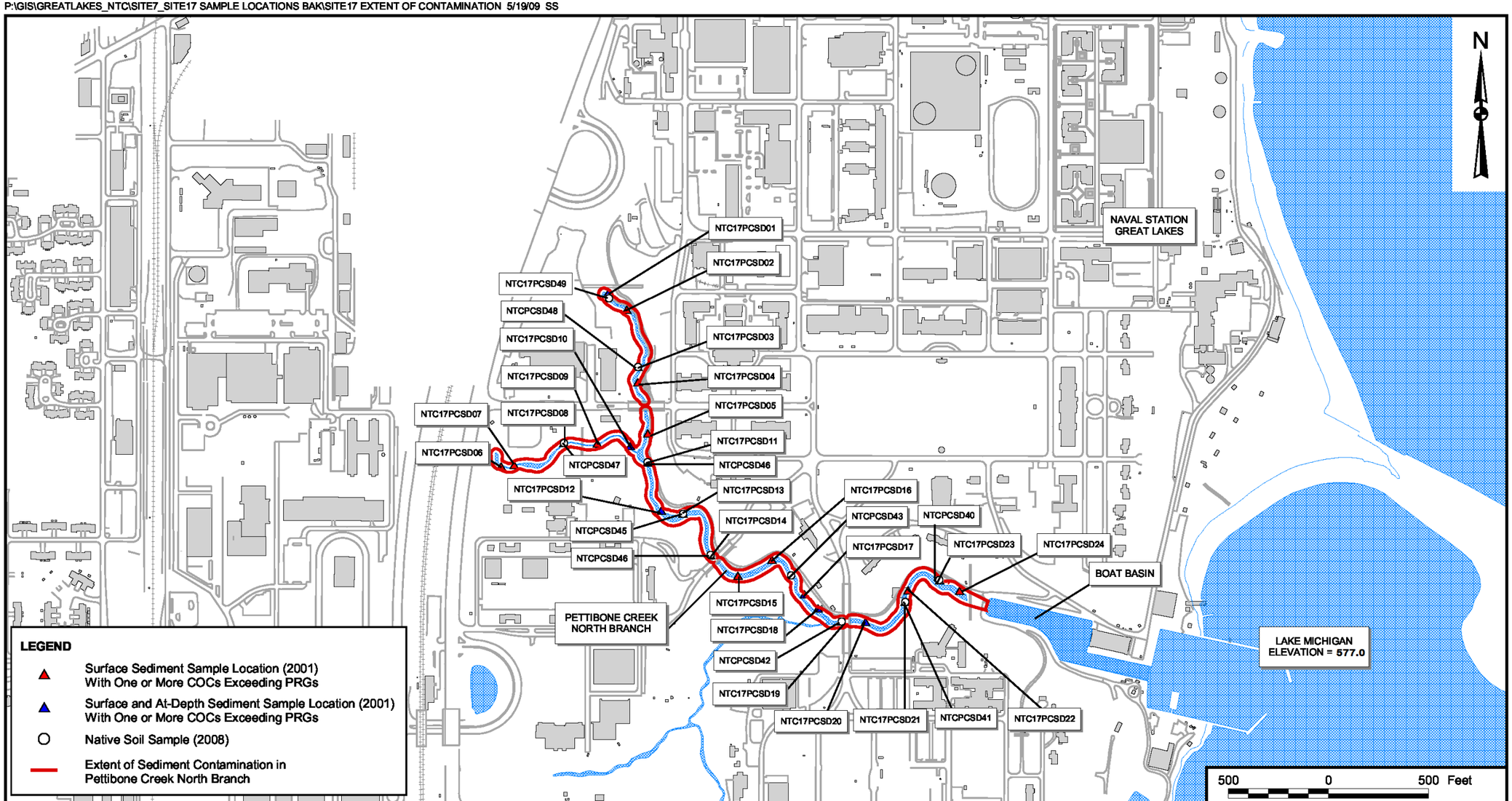
DRAWN BY	DATE
S. STROZ	03/30/09
CHECKED BY	DATE
T. SMITH	5/19/09
COST/SCHED-AREA	
SCALE	AS NOTED

NAVFAC

2008 INVESTIGATION LOCATIONS AND RESULTS
SITE 17 - PETTIBONE CREEK
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NO.	
01021	
APPROVED BY	DATE
RFD	05/19/09
APPROVED BY	DATE
DRAWING NO.	REV.
FIGURE 2-2	0

P:\GIS\GREATLAKES_NTC\SITE7_SITE17 SAMPLE LOCATIONS BAK\SITE17 EXTENT OF CONTAMINATION 5/19/09 SS



NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY S. STROZ	DATE 2/26/08
CHECKED BY T. SMITH	DATE 5/19/09
COST/SCHEDULE-AREA	
SCALE AS NOTED	

Tetra Tech NUS, Inc.

EXTENT OF CONTAMINATION
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER 01021	OWNER NUMBER 0474
APPROVED BY RFD	5/15/09
APPROVED BY	DATE —
DRAWING NO. FIGURE 2-3	REV 0

3.0 REMEDIAL ACTION WORK PLAN

The intent of this RAP is to remove the brown/tan silty sand sediment down to the native blue gray clay from the North Branch Pettibone Creek portion of Site 17. The activities associated with this RAP are intended to decrease human health and ecological risks associated with the sediment in the North Branch Pettibone Creek within the limits of Naval Station Great Lakes property.

3.1 DESCRIPTION OF THE REMEDIAL ACTION

The RAP specifies the removal of contaminated sediment from Site 17 Pettibone Creek within the property limits of Naval Station Great Lakes. In addition, the RAP specifies the restoration of the creek and tributary disturbed/impacted by RAP activities. The contaminated sediment to be removed has been identified as containing PAHs, PCBs, pesticides, and metals. A list of the specific COCs detected in the sediment is presented in Section 2.4, COCs based on previous investigations. The volume of sediment to be excavated are in-place estimates; it is anticipated that this volume will increase 2 to 5 percent after the sediment is excavated and is in an unconsolidated state.

A work assignment responsibility chart (Table 3-1) identifies the responsibilities of the Environmental Multiple Award Contract (EMAC) contractor, Naval Station Great Lakes, and Tetra Tech in the implementation of this RAP.

Specifically, this RAP consists of the following major components:

- Sediment Excavation/Removal - Sediment with PAH, PCB, pesticide, and metal concentrations greater than PRGs are present in the North Branch Pettibone Creek (3,540 linear feet of stream) and a small unnamed tributary that feeds the North Branch Pettibone Creek from the west (900 linear feet of tributary). The sediment will be excavated/removed from the creek and tributary to a depth that exposes native stream bed soil. The excavated sediment will be dewatered, processed, characterized for disposal purposes, and transported and disposed off site. The locations of the sediment excavation/removal areas are identified on Figure 3-1.

- Dewatering of Excavated/Removed Sediment - Prior to off-site disposal, the sediment will be stockpiled on a dewatering pad located within the construction area. It is expected that the water drained from the sediment will be filtered and discharged back to Pettibone Creek. It is the EMAC contractor responsibility to verify the water can be discharged back to Pettibone Creek. Due to the sandy nature of the sediment to be removed from Pettibone Creek, the volume of water collected

through dewatering is not expected to be large, unless sediment excavation/removal is performed during periods of heavy rain.

- Sediment Processing – During excavation, larger stone and rock material (greater than 3-inches in diameter) will be removed along with the sediment. Following dewatering and prior to off-site disposal characterization sampling, the sediment will be processed through a screening mechanism that will remove rock material with a nominal diameter of 3 inches or more. This material will be stockpiled, washed if necessary, and reused during stream restoration.

- Stream Backfilling and Restoration - After the collection of post-removal samples, the creek and tributary will be backfilled to pre-construction conditions and restored using stabilization practices that include use of the stabilized rock material from the sediment processing, gravel, rock, and vegetation.

- Verification Sampling and Analysis - At the completion of remedial action activities and following the removal of the support facilities (e.g., haul roads, dewatering pad, decontamination pad, and material storage area), the Navy's representative will collect verification samples within the footprint of each support facility to confirm that remedial action activities did not result in the spreading of contamination. If it is determined that contamination was spread to the soil below the support facilities, the EMAC contractor will be required to remove and dispose of that contamination at their expense. Section 5.0 presents the verification sampling and analysis procedures.

- Off-Site Disposal of Sediments - Sediments will be disposed at an off-site Naval Station Great Lakes-approved, waste disposal facility. It is expected that the excavated sediments can be directly loaded and transported to a non-hazardous waste disposal facility following dewatering and characterization. Verification of this disposal assumption will be the responsibility of the EMAC contractor through characterization sampling and analysis that follows the Naval Station Great Lakes Hazardous Waste Management Plan (NSGL, 2002) and satisfies the requirements of the selected and approved disposal facility.

- Note that the outfalls of existing stormwater piping emptying into the North Branch of Pettibone Creek typically are unprotected and likely contributing significantly to the stream bank erosion. The Navy plans to conduct future studies to assess potential remedies for addressing unprotected piping outfalls. Addressing these outfalls is not within the scope of this action. However, allowing existing stormwater outfalls to remain unprotected will continue to contribute to the stream bank deterioration of Pettibone Creek, even upon implementing currently envisioned stream bank stabilization measures.

3.2 PERFORMANCE STANDARDS

The performance standards for this RAP are presented in the following paragraphs.

3.2.1 Stream Excavation

The sediment in the North Branch Pettibone Creek and tributary, within the limits identified in Figure 3-1, have PAH, PCB, pesticide, and metal COC concentrations greater than PRGs. This sediment will be removed from the identified limits to a depth that exposes the native stream bed soil. For comparison purposes, the sediment to be removed is brown to brownish gray in color and consists of sand and silty sand. The native stream bed soil is gray in color and consists of clay and silty clay. The removed sediment will be processed, characterized, and disposed at an approved off-site non-hazardous waste disposal facility. Excavated sediment will be placed in a small off-road dump truck with a sealed tail-gate to prevent the loss of sediment while the material is transported to a dewatering pad. The excavated sediment will gravity-drain within the dewatering pad prior to processing, characterization, off-site transport, and disposal. Creek and tributary excavation will occur along the North Branch Pettibone Creek upstream of the Boat Basin to the discharge end of the culverts located near Sheridan Road at the northern Naval Station Great Lakes property boundary. Sediment will also be removed from the unnamed tributary the feeds North Branch Pettibone Creek within the Naval Station property limits, north of the confluence of the North and South Branches of Pettibone Creek.

Because the remedial action construction activities will be occurring within a perennial stream, excavation of sediments will begin at the upstream reaches of the removal limits and proceed downstream in manageable construction increments such as 1) the culverts to the tributary, 2) the tributary to confluence with the South Branch, and 3) the confluence with the South Branch to the Boat Basin. Creek and tributary increments in which construction activities will occur will be isolated from the rest of the creek and tributary using a portable dam and a filtration device. The portable dam will be located on the upstream end of each construction increment. This portable dam will be impermeable to prevent flow into the construction area. The filtration device will be located on the downstream end of each construction increment. This filtration device will be a permeable structure designed to trap sediment but allow water to pass. During operational hours, the stream must be diverted around the construction area. At the end of each work day and during storm events (down time), a flexible pipe or series of flexible pipes will be placed through the construction area discharging downstream of the construction area. This pipe will be used to convey twice the base flow through the construction areas during operation down times. To allow for gravity flow through the piping, the pipes used to convey flow through the construction areas must be sized so that the exit invert elevation of the pipe is a minimum of one full inside pipe diameter below the inlet invert elevation of the pipe. Pipe sizes and diversion system sizes are not provided because the length of construction increment will be determined by the EMAC contractor. Prior to starting excavation

within the next downstream construction area, the current construction area must be restored and the portable dam and filtration structures must be moved.

The estimated volume of sediment to be removed from the North Branch Pettibone Creek and the unnamed tributary to the North Branch Pettibone Creek is based on the average thickness of sediment, average width of the stream (base width plus height of channel banks), and length of each stream segment. The average depth of sediment (1 foot) was determined during the December 2008 investigation (see Section 2.4). However, the EMAC contractor should expect that portions of the creek and tributary will require no sediment removal and portions of the creek and tributary will require removal of sediment in layers that exceed a depth of 3 feet. The extent of excavation is identified on Figure 3-1. A typical excavation detail is provided as Figure 3-2. The calculations for excavated sediment volumes are provided in Appendix D. The average channel dimensions and anticipated sediment volume from each stream segment are summarized below.

Creek/Tributary	Avg. Sediment Thickness	Avg. Stream Width	Stream Length	Volume of Sediment
North Branch Pettibone Creek (Boat Basin to North/South Branch Junction)	1 foot	25 feet	1,000 feet	930 cy
North Branch Pettibone Creek (North/South Branch Junction to Tributary)	1 foot	20 feet	1,580 feet	1,170 cy
North Branch Pettibone Creek (Tributary to Upstream Culverts)	1 foot	15 feet	960 feet	530 cy
Tributary to North Branch Pettibone Creek	1 foot	15 feet	900 feet	500 cy
Total Volume of Stream Sediment to be Excavated				**3,130 cy**

In addition to the sediment material, man-made materials (concrete, pipe material, lumber, etc.) and rock (3-inch nominal diameter and greater) are also expected within the limits of excavation. Man-made materials will be cleaned of adhering sediments and stockpiled for off-site disposal as construction debris. Unless otherwise indicated, man-made material encountered outside the stream (excavation area) will not be removed and will remain in place. Rock material will be excavated along with the sediment. Large rock material (average nominal diameter of 9 inches or more) will be removed, cleaned of adhering sediment, and placed along the side the stream (out of the way of construction activities) in the general vicinity from where they were removed so that they can be placed back in the stream during restoration activities. Note, as with the man-made material, rock encountered outside the limits of excavation, will remain in place. The following table summarizes the anticipated volumes of material to be removed from

North Branch Pettibone Creek and tributary within the limits of excavation (volume calculations are provided in Appendix D).

Material	Estimated Volume	Material Disposition
Sediment	3,130 cy	Off-site disposal (non-hazardous subtitle D)
Man-made Material	30 cy	Off-site disposal (non-hazardous construction debris)
Rock Material	1,440 cy	Reused for Stream Restoration
Total Volume removed from North Branch Pettibone Creek	4,600 cy	NA

Sediment that accumulates at the erosion and sediment control devices (see Section 4.0) prior to stream segment restoration and completion of sediment off-site disposal will be disposed off site along with the contaminated sediment. Following verification of contaminated sediment removal, sediment that accumulates in the erosion and sediment control devices will be used to restore the areas of disturbance.

To move excavated sediment, rock, and man-made materials from the excavation areas to the dewatering and process locations, the EMAC contractor may use the existing roadway along North Branch Pettibone Creek. The EMAC contractor will ensure that this access road is not contaminated with excavated sediment. In the event the EMAC contractor spills excavated sediments on this access road, the EMAC contractor will be responsible for removing the contaminated sediments along with the impacted surface soil, verifying that the contaminated materials have been removed, and disposing of that material at their expense.

3.2.2 Dewatering and Processing

Excavated/removed rock and sediment will be transported to a centrally located dewatering pad where the sediment can be dewatered prior to processing, off-site transportation, and off-site disposal. This material will be placed on the dewatering pad at a lift thickness no greater than 3 feet and allowed to drain by gravity. The dewatering pad must be constructed in accordance with Section 3.2.9. It is estimated that following 24 hours of dewatering, the moisture content of the material will have been sufficiently reduced to allow the material to be processed. Following dewatering, the EMAC contractor will process the material through a screening device capable of segregating rock with a nominal diameter of 3 inches or greater from the sediment. This segregated rock material will be stockpiled for reuse during stream restoration activities. Based on site observations, it is anticipated that approximately 20 percent of the excavated/removed material will contain rock with a nominal diameter of 3 inches or more, resulting in a

retained rock volume of approximately 620 cy. The removed rock fraction will be washed within a containment system to remove adhering sediment particles, and sediment particles removed will be dewatered and added to the sediment to be disposed off site. Water used in the washing process will be filtered and tested to determine the proper disposal method.

Following material processing, the EMAC contractor will collect the required disposal characterization samples from the segregated sediment pile (material passing through a 3-inch screen). The disposal characterization sampling will follow the requirements discussed in the following sections and in Section 5.0 and any additional sampling requirements established by the selected and approved disposal facility. Following processing and sampling, the sediment will not require the addition of an absorbent agent to be suitable for transportation and disposal.

The contractor should have the capacity to store and transport the water created through the material handling and transfer process, pore water eminating from material removal, and waters used in the washing of rocks greater than three-inches in nominal diameter. Also, upland soils should be segregated from sediments during the sediment dewatering process in order to minimize the total quantity of water requiring treatment.

3.2.3 Post-Removal Sampling and Analysis

Post-removal samples will not be collected by the Navy from the native stream bed soil following removal of overlying sediment.

3.2.4 Disposal

Following the dewatering process, excavated sediments will be sampled and analyzed for waste disposal characterization in accordance with the Naval Station Great Lakes Hazardous Waste Management Plan (NSGL, 2002). In addition, the EMAC contractor is responsible for satisfying the disposal requirements of the selected and approved disposal facility. Section 5.0 presents the Naval Station Great Lakes sampling requirements for off-site disposal. It is anticipated that the excavated sediment will be disposed as non-hazardous waste in a Subtitle D (nonhazardous) Landfill. In the event that excavated sediment characterization identifies a volume of sediment as a hazardous waste, the volume of hazardous sediment will be disposed of within a Subtitle C (hazardous) landfill or pre-treatment will be required to allow for non-hazardous disposal. The following is a summary of the volumes expected to be disposed off site.

Locations	Volume
North Branch Pettibone Creek	2,630 cubic yards
Tributary to North Branch Pettibone Creek	500 cubic yards
Man-Made Debris	30 cubic yards
Material in Sediment Usable for Restoration	(620 cubic yards)
Total Off-site Disposal Volume	**2,540 cubic yards**

As indicated above, it is assumed that all excavated sediment and man-made debris will be disposed as non-hazardous waste. This assumption must be verified through disposal characterization samples.

3.2.5 Stream Backfilling/Restoration

Restoration activities associated with the stream excavation areas include seeding and placing bank-run sands and gravels (imported from an off-site source), retained rock from sediment processing, and large rocks removed during excavation. Seeding will be performed on the banks of the excavated creek and tributary. Placing bank-run sands and gravels, rocks retained from sediment processing, and large rocks moved aside during excavation will be performed within the limits of the disturbed stream bed. The EMAC contractor will identify and document pre-construction stream conditions and take photographs of natural pools, locations of natural aquatic features, and locations of stream bed condition transitions prior to excavation so that disturbed stream sections can be restored to pre-construction conditions.

The bank-run sand and gravel obtained from an off-site borrow source will have properties similar to the exposed North Branch Pettibone Creek sediment and will be subject to analytical testing to assure that the material satisfies the following requirements:

- Total petroleum hydrocarbon, diesel-range organics, USEPA SW-845 8015M DRO - less than 1 part per million (ppm)

- Total petroleum hydrocarbon, gasoline-range organics, USEPA SW-845 8015M GRO - less than 1 ppm

- Sum of benzene, toluene, ethylbenzene, and xylenes, USEPA SW-846 5030/8021 - less than 1 ppm

- Characteristic waste determination (ignitability, corrosivity, reactivity, and toxicity), USEPA SW-846 1311 - shall not fail the test for characteristic waste

- PAH COCs only, USEPA SW-846 8310 – less than individual PRGs (COCs and their PRGs are identified in Table 2-5).

- Pesticide COCs only, USEPA SW-846 8081A – less than individual PRGs (COCs and their PRGs are identified in Table 2-5).

- PCB COCs only, USEPA SW-846 8082 – less than individual PRGs (COCs and their PRGs are identified in Table 2-5).

- Metal COCs only, USEPA SW-846 6010B/7471A – less than individual PRGs (COCs and their PRGs are identified in Table 2-5).

Additionally, the backfill soil for the stream excavation areas will be placed and compacted by track-walking across the backfilled area with a track-type tractor or equivalent. The backfill material to be used to re-establish the creek and tributary beds will satisfy the Illinois Department of Transportation (Illinois DOT) requirements for bank-run sands and gravel. Large rocks that were removed from the creek and tributary, cleaned, and saved during excavation activities and smaller rocks that were removed from the waste stream through screening will be used to help re-establish the creek and tributary. The creek and tributary banks will be lined with large rock material average stone size of 1.5 feet (nominal diameter) with a unit weight of 150 pounds per cubic foot. Figure 3-3 presents the typical backfilling detail.

3.2.6 Verification Sampling and Analysis

Following the completion of the remedial action activities, verification samples will be collected from the surface soil below the decontamination pad, material storage area, dewatering pad, temporary access roads, and any other construction support features on which contaminated sediment was placed to make sure contamination was not spread during remedial action activities. The verification samples will be collected by the Navy's representative. Although not required, the EMAC contractor may collect pre-excavation samples in areas where support facilities are planned, so that results of the pre-construction samples can be compared to verification sample results. If verification sample results exceed the PRGs, or pre-construction sample results and PRGs, the EMAC contractor will remove the impacted soil and dispose of this soil at the same facility as the contaminated sediment at their expense. Verification sampling and analysis procedures are provided in Section 5.0.

3.2.7 Erosion and Sediment Control

Before excavation activities begin, erosion and sediment controls will be established to prevent impacts to surface water bodies (North Branch Pettibone Creek, Boat Basin, and Lake Michigan) downstream of the disturbance areas. Implementation (placement and maintenance) of erosion and sediment control devices must comply with the requirements identified in the Illinois Procedures and Standards for Urban

Soil Erosion and Sediment Control Handbook (Illinois EPA, 1988). During excavation, backfilling, and restoration operations and until vegetation is established, the erosion and sediment controls will be regularly inspected and maintained. Erosion and sediment control requirements to be complied with during RAP implementation are identified in Section 4.0 of this report.

3.2.8 Stabilized Construction Entrance

Ingress and egress to and from the disturbed areas will be controlled using a stabilized construction entrance, which is described in detail in Section 4.0. The EMAC contractor is required to minimize the amount of disturbance to the wooded areas adjacent to where excavation activities will be performed. As a result, the EMAC contractor may use the existing access road along the northern side of Pettibone Creek to access work areas. The EMAC contractor will be required to have a stabilized construction entrance at both ends of this access road or restrict traffic to only one end of this access road.

3.2.9 Decontamination Pad

A temporary decontamination pad will be set up to clean equipment used to excavate and transport contaminated sediment. The pad will be sized to accommodate the equipment to be used at the site and will be constructed in a manner that contains the contaminated materials removed from equipment and the liquids used to clean the equipment. Contaminated materials removed from the equipment will be disposed off site with the excavated sediment. Wash water will be filtered, characterized, and discharged to the creek or tributary. Additional decontamination pad requirements are discussed in Section 4.5. Care will be taken to keep off-road transport equipment clean to minimize the spread of contaminated sediment to areas adjacent to the excavations or the access road. Any soil or sediment removal from these areas and the associated disposal and restoration costs will be the responsibility of the EMAC contractor.

3.2.10 Dewatering Pad

A temporary dewatering pad will be set up to dewater sediments excavated from the identified excavation areas. The dewatering pad will be sized to accommodate excavated sediments, material processing equipment, and loading equipment as necessary. The dewatering pad will be constructed in such a manner that will retain all materials and allow the water to drain by gravity from the sediment and be collected in a sump. The collected water will then be filtered to remove any remaining sediments. Following filtration, with the approval of the Officer in Charge of Construction (OICC), the water will be discharged back to a stabilized portion of the creek or tributary. At a minimum, the dewatering pad shall be constructed of a minimum 10-mil-thick polyethylene geomembrane overlain by a 6-inch thick gravel drainage layer (the EMAC contractor should evaluate the geomembrane thickness and gravel layer

thickness to support the equipment used in this area). During rain events and downtime, stockpiled materials within the dewatering pad must be covered with a minimum 8-mil-thick polyethylene geomembrane to prevent movement of material to surrounding areas and to minimize collection of additional water. The geomembrane cover will be secured daily. Additional dewatering pad requirements are discussed in Section 4.5.

3.2.11 Access Roads

As indicated above, the existing access road along the northern side of Pettibone Creek will be available to the EMAC contractor to access the excavation areas. This access road will provide access to areas of the excavation with the exception of the tributary that feeds North Branch Pettibone Creek from the west, near the Farragut Avenue Bridge. Access to this portion of the excavation area will require the construction of a temporary access road or use of the stream bed itself. Material for construction of the temporary access road will be restricted to wood chips and/or mulch material obtained from an on-site or off-site borrow source and will be left in place following the completion of RAP activities. The existing access road along Pettibone Creek will be restored to pre-construction conditions or better following RAP implementation.

3.2.12 Clearing

Clearing will be performed only within the limits of disturbance shown on Figure 3-1. Clearing activities will be kept to a minimum to minimize impacts to natural habitat. It is anticipated that the EMAC contractor will need to clear some trees and underbrush between the existing access road and Pettibone Creek to access the creek with excavation and restoration equipment. However, the EMAC contractor will be restricted to clearing one access point to each length of disturbed stream segment. Clearing vegetation along the entire length of disturbed stream segment will not be allowed. Cleared vegetation will be chipped and used for the construction of the temporary access road along the western tributary or stored where directed by the OICC. Prior to the removal of standing trees, the EMAC contractor will identify trees to be removed and approval for tree removal must be obtained from the OICC and Naval Station Great Lakes Environmental prior to removal. Tree removal shall be approved by the NSGL Natural Resources Program Manager prior to commencing removal activities.

3.3 SEQUENCE OF RAP IMPLEMENTATION

The time required to perform the proposed RAP activities at the site is estimated to be approximately 15 weeks. The generalized sequence of construction activities is presented below. This sequence of construction is subject to change based on the EMAC contractor's work plan.

1. Hold a pre-remedial action implementation meeting with the Naval Station Great Lakes OICC, Contracting Officer, EMAC contractor, and Tetra Tech, at a minimum.

2. Inspect limits of Pettibone Creek excavation area to document existing site conditions and overhead and underground utility locations, and obtain the required permits as detailed in Table 3-1.

3. Install perimeter controls for the gravel construction entrance(s) and construct the entrance(s). Install the remaining perimeter controls as indicated in the Erosion and Sediment Control Plan (Section 4.0).

4. Clear areas for support features including, but not limited to, the decontamination pad, dewatering pad, and materials storage area. Construct the support features.

5. Begin excavating sediments from the upper reaches of the Pettibone Creek excavation area by establishing an isolated stream segment using an upstream impermeable dam structure and a downstream permeable dam structure. Excavation should continue from the uppermost reaches and continue in the direction of stream flow in consecutive stream segments that do not exceed 300 feet in length. Following excavation, restore the drainage channels as required (restoration includes stream backfilling, and seeding). Following stream restoration, move the permeable and impermeable dam structures to the next downstream stream segment and repeat the excavation, sampling, and restoration process.

6. Transport excavated sediments to the dewatering pad. Mixing excavated sediments to promote additional dewatering is allowed. Following dewatering, process the excavated material to remove reusable material from the waste stream. Following material processing, collect disposal characterization samples from the sediment stockpiled for off-site disposal. After obtaining permission from the OICC and Naval Station Great Lakes-approved off-site disposal facility, load and transport sediment to the Naval Station Great Lakes-approved off-site disposal facility. During excavation, material processing, and loading operations, maintain erosion and sediment controls.

7. Following transportation and disposal of the excavated sediments and restoration of the construction increments within North Branch Pettibone Creek and tributary, remove the dewatering pad, decontamination pad, and the support facilities. The Navy's representative will collect verification samples from within the footprint of the support features including the access roads and temporary access road, as described in Section 5.0. Following verification that the temporary access roads and the ground below the support features was not impacted by construction activities, regrade as necessary and establish permanent stabilization.

8. Following permanent stabilization of the disturbed areas, and with the approval of the OICC, remove the remaining perimeter controls and immediately stabilize the remaining disturbed areas.

3.4 STORMWATER POLLUTION PREVENTION

The disturbed area is estimated to be approximately 2.3 acres (including support areas and access roads); therefore, an Illinois DOT Stormwater General Permit is required (stormwater permits are required for disturbances greater than 1 acre). In addition, because RAP activities include working in and around a water course, United States Army Corps of Engineers permits are also required. These permits are discussed in Section 3.5.2 and are identified on Table 3-1. Additionally, RAP implementation activities require the use of best management practices for erosion and sediment control and stormwater pollution prevention as described in Section 4.0.

The limits of construction are confined to the limits of Pettibone Creek itself; therefore, the watershed that contributes flow to the construction site will remain unchanged between pre- and post-construction conditions. Additionally, the stream will be restored to its original alignment. Therefore, pre- and post-construction runoff from the limits of disturbance will be the same and additional stormwater detention capacity is not required. However, the existing flows conveyed by Pettibone Creek are often greater than the current stream depth and alignment can handle. As a result, severe erosion occurs during storm events. The EMAC contractor should be prepared for storm events to minimize disruption to the construction schedule.

3.5 OTHER RAP IMPLEMENTATION REQUIREMENTS

3.5.1 Existing Stabilization Structures

During the removal of contaminated sediment, the EMAC contractor will encounter man made slope stabilization devices. Construction activities must be performed in a manner that does not disturb these stabilization features. The restoration of these stabilization features is not a part of this RAP.

3.5.2 Permits

The removal of contaminated sediments from Pettibone Creek involves excavation and filling of wetlands (Pettibone Creek and its adjacent banks do not qualify as jurisdictional wetlands though the channel itself does qualify as a jurisdictional 'waters of the United States' below the OHWM), which would require a Section 404 permit under the Federal Clean Water Act. This would require a Category 13 Bank Stabilization Permit.

The project also requires a regional statewide permit under the Illinois Rivers, Lakes, and Streams Act, which regulates activities in floodplains designated by Federal Emergency Management Administration (FEMA) or in streams with an upstream watershed area of over 1 square mile. The permit is required because of the associated upstream watershed. Floodplains are not found within the project area due to the steep stream banks that characterize the water course. The Lake County Stormwater Management Commission would issue the permit as the delegated authority under this legislation.

In addition to Lake County requirements, the Illinois Soil and Water Conservation District requires the submission of erosion and sediment control plans, stormwater pollution prevention plans, notice of intent forms, and notice of termination forms. The Illinois Soil and Water Conservation District has developed requirements for the contents of these plans and will provide the EMAC contractor with the required notification forms.

3.5.3 Utilities

The EMAC contractor is required to verify the utility locations and adequately protect any utilities located in the active work areas before any earth-disturbing activities begin.

Potable water for project personnel and equipment decontamination will be provided by Naval Station Great Lakes.

3.5.4 Traffic Control Plan

Access to Naval Station Great Lakes is via three gates located off Sheridan Road. The Main Gate provides access to the station via Farragut Avenue and the remaining gates are contractor gates located off Sheridan Road north of the Main Gate. The gate providing access to the station via Culverius Avenue is the preferred access location for this project. The gate providing access to the station via Meyer Circle is an alternative access gate for contractors. Using the preferred gate located on Culverius Avenue, the identified site access point can be found by following Culverius Avenue to Isherwood Avenue and following Isherwood Avenue to the construction area entrance at the intersection of Isherwood Avenue and Bronson Avenue. The primary and alternative traffic routes to access the work area are illustrated on Figure 3-4. The EMAC contractor is not permitted to use other routes for construction equipment without permission from the OICC. Waste hauling vehicles will be weighed upon arrival and at time of departure using the certified weight scale. The EMAC contractor must supply scales at the construction access location.

3.5.5 EMAC Contractor Requirements

The EMAC contractor will be required to perform the RAP implementation activities in accordance with the EMAC Basic Contract and supplemental specifications provided in Appendix D. The EMAC contractor will also submit a work plan and other documents necessary to describe the procedures the EMAC contractor plans to implement to achieve the requirements of this RAP.

The RAP will be implemented by the EMAC contractor, Naval Station Great Lakes, and Tetra Tech, with work assignments summarized on Table 3-1.

3.6 IMPLEMENTATION

The EMAC contractor will coordinate the field work through the OICC. RAP implementation may be impacted by Naval Station Great Lakes activities and the facility's "Protective Measures." Naval Station Great Lakes implements a "Protective Measures" based on the warnings provided by the Homeland Security Advisory System in the form of graduated "Threat Conditions." The EMAC contractor will be subject to any implemented "Protective Measures."

The Navy will provide a full-time oversight representative during RAP implementation.

TABLE 3-1

WORK ASSIGNMENT RESPONSIBILITY CHART
SITE 17 – PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

WORK ITEM	EMAC CONTRACTOR	NAVAL STATION	TETRA TECH
Pre-RAP Implementation Meeting	X	X	X
RAP Implementation	X		
EMAC Contractor Work Plan (1)	X		
Site Specific Health and Safety Plan / Activity Hazard Analysis	X		
Project Quality Control Plan	X		
Environmental Conditions Report	X(2)		X
Field Work Reports and Submittals (3)	X		
Sampling and Analysis	X(4)	X(4)	
Wastewater Disposal (Decontamination Water)	X(5)		
CTO Closure Report	(6)		X
Permits (7)			
- Digging Permit / Utility Clearance	X(8)		
- Tree Clearing Permit (if needed)	X		
- IEPA Stormwater General Permit	X		
- 404 Permit Under Federal Clean Water Act	X		
- Category 13 - Bank Stabilization Permit (9)	X		

1. EMAC contractor Work Plan includes, but is not limited to, an excavation and handling plan, waste management plan, environmental protection plan, erosion and sediment control plan, stormwater pollution prevention plan, and transportation and disposal plan.
2. EMAC contractor will document environmental conditions before, during, and after implementation of the RAP.
3. EMAC contractor will furnish items identified in the Basic Contract and the Supplemental Specifications provided in Appendix D.
4. EMAC contractor will be responsible for the collection of characterization samples required for off-site disposal of excavated sediment. verification samples from the surface soils below the support facilities following the removal of the support facilities will be collected by Tetra Tech. The EMAC contractor will need to coordinate and accommodate all sampling and field activities.
5. EMAC contractor will be responsible for collection, storage, characterization, and discharge of water to the Naval Station Great Lakes approved discharge location.
6. EMAC contractor will furnish items identified in the Supplemental Specifications provided in Appendix D and any other field information requested by the Navy for the completion of the CTO Closure Report.
7. EMAC contractor will obtain any and all permits specified by their general contract regardless as to whether the permit is listed on this table.
8. EMAC contractor will coordinate with Naval Station Great Lakes and the Illinois JULIE system. Utility location by Naval Station Great Lakes and the Illinois JULIE system must be complete prior to intrusive activities.
9. The Category 13 – Bank Stabilization Permit is a part of the 404 Permit under the Federal Clean Water Act.

CTO - Contract Task Order
EMAC - Environmental Multiple Award Contract
X – Indicates responsible party
RAP – Remedial Action Plan

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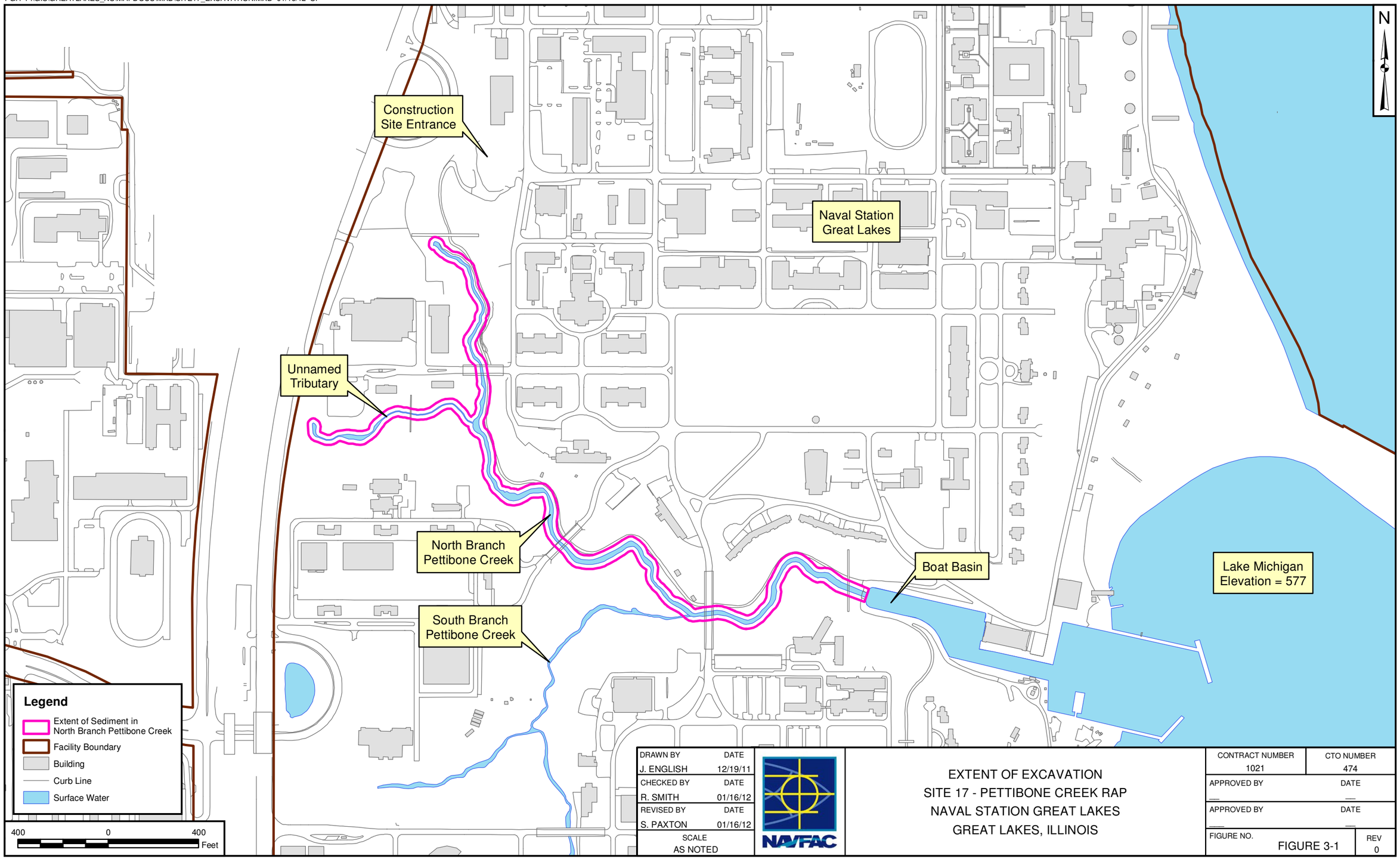
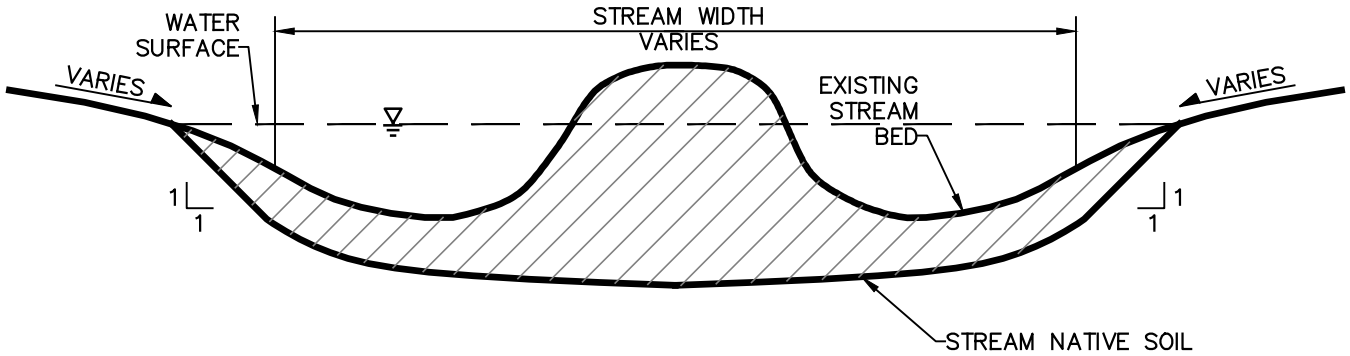


DRAWN BY	DATE
J. ENGLISH	12/19/11
CHECKED BY	DATE
R. SMITH	01/16/12
REVISED BY	DATE
S. PAXTON	01/16/12
SCALE	
AS NOTED	

NAVFAC

EXTENT OF EXCAVATION
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
1021	474
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. FIGURE 3-1	REV 0



NOTES:

1. STREAM THICKNESS VARIES DEPENDING ON LOCATION AND CAN EXCEED 3 FEET.

LEGEND:

SEDIMENT REMOVAL

DRAWN BY MF	DATE 3/3/08	TYPICAL STREAM EXCAVATION SITE 17 PETTIBONE CREEK NAVAL STATION GREAT LAKES GREAT LAKES, ILLINOIS	CONTRACT NO. 01021
CHECKED BY TWS	DATE 5/15/09		OWNER NO. 474
REVISED BY	DATE		APPROVED BY RFD / DATE 5/15/09
SCALE NOT TO SCALE			DRAWING NO. FIGURE 3–2 / SIZE A / REV. 0

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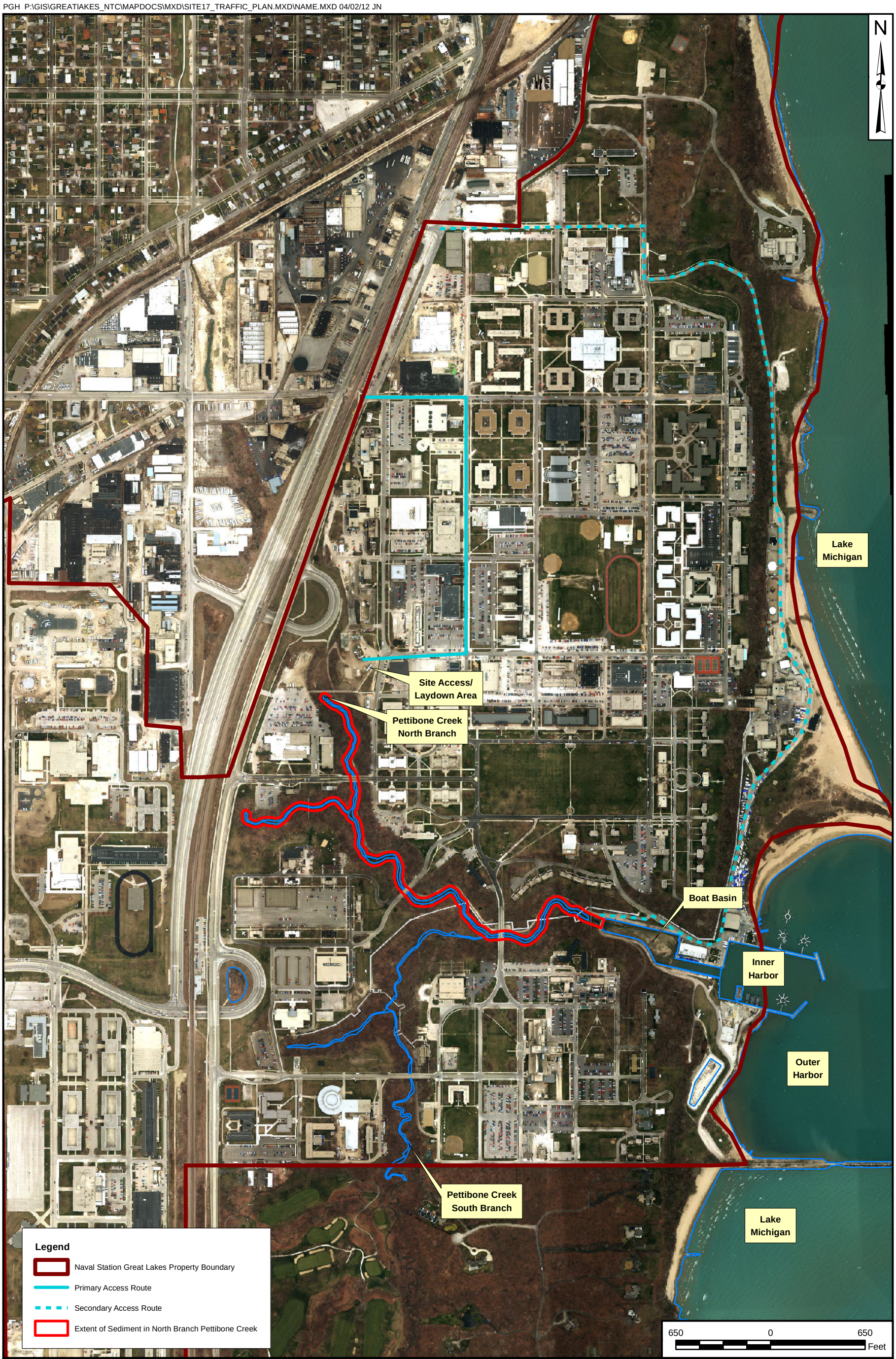


DRAWN BY	DATE
S. STROZ	02/28/08
CHECKED BY	DATE
B. SMITH	04/02/12
REVISED BY	DATE
J. NOVAK	04/02/12
SCALE	
AS NOTED	

NAVFAC

TRAFFIC PLAN
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
01021	—
APPROVED BY	DATE
RFD	03/15/12
APPROVED BY	DATE
—	—
FIGURE NO.	REV
FIGURE 3-3	0

4.0 EROSION AND SEDIMENT CONTROL PLAN

4.1 PURPOSE

The purpose of this section is to provide the steps required to minimize and/or eliminate erosion and sedimentation during the implementation of the RAP at Site 17. The Erosion and Sediment Control Plan has been developed in accordance with the guidelines defined in the Illinois Procedures and Standards for Urban Soil Erosion and Sediment Control (Illinois EPA, 1988) (E&S Manual). Relevant standards and specifications from the E&S Manual are included in this section and Appendix E. The erosion and sediment control devices described in this text can be modified based on construction equipment and techniques presented in the EMAC contractor's Work Plan. Selected erosion and sediment control devices must be identified in the Erosion and Sediment Control Plan submitted with the EMAC contractor Work Plan. After the Erosion and Sediment Control Plan is approved, no changes can be made without approval by the OICC and the Illinois EPA.

4.2 EROSION AND SEDIMENT CONTROL REQUIREMENTS

Erosion and sediment control measures are implemented to reduce or eliminate erosion and sedimentation of soil that would be detrimental to surface water quality. These devices are particularly important because the excavation activities associated with the RAP are within North Branch Pettibone Creek and the unnamed tributary to North Branch Pettibone Creek. The surface water runoff from the disturbed areas eventually discharges to the lower reaches of Pettibone Creek and Lake Michigan. Past investigations indicate that North Branch Pettibone Creek receives flow from dozens of storm drains during storm events and has a base flow fed by groundwater. The limits of excavation extend from Pettibone Creek's discharge point at the Boat Basin (Lake Michigan) and extends 3,540 feet up the North Branch Pettibone Creek. The excavation also extends 900 feet up a small tributary of the North Branch Pettibone Creek, which is located 2,580 feet upstream of Lake Michigan.

RAP implementation activities for Site 17 Pettibone Creek consist of excavation and off-site disposal PAH-, pesticide-, PCB-, and metal-contaminated sediments, backfilling excavations, and restoration of disturbed areas. Because of site conditions, temporary access trails will need to be constructed to allow access to the excavation areas.

Based on the type of RAP activities and access issues, the proposed erosion and sediment control measures include the following:

- Synthetic Filter Fence – Placed along the downslope sides of the surface soil disturbance areas and the gravel construction entrances to provide a temporary sediment barrier. Synthetic filter fences (silt fencing) consists of synthetic filter fabric and wooden posts. Procedures and standards for the synthetic filter fence are provided in Appendix E and Figure 4-2.

- In-Stream Sediment Trap – Placed within the streams from which the contaminated sediment will be removed to provide a temporary sediment barrier while allowing flow within the disturbed stream. Multiple in-stream sediment traps will be required based on the proposed segments of channel to be disturbed within a given time period. In-stream sediment traps are constructed of gabion baskets wrapped with filter fabric, are located downstream of disturbed stream segments, and will remain in place until the disturbed areas upstream are restored and stabilized. The in-stream sediment traps will not be placed greater than 300 feet apart. A construction detail for the in-stream sediment trap is provided as Figure 4-1.

- In-stream Impermeable Berm and Outfall - Placed within the streams from which the contaminated sediment will be removed to provide a temporary dry construction area. Multiple in-stream impermeable berm and outfall structures will be required, based on the proposed segments of stream to be disturbed within a given time period. In-stream impermeable berm and outfall structures are constructed of gabion baskets wrapped with an impermeable membrane, and are equipped with a flexible pipe that will convey base and stormwater flow through the disturbed portion of stream. The flexible pipe will then discharge downstream of the associated in-stream sediment trap. These devices will remain in place until the disturbed areas downstream are restored and stabilized, and until the next in-stream impermeable berm and outfall structure is constructed. A construction detail for the in-stream impermeable berm and outfall structure is provided on Figure 4-1.

- Stabilized Construction Entrance – Placed as a controlled site entrance to reduce the amount of sediment transported by construction vehicles onto facility and public roads. A stabilized construction entrance will be placed at all points of egress from the work area. Procedures and standards for the stabilized construction entrance are provided in Appendix E and shown in Figure 4-2.

- Dust Control – Utilized to prevent surface and air movement of dust from exposed excavation areas and to reduce the amount of airborne substances that may present health hazards, traffic safety problems, or harm plant/animal life. Procedures and standards for dust control are provided in Appendix E.

- Permanent Seeding – Utilized to establish perennial vegetation on disturbed areas by planting seeds of native grasses. Procedures and standards for permanent seeding are provided in Appendix E.

The construction, implementation, and maintenance of these erosion and sediment control devices will be in accordance with the E&S Manual. Figure 4-3 presents the proposed excavation areas along with the limits of disturbance and locations of the proposed erosion and sediment control devices. As indicated above, Figure 4-1 provides typical details of the in-stream sediment trap and the in-stream impermeable berm and outfall structure and Appendix F contains procedures and standards for the synthetic filter fence, stabilized construction entrances (shown on Figure 4-2), dust control, and permanent seeding. Permanent seeding is further discussed in Section 4.4. Dust control will be addressed in the EMAC contractor's Work Plan. All erosion and sediment controls will remain in place until disturbed upstream areas have been stabilized. Stabilization will be determined by the OICC.

4.3 INSPECTION AND MAINTENANCE OF EROSION AND SEDIMENT CONTROLS

In general, the erosion and sediment control measures will be inspected daily and after each runoff-producing rainfall event. Required repairs will be made immediately. The following items will be checked:

- The stabilized construction entrance will be maintained in a condition that will minimize tracking sediment onto facility or public roads.

- The synthetic filter fence will be checked for undermining or deterioration of the fabric. Sediment will be removed from the device when the level of sediment causes bulging, after each storm event, and when the sediment reaches one-half of the fabric height.

- In-stream sediment traps will be checked for undermining or erosion around the edges of the trap(s). Sediment will be removed when the level of sediment reaches one-half the height of the in-stream sediment trap or when the quantity of flow through the in-stream sediment trap is significantly reduced. Sediment removed from the device prior to verification that COCs have been removed from the upstream stream segment will be disposed off-site. Sediment removed from the device following verification of COC removal will be used for stream restoration activities.

- In-stream impermeable berm and outfall structures will be checked for undermining or erosion around the edges of the structure. Sediment will be removed from the structure when the level of sediment reaches one-half the height of the structure. Sediment removed from the device will be used for stream restoration activities. The outfall piping will be checked for leaks and worn connections that may result in failure during construction activities. The outfall piping should flow by gravity. The gravity flow pipe can be replaced by pumps and hoses, if necessary. However, during downtime the gravity pipe will be in place.

- Seeded areas will be checked regularly to make sure that a good growth of vegetation is maintained and these areas will be fertilized and reseeded, as needed.

- The use of fertilizers during reseeding and other related activities is prohibited.

The erosion and sediment control devices will be inspected and maintained until the OICC has formally accepted the permanent stabilization of the disturbed areas. The EMAC contractor will maintain a log book of erosion and sediment control device inspections and maintenance. This log book will be available at the site for inspection by duly authorized officials including Naval Station Great Lakes personnel, Navy representatives, and the Illinois EPA.

4.4 SITE RESTORATION

The areas disturbed by the RAP implementation activities (excavation and support facility areas) will be restored/stabilized to pre-construction conditions using gravel, bank-run sands and gravels, riprap/rock, and permanent seeding. Activities to establish permanent stabilization will be implemented as soon as possible following establishing of final grades and removal of support facilities. The establishment of permanent vegetation includes site/seed bed preparation, seeding, and mulching along the banks of restored Pettibone Creek and on the surface soils below support facilities. Note that the areas suitable for support facility placement are currently gravel paved or bituminous concrete paved areas. Permanent vegetation will only be required in areas that are vegetated prior to support facility construction.

The procedures and requirements for permanent seeding activities are presented in Section 6 of the E&S Manual. These procedures are provided in Appendix E. The seed mixture proposed for use along the banks of Pettibone Creek is a mixture of native ground cover species that was recommended in the Restoration and Maintenance Plan for Pettibone Creek Ravine (EQM, 2000). This mixture includes bottlebrush grass (*Elymus hystrix*), rice grass (*Oryzopsis racemosa*), lang-awned wood grass (*Brachyelytrum erectum*), panic grasses (*Panicum virgatum*), native bromes (native *Bromus* species), bluegrass (*Poa annua*) and a variety of woodland sedges (*Carex* species). If canopy reduction from removal of trees for access to North Branch Pettibone Creek or tributary is not achieved during clearing operations, this seed mixture should be replaced with a standard Illinois seed mixture that is tolerant of shade and wet conditions. Following seeding, the seeded areas will be covered with temporary erosion control matting (e.g., coconut fiber matting) to provide additional stabilization until vegetation is established.

The seed mixture proposed for use on surface soil following the removal of the support facilities is a standard Illinois permanent seed mixture that includes Kentucky bluegrass (*Poa pratensis*) and perennial ryegrass (*Lolium perenne*). Planting rates and optimum soil pH for this mixture and soil amendments are

presented in Section 6 of the E&S Manual (Appendix F). In the event that RAP activities disturb an area requiring restoration with sod, sodding requirements are found in the E&S Manual (Appendix F).

In the event that disturbed areas are brought to final grade outside of the optimal growing season for the proposed permanent seed mixtures, the disturbed areas will be temporarily stabilized using a temporary seed mixture. The procedures and requirements for establishing temporary stabilization are also provided in the seeding exhibit provided in Appendix E. Permanent seeding will then occur during the next optimal growing season.

As indicated in the E&S Manual, erosion and sediment control devices will remain in place until permanent stabilization is established over the disturbed areas. Therefore, erosion and sediment control devices will not be removed by the EMAC contractor until directed by the OICC. Erosion control devices (mulching) capable of withstanding high rainfall events must be used along stream banks. The use of starch-based tackifiers or all-in-one erosion control matting (erosion mat, seeding, mulch) is required in areas susceptible to high flows.

4.5 RESPONSE PROCEDURES FOR SPILL MITIGATION

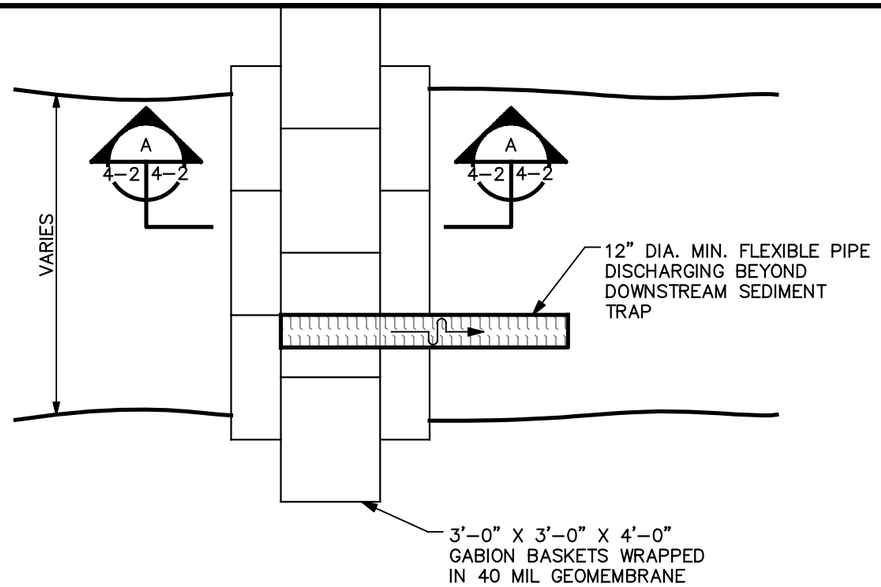
Potential non-stormwater discharges anticipated during RAP implementation activities include wash water resulting from decontamination of field equipment and vehicles; fuel and lubricant spills from vehicle fueling, lubrication, and maintenance; spills of fertilizers; and small quantities of laboratory chemicals used in sample collection.

The decontamination wash water will be collected in a lined decontamination and equipment wash pad area. The wash water generated from decontamination and/or other washing activities will be collected, characterized, and transported to an approved off-site treatment facility. Vehicle fueling, lubrication, and maintenance will be performed utilizing drip pans to contain spills that may occur during maintenance activities. Containers of detergents and vehicle maintenance fluids (oil, grease, antifreeze, hydraulic fluid, etc.) will be stored within an enclosed, lined, diked area along with equipment fuel, which will be stored in tanks. This area, referred to as the materials storage area, will be bermed and lined with a 40-mil low-density polyethylene (LDPE) geomembrane and will be sized to contain 110 percent of the volume stored within the area. A small sump or low point in the liner will be designed to serve as a collection and monitoring point for leaks or spills from the containers stored within the materials storage area. The materials storage area will be checked daily to make sure that stored containers are not leaking and that the lining system is functioning properly. When not in use, chemicals, paints, and other flammable substances will be stored in a flammable storage cabinet located within the EMAC contractor's equipment trailer.

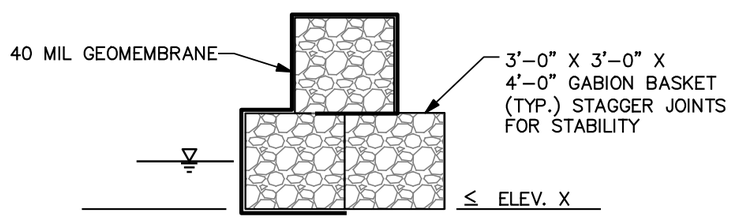
Good housekeeping procedures will be followed to reduce risks associated with these materials. These procedures include, but are not limited to, keeping materials in their original containers whenever possible, maintaining original labels and Material Safety Data Sheets (MSDSs), and using proper disposal methods for surplus materials. Accidental spills that may occur will be contained as appropriate for the spilled medium (liquid or solid) and collected and containerized immediately after discovery of the spill. Containerized material will be characterized for off-site transportation and disposal. The following spill mitigation equipment should be available on site during construction activities:

- Drip pans
- Oil-dry or similar compound
- Absorbent socks
- Shovels
- 55-gallon drums or storage tanks (for containerization)
- Labels for contents identification

Following spill cleanup, the cause of the spill will be investigated, and material storage and handling procedures will be reviewed and revised where appropriate. Spills will be reported to the Naval Station Great Lakes Environmental Department. Following removal of the materials from the storage area, if not located within the decontamination pad area or dewatering area, verification samples will be collected from exposed surface soil per Section 5.0 of this RAP. Note that only two above ground storage tanks (ASTs) will be allowed during remediation activities and the maximum allowable volume of each tank shall be 500 gallons. Temporary ASTs will be inspected and approved by the NSGL Fire Department and Public Works Department (PWD)-Environmental Division before initial filling. The Naval Station Great Lakes Spill Procedures are provided in an Appendix F.



PLAN VIEW

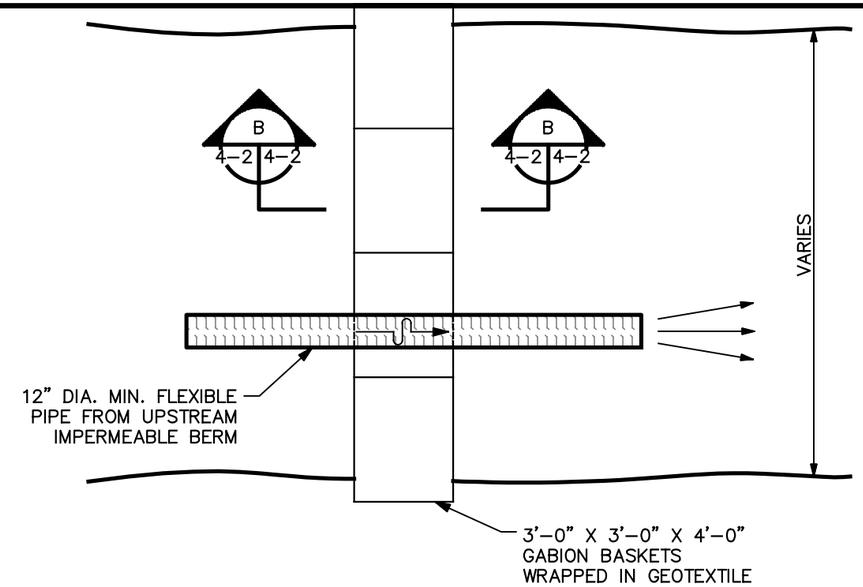


SECTION A – A'

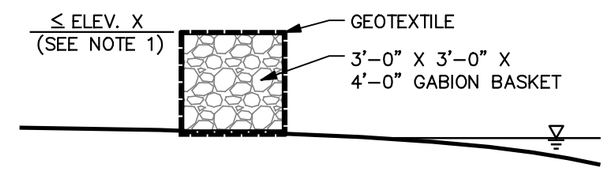
NOTES:

1. UPSTREAM IMPERMEABLE BERM MUST REMAIN IN PLACE UNTIL THE SECTION OF STREAM BETWEEN THE IMPERMEABLE BERM AND DOWNSTREAM SEDIMENT TRAP HAS BEEN EXCAVATED AND RESTORED.
2. USE PUMPS AND HOSES ALONG WITH FLEXIBLE SPILLWAY PIPE TO TRANSPORT BASE FLOW TO DOWNSTREAM SIDE OF THE DOWNSTREAM SEDIMENT TRAP.

UPSTREAM IMPERMEABLE BERM



PLAN VIEW



SECTION B – B'

NOTES:

1. THE TOP ELEVATION OF THE DOWNSTREAM SEDIMENT TRAP SHOULD BE AT THE SAME ELEVATION OR LOWER THAN THE BOTTOM ELEVATION OF THE UPSTREAM IMPERMEABLE BERM. IF THIS CANNOT BE ACHIEVED THE SPILLWAY PIPE MUST GO THROUGH THE DOWNSTREAM SEDIMENT TRAP RATHER THAN OVER IT.

DOWNSTREAM SEDIMENT TRAP

DRAWN BY MF	DATE 3/10/08	EROSION AND SEDIMENT CONTROL DEVICES SITE 17 PETTIBONE CREEK RAP NAVAL AIR STATION GREAT LAKES GREAT LAKES, ILLINOIS	CONTRACT NO. 01021
CHECKED BY TWS	DATE 5/15/09		OWNER NO. 474
REVISED BY	DATE		APPROVED BY RFD / DATE 5/15/09
SCALE NOT TO SCALE			DRAWING NO. FIGURE 4–1 / SIZE B / REV. 0

NAVFAC

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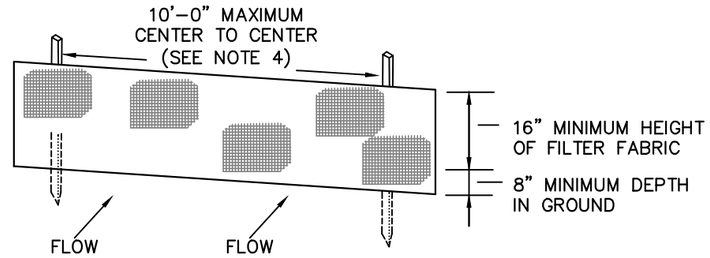
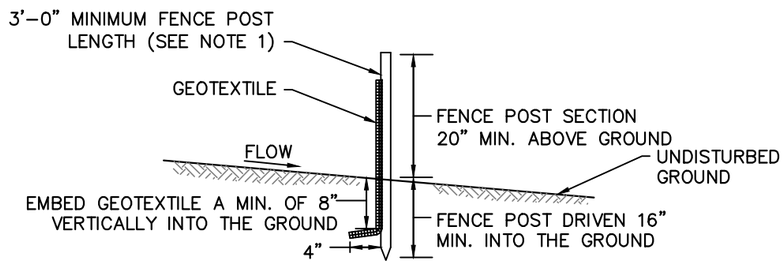
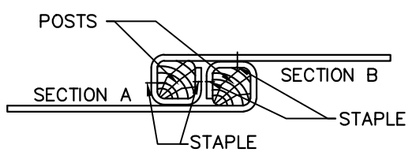


PERSPECTIVE VIEW



CROSS SECTION

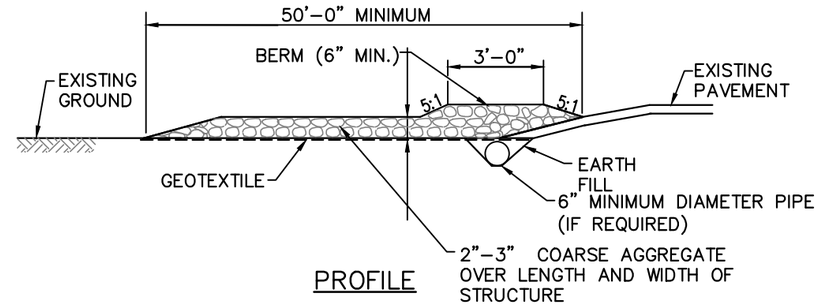


TOP VIEW – JOINING TWO
ADJACENT SILT FENCE SECTIONS

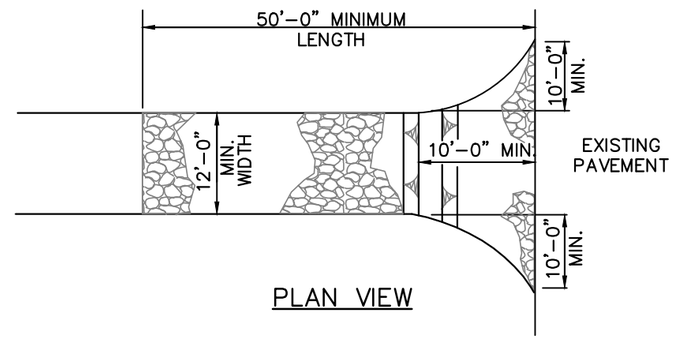
NOTES:

1. WOOD POSTS SHALL BE 1.5" BY 1.5" SQUARE (MIN) CUT OR 1.75" DIAMETER (MIN) ROUND AND SHALL BE OF SOUND QUALITY HARDWOOD. STEEL POSTS WILL BE STANDARD T OR U SECTION WEIGHING NOT LESS THAN 1.00 POUND PER LINEAR FOOT.
2. GEOTEXTILE SHALL BE FASTENED SECURELY TO EACH FENCE POST WITH WIRE TIES OR STAPLES AT TOP AND MID–SECTION.
3. INSTALL SILT FENCE PARALLEL TO THE CONTOUR OF THE LAND.
4. A MINIMUM CENTER TO CENTER SPACING OF 5'–0" IS RECOMMENDED ON STEEP SLOPES.

SYNTHETIC FILTER FENCE



PROFILE



PLAN VIEW

NOTES:

1. ALL SURFACE WATER FLOWING TO OR DIVERTED TOWARD CONSTRUCTION ENTRANCES SHALL BE PIPED THROUGH THE ENTRANCE, MAINTAINING POSITIVE DRAINAGE.
2. IF REQUIRED PIPE SHOULD BE SIZED ACCORDING TO THE AMOUNT OF RUNOFF TO BE CONVEYED. A 6" MINIMUM DIAMETER WILL BE REQUIRED

STABILIZED CONSTRUCTION ENTRANCE

DRAWN BY ND DATE 3/30/12	NAVFAC	EROSION AND SEDIMENT CONTROL DEVICES SITE 17 PETTIBONE CREEK RAP NAVAL AIR STATION GREAT LAKES GREAT LAKES, ILLINOIS	CONTRACT NO. 01021
CHECKED BY TWS DATE 3/30/12			OWNER NO. 474
REVISED BY DATE			APPROVED BY RFD DATE 3/30/12
SCALE NOT TO SCALE			DRAWING NO. FIGURE 4–2 SIZE B REV. 0

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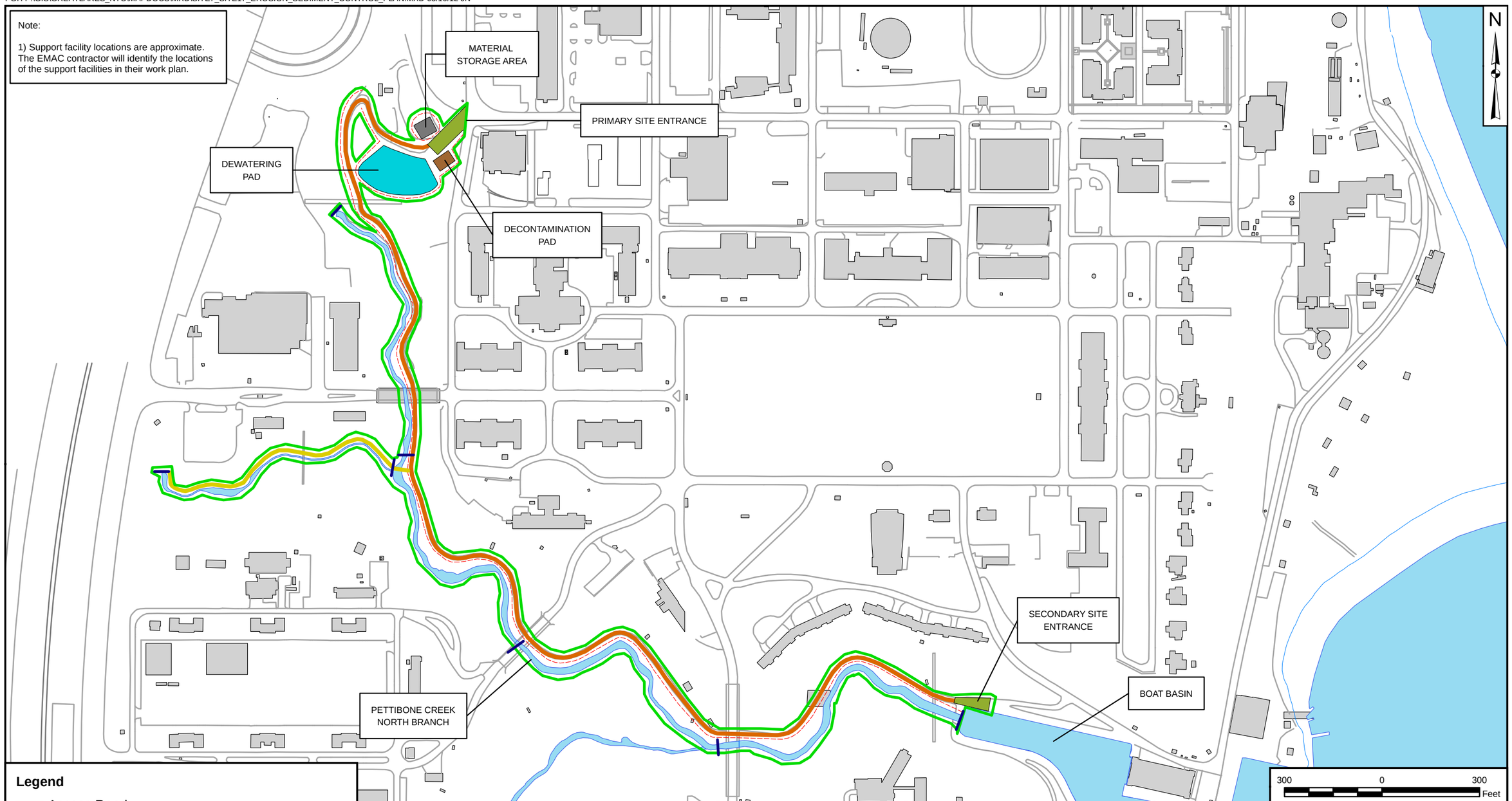

Legend

- Access Road
- Temporary Access Road
- Limit of Disturbance
- Sediment Traps (See Figure 4-1)
- Synthetic Filter Fence (See Figure 4-2)
- Stabilized Construction Entrance (See Figure 4-2)

DRAWN BY	DATE
J. NOVAK	03/15/12
CHECKED BY	DATE
B. SMITH	03/16/12
REVISED BY	DATE
J. NOVAK	03/16/12
SCALE	
AS NOTED	

NAVFAC

EROSION AND SEDIMENT CONTROL PLAN
SITE 17- PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
01021	0474
APPROVED BY	DATE
RFD	03/16/12
APPROVED BY	DATE
FIGURE NO.	REV
Figure 4-3	0

5.0 VERIFICATION SAMPLING PLAN

5.1 PURPOSE

The purpose of this section is to present the verification sampling required following implementation of the RAP. Sampling includes collecting verification samples. Verification samples will be collected from surface soil located beneath support facilities (decontamination pad, dewatering pad, material storage area, access roads, etc.) to make sure that RAP implementation did not spread contamination to support facility areas. This section also presents criteria and procedures used for the verification sample data to determine the acceptability of residual soil contamination, if present. The sampling procedures and fixed-base laboratory analytical methods will be performed in accordance with the procedures specified in the Quality Assurance Project Plan (QAPP) dated July 2001 (TtNUS, 2001).

5.2 VERIFICATION SAMPLING OF SUPPORT FACILITIES

The support facilities requiring verification sampling following RAP implementation include the access roads, dewatering pad, material storage area, decontamination pad, and any other pad or trail used to contain or transport contaminated sediment. The frequency of verification sample collection for these support facilities varies. For the access roads, verification samples will be collected at a rate of one sample for every 300 linear feet of access road. For the dewatering pad, material storage area, and decontamination pad, verification samples will be collected at a rate of one sample per 1,000 square feet of disturbed area, with a minimum of one verification sample from each of the support facilities. Based on the anticipated areas of the dewatering pad, decontamination pad, material storage area, and access roads, it is estimated that two verification samples will be collected from two defined sampling areas within the dewatering pad, one verification sample will be collected from the decontamination pad, one verification sample will be collected from the material storage area, and 15 verification samples will be collected from the access roads. To avoid biasing the location of each grab sample, the locations of each grab sample have been generated using a random number generator. The random number generator will establish the location of each grab sample by identifying the percent distance along the length of the access road and a percentage width across the access road measured from left to right bank (facing in the direction of flow). Table 5-1 presents the anticipated verification samples to be collected beneath the support facilities along with the percent distances locating each grab sample location for each composite sample. The proposed verification sample areas for the support facilities are identified on Figure 5-1.

The results of these verification samples will be compared to PRGs to determine if contamination was spread to the temporary access roads or the surface soil below the footprint of the support facilities at concentrations greater than PRGs. In the event that the EMAC contractor collects pre-construction

samples from each support area, the results of the verification samples will also be compared to these results. In the event that a verification sample result for one or more COC exceeds PRGs, 6-inches of soil will be removed from the associated access road section or support facility footprint (support facility footprint equals the actual footprint plus an additional 10 feet in all directions). In the event that pre-construction samples are collected and verification sample results are less than the pre-construction results, excavation will not be required even if the verification sample results exceed PRGs. Following additional excavation (if needed), additional verification samples will be collected and analyzed. Excavation expansion may continue until the verification samples indicate that COC concentrations are less than PRGs. Excavation of surface soil beneath the support facilities and associated handling and disposal of that material will be completed at the EMAC contractor's expense.

The verification samples for the support facilities will be composite samples made up of material collected from six randomly located grab sample locations. For access roads, each 300 foot length of access road will be divided into 50 foot long sub-sections, and one grab location will be randomly located in each sub-section. For the dewatering pad and decontamination pad areas, each grab location will be randomly located within each designated sample area. Each verification sample collected will be analyzed for the COCs identified in Section 2 and the results will be compared to the PRGs presented on Table 2-3. Sampling procedures will follow the SOP presented in Appendix G and sample preparation, sample shipment, and fixed-base laboratory sample analysis will be performed in accordance with the 2001 QAPP (TtNUS).

TABLE 5-1

VERIFICATION SAMPLES
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Sample Area	Sample ID Number	Grab Sample Location			Analysis		
		Grab Number	Percent X (1)	Percent Y (2)	PAHs (3)	Pest/PCBs (4)	Metals (5)
SA01	NTC17PC-SSCP-SA01	1	93	63	X	X	X
		2	71	40			
		3	17	56			
		4	75	69			
		5	1	14			
		6	40	54			
SA02	NTC17PC-SSCP-SA02	1	39	92	X	X	X
		2	3	20			
		3	45	62			
		4	35	22			
		5	33	29			
		6	6	89			
SA03	NTC17PC-SSCP-SA03	1	68	70	X	X	X
		2	62	72			
		3	78	54			
		4	48	87			
		5	43	63			
		6	88	60			
SA04	NTC17PC-SSCP-SA04	1	25	23	X	X	X
		2	50	88			
		3	48	66			
		4	57	66			
		5	30	60			
		6	64	80			
SA05	NTC17PC-SSCP-SA05	1	77	11	X	X	X
		2	38	83			
		3	88	72			
		4	94	69			
		5	35	65			
		6	65	36			
SA06	NTC17PC-SSCP-SA06	1	15	85	X	X	X
		2	92	67			
		3	62	30			
		4	65	79			
		5	39	99			
		6	23	78			
SA07	NTC17PC-SSCP-SA07	1	80	39	X	X	X
		2	73	67			
		3	43	31			
		4	91	44			
		5	37	92			
		6	0	58			

TABLE 5-1

VERIFICATION SAMPLES
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Sample Area	Sample ID Number	Grab Sample Location			Analysis		
		Grab Number	Percent X (1)	Percent Y (2)	PAHs (3)	Pest/PCBs (4)	Metals (5)
SA08	NTC17PC-SSCP-SA08	1	58	48	X	X	X
		2	40	51			
		3	69	90			
		4	39	14			
		5	0	37			
		6	27	37			
SA09	NTC17PC-SSCP-SA09	1	60	48	X	X	X
		2	63	62			
		3	61	4			
		4	81	33			
		5	50	84			
		6	55	58			
SA10	NTC17PC-SSCP-SA10	1	92	37	X	X	X
		2	80	79			
		3	42	11			
		4	54	70			
		5	17	24			
		6	46	43			
SA11	NTC17PC-SSCP-SA11	1	68	100	X	X	X
		2	89	54			
		3	14	100			
		4	24	39			
		5	85	53			
		6	53	85			
SA12	NTC17PC-SSCP-SA12	1	62	19	X	X	X
		2	12	39			
		3	61	31			
		4	50	47			
		5	48	36			
		6	13	56			
SA13	NTC17PC-SSCP-SA13	1	37	19	X	X	X
		2	10	26			
		3	96	45			
		4	20	89			
		5	19	38			
		6	99	23			
SA14	NTC17PC-SSCP-SA14	1	92	58	X	X	X
		2	37	37			
		3	68	49			
		4	42	10			
		5	14	55			
		6	82	5			

TABLE 5-1

VERIFICATION SAMPLES
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

Sample Area	Sample ID Number	Grab Sample Location			Analysis		
		Grab Number	Percent X (1)	Percent Y (2)	PAHs (3)	Pest/PCBs (4)	Metals (5)
SA15	NTC17PC-SSCP-SA15	1	30	93	X	X	X
		2	68	46			
		3	81	61			
		4	36	90			
		5	22	97			
		6	29	81			
SA16	NTC17PC-SSCP-SA16	NA	NA	NA	X	X	X
SA17	NTC17PC-SSCP-SA17	NA	NA	NA	X	X	X
SA18	NTC17PC-SSCP-SA18	NA	NA	NA	X	X	X
SA19	NTC17PC-SSCP-SA19	NA	NA	NA	X	X	X
SA20	NTC17PC-SSCP-SA20	NA	NA	NA	X	X	X

Notes Sampling Areas SA01 through SA15 represent verification samples collected on the access road. Sampling Areas SA16 and SA17 represent verification samples collected from the dewatering pad footprint. Sample Area SA18 represents the verification sample location collected from the decontamination pad footprint. Sample Area SA19 represents the verification sample location collected on the primary site entrance and Sample Area SA20 represents the verification sample location collected from the material storage area.

In the event that additional soil excavation is required, the subsequent verification sample will be labeled NSGL-SAxx-02. The last numbers would continue to increase in increments of 1 if additional samples are required.

1 Percent X represents the percentage along the creek or tributary sub-segment (in direction of flow) where the grab sample is located.

2 Percent Y represents the percentage across the creek or tributary sub-segment (from left to right looking in the direction of flow) where the grab sample is located.

3 PAHs include anthracene, benzaldehyde, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, caprolactam, carbazole, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, and total PAHs.

4 Pest/PCBs include 4,4'-DDD, 4,4'-DDE, 4,4'-DDT, Total DDT, Aroclor-1254, Aroclor-1260, Endosulfan I, and Endosulfan II.

5 Metals include copper, lead, mercury, and zinc.

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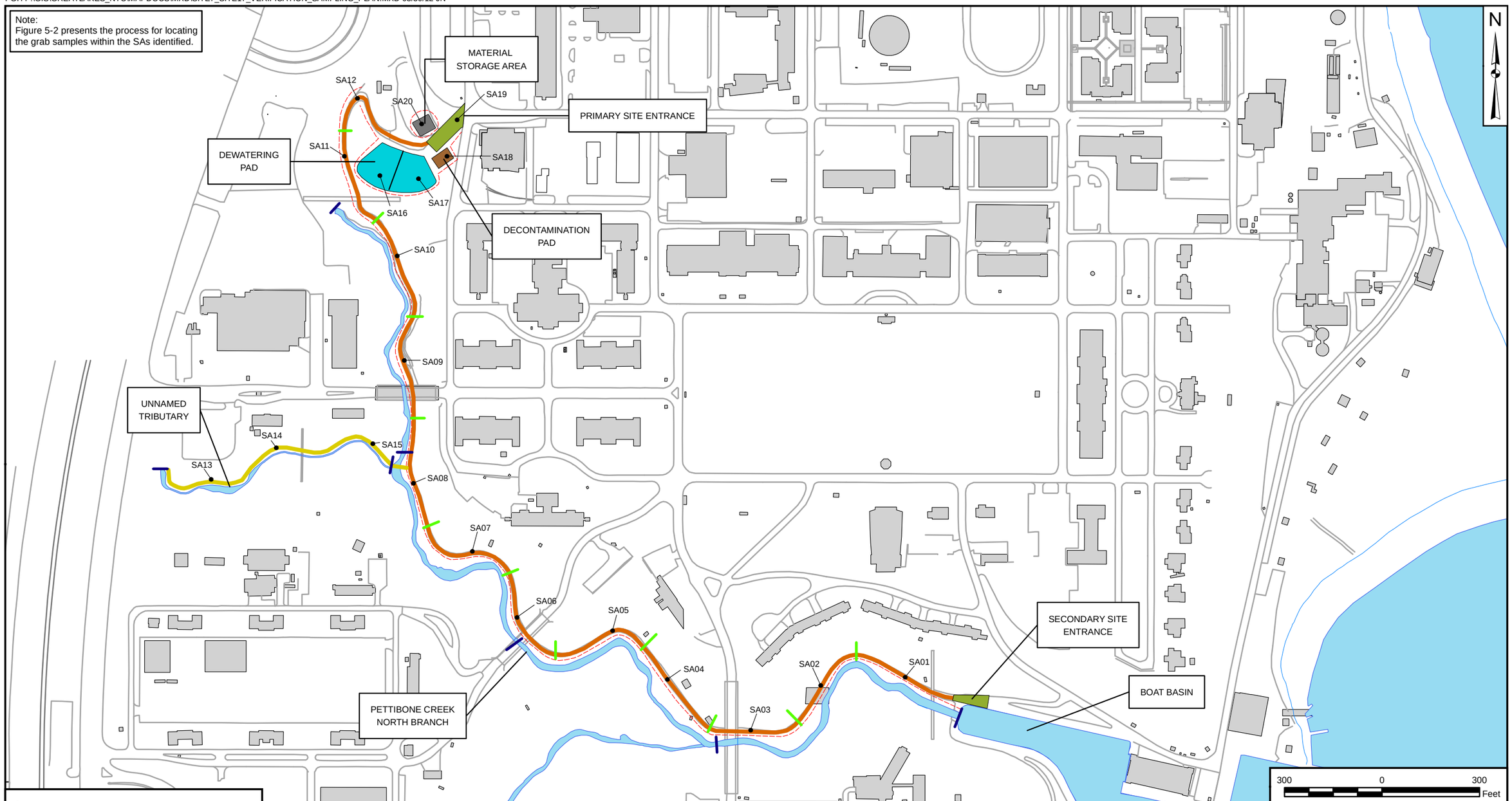

Legend

- Access Road
- Temporary Access Road
- Sample Area Designation
- Sediment Traps (See Figure 4-1)
- Synthetic Filter Fence (See Figure 4-2)
- Stabilized Construction Entrance (See Figure 4-2)
- SA05 Proposed Sediment Sample

DRAWN BY	DATE
J. NOVAK	03/15/12
CHECKED BY	DATE
B. SMITH	03/30/12
REVISED BY	DATE
J. NOVAK	03/30/12
SCALE	
AS NOTED	

NAVFAC

VERIFICATION SAMPLING PLAN
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
01021	0474
APPROVED BY	DATE
RFD	03/16/12
APPROVED BY	DATE
FIGURE NO.	REV
Figure 5-1	0

6.0 PETTIBONE CREEK STREAM RESTORATION ACTIVITIES

6.1 PURPOSE

The purpose of this section is to present the proposed remedial (stream restoration) action that will address both erosion and sedimentation issues currently present within the North Branch of Pettibone Creek (Site 17). The primary focus of the stream restoration activities will be on the North Branch of Pettibone Creek (Figure 6-1) where it flows onto the Naval Station Great Lakes through culverts. The implementation of this remedial action falls under Phase 5 of the Navy's IR Program. Appendix I (Northern Branch-Pettibone Creek Photographs) provides existing condition photographs of areas of the North Branch of Pettibone Creek requiring stream restoration. Note that the locations of each photo are depicted on Figure 6-1. Selected photos are enlarged on Figure 6-1 highlighting particularly important areas requiring stream remedial actions.

6.2 DESCRIPTION OF THE SUPPLEMENTAL REMEDIAL ACTION

The North Branch of Pettibone Creek north of Naval Station Great Lakes has been previously evaluated for site-specific flood mitigation planning (Ciorba, 2004). As discussed in the Ciorba study, the North Branch of Pettibone Creek area has received a large amount of flooding waters occurrences experienced by North Chicago due in part to urbanization and the addition of impervious areas in North Chicago and within the Pettibone Creek watershed.

The sediment associated with flows emanating upstream of the North Branch Pettibone Creek are potentially impacted with contaminants typically associated with industrial activities. Therefore, in addition to remedial activities directed at removal of contaminated sediments as described in Section 3.0, this section includes remedial activities that will address stabilizing the banks of the North Branch of Pettibone Creek prior to discharge into the Boat Basin, Inner Harbor, and Outer Harbor. In March 2011, Tetra Tech performed a site visit to document specific areas of the North Branch of Pettibone Creek that required stream bank stabilization. Appendix I provides the photographs taken during this field investigation that were used in the formulation of the stream bank stabilization strategy. Select photographs are presented on Figure 6-1. Figure 6-2 depicts the North Branch of Pettibone Creek site location contouring which is presented to illustrate the notable features of the creek including the steep side slopes of the ravine and stream bed slope.

In the past, Pettibone Creek bank stabilization efforts have included placement of hard-surfaced structures such as gabion basket walls and placement of riprap and concrete debris. While measures such as these provide limited, localized stabilization to severely eroded stream banks, they can increase

stream velocity thereby increasing downstream sedimentation, thus carrying sediment farther downstream, eventually settling in the Boat Basin. The stream stabilization approach recommended in this section includes measures that provide stream bank stabilization but are also designed to reduce stream velocity during high flow periods. Finally, engineered wetlands are proposed to act as natural flood plains to address high flow period sediment capture.

The proposed remedial (stream restoration) action for the North Branch of Pettibone Creek includes construction of select stream bank stabilization chosen specifically for riparian sites and disturbed/steep slope sites (see Figure 6.2). These remedial alternatives were chosen based on "environmental friendliness" and effectiveness in both sediment retention and stream bank stabilization. Particular stream stabilization and sediment collection features proposed for the North Branch of Pettibone Creek include:

- ERTEC Bank Stabilization System(BSS)™
- Rootwads
- Log Vanes
- J-Hook Vanes
- LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotaxic Salmonids)
- Engineered Side Channel Flood Plains

It is important to note that the effectiveness of the recommended stream stabilization and sediment collection measures proposed herein will be dramatically reduced if storm water piping outfalls remain in their current state of little to no outfall protection and energy dissipation. It is recommended that Naval Station Great Lakes inventory, design, and install energy dissipation structures at each of the 30 plus existing stormwater outfalls. Also, it is recommended that signage be placed near newly installed stream bank stabilization features such as Rootwads and Log Vanes indicating they are intended to remain in place as installed.

The article, "The Cross-Vane, W-Weir and J-Hook Vane Structures…Their Description, Design and Application for Stream Stabilization and River Restoration", D.L. Rosgen, P.H., has been included in Appendix Q as an additional reference.

6.3 BASELINE FLOW ANAYSIS

Given the history of flooding in the North Chicago area during most storm events, local governmental agencies have stressed the importance of evaluating impacts to Pettibone Creek when construction practices occur within the associated watershed.

In order to evaluate the impacts of installing and implementing stream bank stabilization and sediment retention measures in the North Branch of Pettibone Creek, peak storm water flows from various storm events were calculated using the Army Corps of Engineers HEC-HMS computer program. The HEC-HMS computer program input (cross-sections, design flows, etc.) and output (water surface profiles, cross sections) are provided in Appendix J. Flows from the unnamed tributaries were estimated as well. The design storms events evaluated and the calculated/estimated flow are provided below:

Design Storm (cfs)	IDOT flows (See Appendix K.2)	Flow Onto Base at Culverts (cfs)	Flow at Boat Basin (cfs) (See Appendix K.1)
1	NA	117	210
2	NA	144	252
5	NA	201	353
10	NA	248	441
50	422	378	697
100	569	442	827

Upon determining the various peak flow discharges from Pettibone Creek, a HEC-RAS analysis was performed to estimate the water surface profiles resulting from the above-mentioned storm events under "pre-development" (existing) conditions. Flow results from this HEC-RAS analysis are shown in Appendix J. The design storm peak flows were estimated for the tributaries using HEC-HMS. TR-55 was utilized to estimate the times of concentration. Refer to Appendix K.1 for peak flow calculations.

Illinois DOT estimated peak flows for the 50-year, 100-year, and 500 year storms during the reconstruction of Sheridan Road in 1989 for the culvert design that discharge onto Naval Station Great Lakes. These calculations are included in Appendix K.2 and correlates well with the HEC-HMS modeling. The Lake County Storm Water Management Commission required James Anderson Company to use 321 cfs for a 10 year design flow and 750 cfs for a 100 year design flow as part of a storm water management design for the EMCO Truck Repair facility. This facility is just north of the culverts that discharge onto the Naval Station Great Lakes property and these flows also correlate well with this HEC-HMS modeling.

6.4 POST CONSTRUCTION FLOW ANALYSIS

A post construction flow analysis of the previously mentioned design storms was performed with cross sections added for the constructed wetlands. The other stream bank stabilization features proposed do not change the stream configuration to a degree that they affect the subsequent water surface profile. By comparing the water surface profiles for both the pre- and post-development scenarios, the resultant difference in water surface profiles is minor. Flow results from this HEC-RAS analysis are shown in

Appendix L. The resultant impact of the proposed alternatives (specifically the side channel wetlands), is negligible. Therefore, according to the analysis of the impact of water surface profiles upon implementation of the proposed remedial actions, upstream water surface profiles during the design events analyzed are not predicted to change.

6.5 PROPOSED STREAM BANK STABILIZATION MEASURES

The remedial action is designed to reduce the amount of sediment entering into the Boat Basin from Pettibone Creek, stabilize the banks of Pettibone Creek, and consists of various elements to be installed at strategic locations along and adjacent to the bank of the North Branch of Pettibone Creek. The following sections provide details on each element. Refer to Drawing C-1 for an overall depiction of the proposed location of the remedial alternatives. A detailed location description of each proposed remedial action is shown on Drawings C-2 and C-3 (Drawing C-2 - Proposed Remedial Site Plan, Sheet 1/2 and Drawing C-3 - Proposed Remedial Site Plan, Sheet 2/2). A summary of the stream bank stabilization/sediment retention devices is provided in Table 6-1 along with the appropriate station of Pettibone Creek.

6.5.1 ERTEC Bank Stabilization System (BSS)

The BSS by ERTEC was selected as a major remedial feature for the stabilization of the North Branch of Pettibone Creek. Once in place, BSS allows water flow-through and significantly reduces velocity of stream flow. The BBS system contains an integrated filter and retains soil particles in place, creating a barrier to further erosion. BSS is made from durable and UV stable HDPE. The ERTEC Installation and Maintenance Guide is provided in Appendix M along with the product data sheet. The proposed location of the ERTEC is shown of Drawings C-2 and C-3 and summarized in Table 6-1.

6.5.2 Rootwads

A rootwad composite is a combination of interlocking tree materials where a mass of tree roots, commonly called a rootwad, is utilized with other tree parts and revegetation methods to stabilize stream banks and provide aquatic habitat. Rootwad composites are often a cost-effective bank stabilization and habitat enhancement treatment. Rootwad composites move the current line away from the stream bank so that the bank is less susceptible to erosion through hydraulic forces. This, in effect, reduces the energy environment along the stream bank/water interface so that riparian vegetation can provide the necessary bank protection and habitat values. Rootwad composites also generate turbulence that creates streambed scour and provides cover and substrate for aquatic organisms.

A rootwad is the lower trunk and root fan of a large tree as shown on Detail 2 of Drawing C-7. Individual rootwads are placed in series and utilized to protect stream banks along meander bends. Rootwads are constructed by grading the stream bank back and establishing a desired meander radius. A trench is excavated parallel with the stream bank along the radius. Starting at the downstream end of the meander, a footer log (18- to 24-inch diameter, 8- to 10-foot long) is placed in this trench. A second trench is cut perpendicular to the first, back into the stream bank, angling downstream. The rootwad is placed in this trench so the trunk side of the root fan rests against the footer log and the bottom of the root fan faces into the flow of water. Large boulders are then placed on the top and sides of the footer and rootwad to hold them in place. Moving upstream, the next footer log is placed in the trench with its downstream end extending behind the first footer log and the next rootwad is put in place. This process continues until the rootwads have been installed. Some installation methods utilize a cut-off log on top of each rootwad to hold it in place, rather than boulders.

Once the rootwad revetment is in place, the area between and behind the rootwads is backfilled with rock/fill. The top of the stream bank is graded to transition into the rootwads and this area and the area between the rootwads is stabilized with vegetation.

Rootwad revetments have the potential to greatly enhance stream habitat. Rootwad revetments promote the formation of pool habitat along the outside of meander bends and the root fan portion of the rootwads provides overhead cover for the pools. Once rootwads are installed, they provide up to 15 years of stream bank stabilization at which time the stream bank and riparian system recover from instability. Rootwads are typically spaced 3 to 4 times the projected rootwad length. In practice, spacing of rootwads are field determined based on the availability of the wads. Refer to Appendix N for a reference document providing various design, installation, and overall description of rootwad bank stabilization features. Proposed rootwad locations are depicted on Drawings C-2 and C-3 and summarized in Table 6-1.

6.5.3 Log Vanes

The purpose of log vanes (Detail 4 of sheet C-7) is to reduce erosion along the stream bank by redirecting the stream flow toward the center of the stream. They essentially mimic the effect of a tree partially falling into the stream. Log vanes are linear structures that extend out from the stream bank into the stream channel in an upstream direction. In addition, they tend to create scour pools on the downstream side.

Log vanes grade down from the bankfull elevation at the stream bank to the channel invert at their terminus in the stream. Vanes generally extend out from the stream bank one-third of the bankfull width and are angled upstream from the bank at a 20 to 30 degree angle. The top elevation of the vane will decrease from one-half bankfull elevation toward the center of the channel at a slope of 4 to 20 percent.

Header and footer rocks will be buried along the upstream end of the log under the streambed, as shown on Detail 4, and plate the upstream side of the vane with Type 2 filter fabric and No. 57 stone. The filter fabric will be securely fastened to the back of the log using galvanized roofing nails on approximately 8-inch centers. Voids between the header and footer rocks can be filled with hand-placed Class A riprap, as directed. Footer rocks will be placed such that the header rock is at streambed elevation. The downstream end of the log at the one-half bankfull elevation shall be anchored by pinning with header and footer rocks. The log vane will be keyed into the bank at the downstream end as shown on Detail 4. Native hardwood trees encountered during clearing and grubbing may be identified and stockpiled for use as logs for the log vanes. Log vane locations were selected to provide the reduced bank erosion in areas with moderate, straight-line soil loss risk. The longevity of log vanes can vary from 5 to 15 years at which point natural stream processes become the dominant stream shaping feature (i.e., creation of scour pools downstream of each vane). Proposed log vane locations are depicted on Drawings C-2 and C-3 within Pettibone Creek and summarized in Table 6-1.

6.5.4 J-Hook Vanes

J-Hook vanes are proposed at stream locations directly upstream of engineered wetlands in order to begin the diversion of high flows into the engineered flood plains provided by the engineered side channel wetlands. The longevity of J-hook vanes would essentially be permanent if all other stream stabilization measures are implemented.

J-Hook vanes (Detail 3 of Sheet C-7) are linear structures that extend out from the stream bank into the stream channel in an upstream direction. They essentially mimic the effect of a tree partially falling into the stream. They are usually placed along the stream bank where erosion is occurring along the toe of the slope. The purpose of vanes is to reduce erosion along the stream bank by redirecting the stream flow toward the center of the stream. In addition, they tend to create scour pools on the downstream side.

Vanes can be made of rock or log. They grade down from the bankfull elevation at the stream bank to the channel invert at their terminus in the stream. Vanes generally extend out from the stream bank one-third of the bankfull width and are angled upstream from the bank at a 20 to 30 degree angle. They should be carefully located and installed so as not to produce additional erosion on the upstream side where they meet the bank (eddy scour) or allow flows to outflank them, exacerbating existing bank erosion problems. The only difference between the log vane and the rock vane is the material used.

The J–Hook vane is basically the same as a rock vane with the exception that it curls around at the end in the shape of a “J.” The curved end portion serves to enhance downstream scour pool formation. The rock vane is constructed by first excavating a trench for the footer stones. The footer stones are then placed in the trench so that there is a gap between them equal to one-third of the stone diameter. This

gap will allow the vane stones to interlock with the footer stones. The vane stones should be placed on top of the footer stones so they are staggered over two adjacent footer stones and skewed slightly upstream of the footer stones. As the vane is built out and slopes down from the bank, footer stones will become unnecessary when the vane stones can be placed in the trench and extend up to achieve the desired elevation. J-Hook vanes have significant habitat enhancement potential through the creation of downstream scour pools, narrowing and deepening of the base flow channel, and the enhancement of riffle habitat along the upstream side. Drawings C-2 and C-3 depict the proposed locations of J-Hook vanes along the stream bank of Pettibone Creek and are summarized in Table 6-1.

6.5.5 LUNKERS

LUNKERS are a technique to provide both stream bank stability and edge cover aquatic habitat. The location of the proposed LUNKER systems (Detail 1 of Sheet C-7) were chosen based on visual observation of stream bank deterioration areas not subject to extreme stream velocities, such as present in stream bends. A guidance document on the design and installation is provided for reference in Appendix O.

LUNKERS are crib-like, wooden structures installed along the toe of a stream bank to create overhead bank cover and resting areas for fish. These structures were originally developed in Wisconsin for trout stream habitat improvement projects, but have been found to work well in midwestern streams as bank protection devices.

A LUNKER consists of two planks with wooden spacers nailed between them. Additional planks are nailed perpendicular across the spacers and a crib like structure is formed. The structure is installed by first grading the stream bank back and creating a trench along the new bank line. This trench must be wide and deep enough so that the lunkers lay flat and are completely covered by water. The LUNKERS are secured to the stream bottom with rebar. Once in place, rock is placed on top of and behind the LUNKERS and the stream bank is graded down to meet the front edge of the LUNKER. Bank stabilization techniques are the used on the upper bank.

As LUNKERS were originally developed as habitat enhancement structures, they have significant potential to improve stream habitat in the form of undercut banks and overhead cover. Drawings C-2 and C-3 depict the proposed locations of LUNKERs along the stream bank of Pettibone Creek and are summarized in Table 6-1.

6.5.6 Soil Loss Calculation/Recommended Energy Dissipation Structure

The headwaters of the North Branch of Pettibone Creek are fed by a 60-inch and a set of two 48-inch culverts emanating west of Sheridan Road. Soil loss calculations were performed to estimate the potential yearly loss of soil from erosion. It should be noted that, according to discussions with local Department of Agriculture personnel, the soil maps for Lake County are currently being revised to account for rapidly increased urbanization in the vicinity of the Naval Station Great Lakes. Therefore, current soil loss calculations are likely high due to the limitations imposed and the nature of the available soil data. Refer to Appendix P for the soil loss calculations using the Revised Universal Soil Loss Equation, Version 2 (RUSLE2) computer program.

With regard to the potential of installing a concrete settling basin to be constructed over the existing scour pool formed at the headwaters of Pettibone Creek where existing piping drains the upstream watershed, many factors were evaluated and include:

- Impact to the hydraulics at the piping outlet
- Existing storm water flows
- Available particle settling times
- Constructability issues

Each of these aspects is detailed herein.

Impact to the hydraulics at the piping outlet

The maximum height (elevation) of the walls of a constructed sediment containment basin should not exceed the lowest invert elevation of the existing piping. Extending the height of the walls of this structure would lead to surcharging of the existing culverts and potentially lead to backflows during peak flow periods, increasing flooding potential in the drainage basin feeding the North Branch of Pettibone Creek. The Pettibone Creek watershed, as with many watersheds surrounding the region, is susceptible to flooding given the relatively flat terrain and increased urbanization in recent years.

Additionally, given that the maximum wall height must be kept at or below the invert of the existing culverts, the resultant basin would essentially be submerged and the flow from the existing culverts would essentially fall onto the open surface of standing water, which is essentially the current situation (i.e., a scour pool formed). Under larger storm events (e.g., 25 to 100 year storm events), flow from the existing culverts would have enough velocity and force to essentially bypass or “flow over” the basin. The greatest potential for increased sediment loads from the contributing watershed would be under the occurrence of these storms.

Existing storm water flows

The Illinois DOT culverts control the flow of Pettibone Creek that discharges onto the Naval Station Great Lakes property. Stormwater systems are typically designed for 10 year storms. It was reported that the typical flow of Pettibone Creek is estimated to be 10 cfs and, at this time of typical flow, the culverts are flowing between one-fourth to one-third full; however, a scour pool, is located at the discharge point which may submerge part of the invert of the culverts. Based on the hydrologic study, a 10 year storm has a flow of approximately 390 cfs. The available flow capacity provided by the existing culverts is at most 220 cfs or almost 100,000 gpm at full flow conditions.

Available particle settling times

A cursory review of the particle settling was performed for a concrete settling basin roughly estimated to be 50 feet square and 6 feet deep. Given the limited storage volume that a concrete basin would provide versus the estimated soil losses from the contributing watershed, the time required for particle settling would most likely not be available for the given structure. Typical settling times for silt and clay particles are 2.5 to 24 hours. A settling basin of this size would provide settling times orders of magnitude less than what would likely be required during large storm events.

Constructability issues

The headwaters of the Northern Branch of Pettibone Creek comprise a scour pool formed by the flows from existing culverts draining the contributing watershed, bounded by steep ravines on either side, thus limiting available space for constructing a basin in this area.

A more beneficial approach to addressing the velocity and energy of flow from the existing system of culverts at the headwaters and the associated sediments may be to construct an energy dissipation apron comprising of concrete with energy dissipating block ramp, followed by a revetment pad, and finally an engineered scour pool with designed weir.

Appendix P contains calculations performed to evaluate the feasibility of installing a sediment retention structure at the mouth of Pettibone Creek North with respect to surface water flows from various design storms including 1, 2, 5, 10 and 100 year storm fall events.

Presented within these calculations are summary tables detailing the various dimensions of sediment retention structures required to accommodate sediment settling based on assumed sediment settling rates. Regardless of the design storm evaluated, the required dimensions of the resultant sediment

retention structure far exceed the available area at the mouth of Pettibone Creek available to construct such a structure.

6.5.7 Engineered Flood Plains

Engineered side channel flood plains (see proposed locations on Drawings C-2 and C-3) are recommended to provide areas where sediment can deposit and accumulate in a controlled manner. Specifically, the design of meandering channels and increased flood plain storage is proposed to reduce storm water runoff rates from upstream sediments conveyed to the North Branch of Pettibone Creek. The design will reduce channel dimensions such that overflows into flood plain side channels will store additional floodwaters and reduce sediment transport to the Boat Basin. Three engineered side channel flood plains (A, B, and C) are proposed as shown on Drawings C-4, C-5, and C-6, including cross sections and proposed berm elevations. The recommended plant list for the engineered side channel flood plains include:

Bank (upper, drier areas)

Shrubs (pots)

- Rough-leaved dogwood (*Cornus drummondii*) or
- Gray dogwood (*Cornus racemosa*)
- Nannyberry *(Viburnum lentago*)
- Arrowwood Viburnum (*Viburnum dentatum*)

Herbaceous

- Canada wildrye (*Elymus canadensis*) (seed 2-4 lbs/acre)
- Virginia wildrye (*Elymus virginicus*) (seed 1 lb/acre)
- Smooth Blue Aster (*Aster laevis*) (seed 1 lb/acre)
- Switch grass (*Panicum virgatum*) (seed 2 lbs/acre)

Bank Stabilization (lower, moist areas)

Trees/Shrubs (pots or whip/sticks as noted)

- Red osier dogwood (*Cornus sericea*)
- Willow (*Salix discolor or Salix interior*) (use as whips in embankment)
- Black willow (*Salix nigra*)

Herbaceous

- Virginia wildrye (*Elymus virginicus*) (seed 1 lb/acre)
- Chairmaker's rush (*Scirpus americanus*) (plugs)
- *Carex* species (*C. vulpinoidea*, depends on nursery stock)(plugs)
- Rice cut grass (*Leersia oryzoides*) (plugs)

Emergent Wetland (low energy areas of channel)

Herbaceous

- River bulrush (*Scirpus fluviatilis*) (plugs or pots)
- *Common Burreed (*Sparganium eurycarpum*) (pots or plugs)
- Arrowhead (*Sagittaria latifolia*) (pots)
- Common rush (*Juncus effusus*) (plugs or pots)

*Note: Can use Cattail (O*Typha latifolia*) but probably will come in on its own

In addition to restoring disturbed areas as described in Section 4.4, "Site Restoration" that are part of the stream bank stabilization, areas that are transformed to flood plains will be vegetated with native species including, but not limited to, the species of herbaceous plant species, shrubs, and trees listed above.

TABLE 6-1

PETTIBONE CREEK REMEDIAL ACTION SUMMARY
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

STATIONS	BANK	REMEDIAL ACTION TO BE TAKEN	Reference
0+10 to 1+80	Right	LUNKERS	--
0+25 to 1+80	Left	LUNKERS	--
1+80 to 1+95	Left	ERTEC Bank Stabilization System	See photo 55.
1+85	--	Remove Fallen Tree Spanning Stream	See photo 55.
1+95 to 2+55	--	Log Vanes	See photo 53.
2+90 to 3+40	Both	Rock Riffle Structures	--
3+20 to 5+85	Right	ERTEC Bank Stabilization System	See photo 52.
3+30 to 4+25	Left	ERTEC Bank Stabilization System	See photo 52.
5+60 to 6+05	Both	Rock Riffle Structures	--
6+15 to 6+95	--	Log Vanes	--
7+00 to 7+35	Right	J-Hooks	--
7+80 to 9+20	Left	LUNKERS	See photo 45.
7+95 to 9+00	Right	Engineered Flood Plains A	See Drawing C-4, See Photos 44, 46, & 47.
9+15 to 9+60	Both	Rock Riffle Structures	--
9+20 to 10+20	Right	ERTEC Bank Stabilization System	See photo 41.
9+90 to 10+20	Left	ERTEC Bank Stabilization System	See photo 41.
10+99 to 11+35	Both	Rock Riffle Structures	--
10+20 to 11+05	Right	LUNKERS	--
10+20 to 11+00	Left	LUNKERS	--
11+30 to 11+60	Right	ERTEC Bank Stabilization System	See photo 41.
12+80 to 13+20	Left	LUNKERS	
12+85 to 13+50	Right	ERTEC Bank Stabilization System	See photo 35.
13+50 to 14+05	--	Remove Concrete Debris From Stream Bed	See Photos 48 & 49.
13+75 to 13+95	Both	Rock Riffle Structures	--
14+10 to 15+00	Left	ERTEC Bank Stabilization System	--
14+15 to 15+05	Right	ERTEC Bank Stabilization System	--
15+10 to 16+90	Left	Rootwad system	See photo 34.
16+00 to 17+40	Right	LUNKERS	See photo 34.
16+90 to 18+00	Both	Rock Riffle Structures	--
17+00 to 17+40	Left	LUNKERS	See photo 34.
17+95 to 18+05	Left	LUNKERS	See photo 33.
19+65 to 20+00	Right	LUNKERS	See Photos 28 & 30.
20+10 to 20+60	Both	Rock Riffle Structures	--
20+50 to 21+05	Left	ERTEC Bank Stabilization System	See Photos 28 & 30.
21+40 to 21+95	Left	LUNKERS	See photo 26.
21+45 to 21+95	Right	LUNKERS	See photo 26.
22+05 to 22+50	Left	ERTEC Bank Stabilization System	--
22+35 to 22+60	Both	Rock Riffle Structures	--
22+40 to 22+90	Right	J-Hooks	--
22+90 to 24+75	Right	Install Engineered Flood Plains B	See Drawing C-5.
23+65 to 23+95	Left	ERTEC Bank Stabilization System	See photo 23.
24+40 to 24+95	Both	Rock Riffle Structures	--
24+90 to 27+05	Right	Remove Concrete Rubble. Repair Eroded Stream Bank	See Figure 6-9, See Photo 16.
25+30 to 26+90	Right	LUNKERS	See photo 16.
25+35 to 26+90	Left	LUNKERS	See photo 16.
25+45 to 25+75	Both	Rock Riffle Structures	--
27+15 to 28+80	Right	ERTEC Bank Stabilization System	See photo 15.
27+15 to 28+75	Left	ERTEC Bank Stabilization System	See photo 15.
29+20 to 29+40	Right	LUNKERS	--
29+40 to 29+90	Both	Rock Riffle Structures	--
29+40 to 33+35	Right	Install Engineered Flood Plains C	See Drawing C-6.
29+85 to 30+85	Left	LUNKERS	--
31+10 to 32+15	Left	Remove Accumulated Sediment From Stream Bank, Stabilize Channel Bank With ERTEC Bank Stabilization System	See Photo 8.
33+45 to 34+15	Right	Replace Damaged Sheeting in Kind	See Photo 4.

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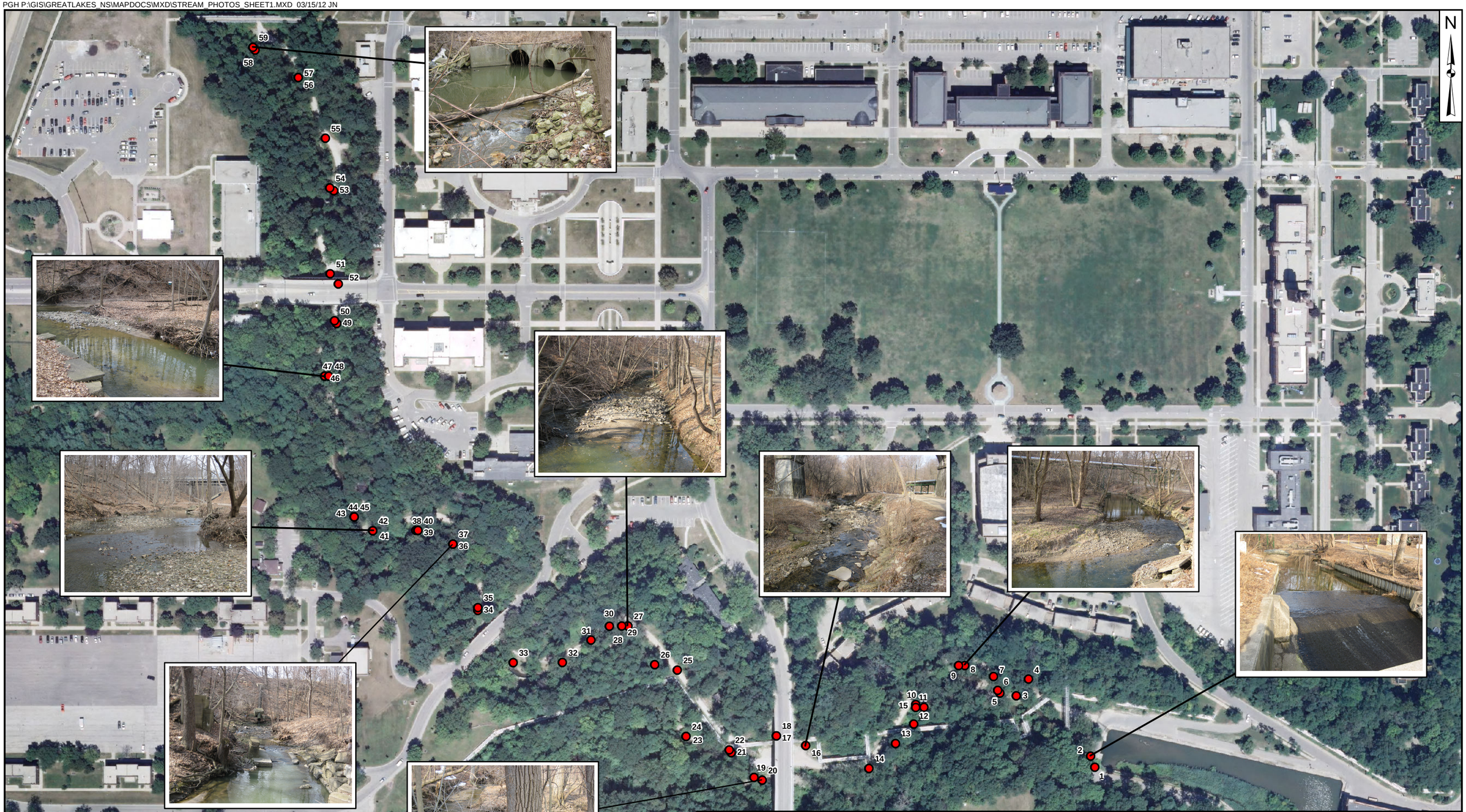

DRAWN BY	DATE
M. MAGUIRE	06/15/11
CHECKED BY	DATE
B. SMITH	03/15/12
REVISED BY	DATE
J. NOVAK	03/15/12
SCALE	
AS NOTED	

NAVFAC

PETTIBONE CREEK
PHOTOGRAPH LOCATIONS

NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
NG2467-04-D-0055	474
APPROVED BY	DATE
RFD	03/15/12
APPROVED BY	DATE
FIGURE NO.	REV
FIGURE 6-1	0

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DRAWN BY	DATE
M. MAGUIRE	05/11/11
CHECKED BY	DATE
B. SMITH	03/15/12
REVISED BY	DATE
J. NOVAK	03/15/12
SCALE	
AS NOTED	

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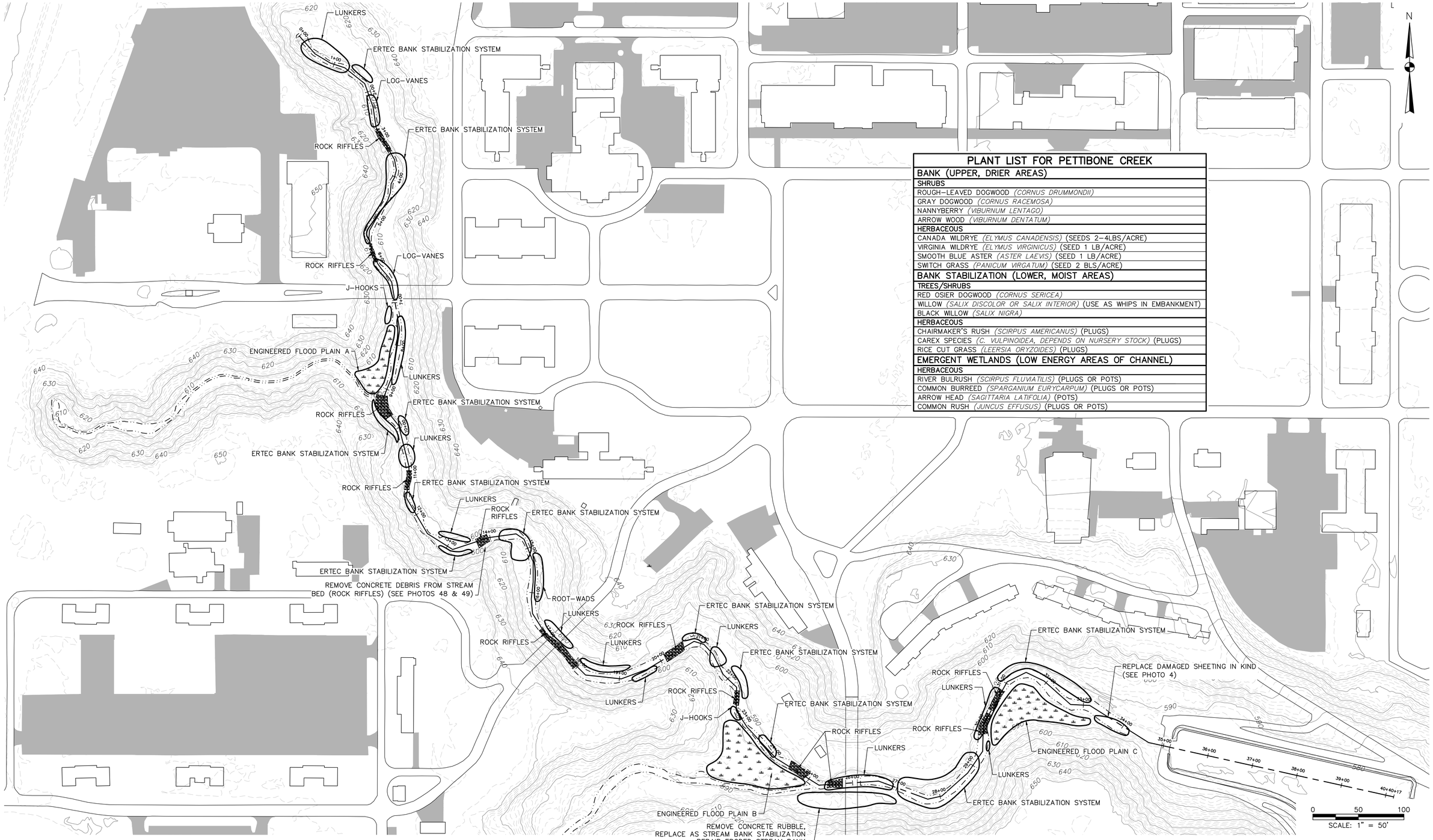
PETTIBONE CREEK CONTOURS

NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. FIGURE 6-2	REV 0

DRAWINGS



PLANT LIST FOR PETTIBONE CREEK
BANK (UPPER, DRIER AREAS)
SHRUBS
ROUGH–LEAVED DOGWOOD *(CORNUS DRUMMONDII)*
GRAY DOGWOOD *(CORNUS RACEMOSA)*
NANNYBERRY *(VIBURNUM LENTAGO)*
ARROW WOOD *(VIBURNUM DENTATUM)*
HERBACEOUS
CANADA WILDRYE *(ELYMUS CANADENSIS)* (SEEDS 2–4LBS/ACRE)
VIRGINIA WILDRYE *(ELYMUS VIRGINICUS)* (SEED 1 LB/ACRE)
SMOOTH BLUE ASTER *(ASTER LAEVIS)* (SEED 1 LB/ACRE)
SWITCH GRASS *(PANICUM VIRGATUM)* (SEED 2 BLS/ACRE)
BANK STABILIZATION (LOWER, MOIST AREAS)
TREES/SHRUBS
RED OSIER DOGWOOD *(CORNUS SERICEA)*
WILLOW *(SALIX DISCOLOR OR SALIX INTERIOR)* (USE AS WHIPS IN EMBANKMENT)
BLACK WILLOW *(SALIX NIGRA)*
HERBACEOUS
CHAIRMAKER'S RUSH *(SCIRPUS AMERICANUS)* (PLUGS)
CAREX SPECIES *(C. VULPINOIDEA, DEPENDS ON NURSERY STOCK)* (PLUGS)
RICE CUT GRASS *(LEERSIA ORYZOIDES)* (PLUGS)
EMERGENT WETLANDS (LOW ENERGY AREAS OF CHANNEL)
HERBACEOUS
RIVER BULRUSH *(SCIRPUS FLUVIATILIS)* (PLUGS OR POTS)
COMMON BURREED *(SPARGANIUM EURYCARPUM)* (PLUGS OR POTS)
ARROW HEAD *(SAGITTARIA LATIFOLIA)* (POTS)
COMMON RUSH *(JUNCUS EFFUSUS)* (PLUGS OR POTS)

DRAWN BY BH	DATE 7/27/11	
CHECKED BY RLS	DATE 7/27/11	
REVISED BY	DATE	
SCALE 1" = 100'		

NAVFAC

OVERALL SITE PLAN
PROPOSED REMEDIAL ACTION PLAN
NS GREAT LAKES
GREAT LAKES, ILLONOIS

CONTRACT NO. N62467–04–D–0055	
OWNER NO. 474	
APPROVED BY RFD	DATE 3/15/12
DRAWING NO. C–1	SIZE D / REV. 0

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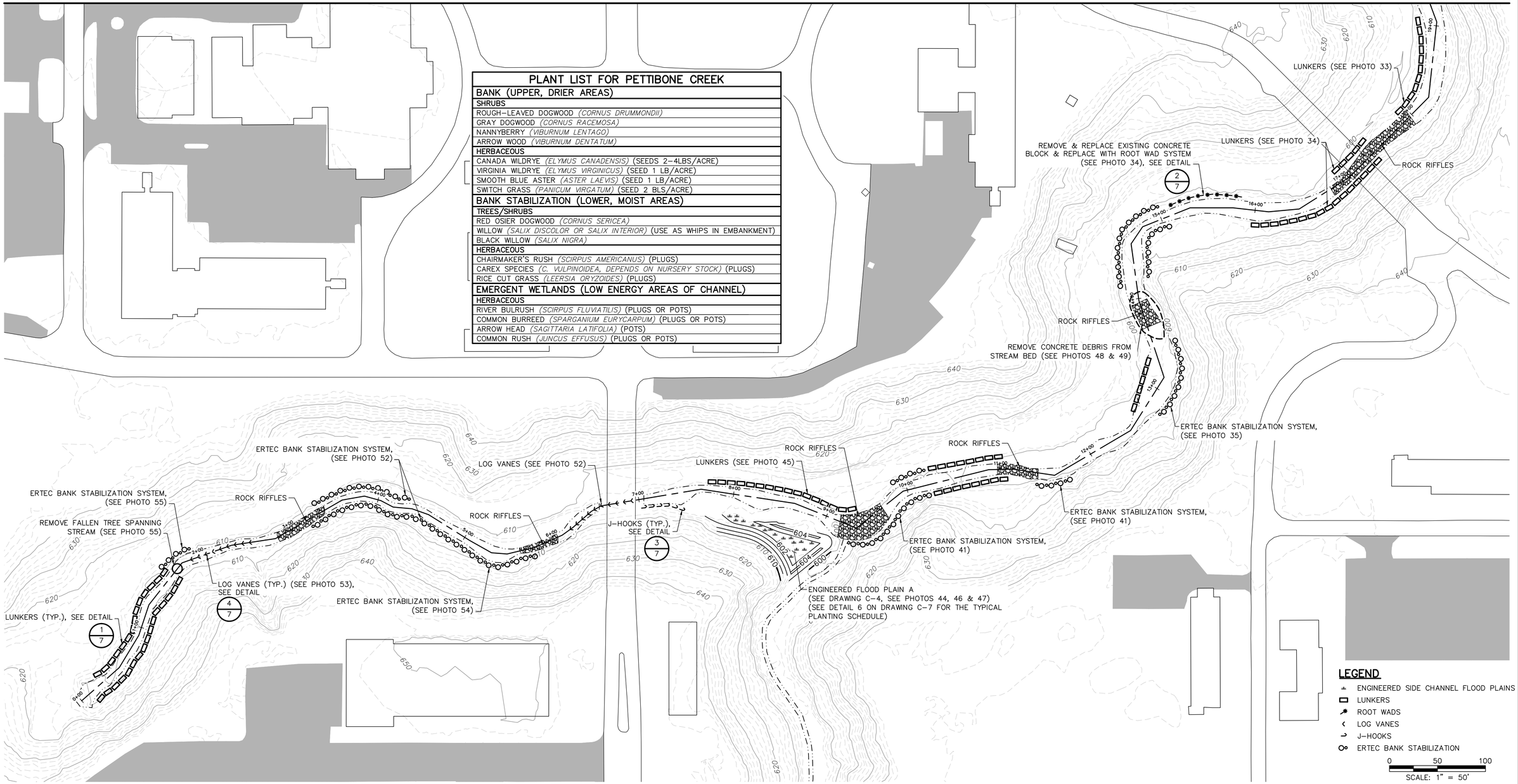
MATCHLINE A

MATCHLINE A



PLANT LIST FOR PETTIBONE CREEK

BANK (UPPER, DRIER AREAS)	
SHRUBS	
ROUGH-LEAVED DOGWOOD *(CORNUS DRUMMONDII)*	
GRAY DOGWOOD *(CORNUS RACEMOSA)*	
NANNYBERRY *(VIBURNUM LENTAGO)*	
ARROW WOOD *(VIBURNUM DENTATUM)*	
HERBACEOUS	
CANADA WILDRYE *(ELYMUS CANADENSIS)*	(SEEDS 2-4LBS/ACRE)
VIRGINIA WILDRYE *(ELYMUS VIRGINICUS)*	(SEED 1 LB/ACRE)
SMOOTH BLUE ASTER *(ASTER LAEVIS)*	(SEED 1 LB/ACRE)
SWITCH GRASS *(PANICUM VIRGATUM)*	(SEED 2 BLS/ACRE)
BANK STABILIZATION (LOWER, MOIST AREAS)	
TREES/SHRUBS	
RED OSIER DOGWOOD *(CORNUS SERICEA)*	
WILLOW *(SALIX DISCOLOR OR SALIX INTERIOR)*	(USE AS WHIPS IN EMBANKMENT)
BLACK WILLOW *(SALIX NIGRA)*	
HERBACEOUS	
CHAIRMAKER'S RUSH *(SCIRPUS AMERICANUS)*	(PLUGS)
CAREX SPECIES *(C. VULPINOIDEA, DEPENDS ON NURSERY STOCK)*	(PLUGS)
RICE CUT GRASS *(LEERSIA ORYZOIDES)*	(PLUGS)
EMERGENT WETLANDS (LOW ENERGY AREAS OF CHANNEL)	
HERBACEOUS	
RIVER BULRUSH *(SCIRPUS FLUVIATILIS)*	(PLUGS OR POTS)
COMMON BURREED *(SPARGANIUM EURYCARPUM)*	(PLUGS OR POTS)
ARROW HEAD *(SAGITTARIA LATIFOLIA)*	(POTS)
COMMON RUSH *(JUNCUS EFFUSUS)*	(PLUGS OR POTS)

DRAWN BY BH	DATE 7/27/11
CHECKED BY RLS	DATE 7/27/11
REVISED BY	DATE
SCALE 1" = 50'	

NAVFAC

SITE PLAN (SHEET 1 OF 2)
PROPOSED REMEDIAL ACTION PLAN
NS GREAT LAKES
GREAT LAKES, ILLONOIS

CONTRACT NO. N62467-04-D-0055	
OWNER NO. 474	
APPROVED BY RFD	DATE 3/15/12
DRAWING NO. C-2	SIZE D / REV. 0

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MATCHLINE A

PLANT LIST FOR PETTIBONE CREEK
BANK (UPPER, DRIER AREAS)
SHRUBS
ROUGH–LEAVED DOGWOOD *(CORNUS DRUMMONDII)*
GRAY DOGWOOD *(CORNUS RACEMOSA)*
NANNYBERRY *(VIBURNUM LENTAGO)*
ARROW WOOD *(VIBURNUM DENTATUM)*
HERBACEOUS
CANADA WILDRYE *(ELYMUS CANADENSIS)* (SEEDS 2–4LBS/ACRE)
VIRGINIA WILDRYE *(ELYMUS VIRGINICUS)* (SEED 1 LB/ACRE)
SMOOTH BLUE ASTER *(ASTER LAEVIS)* (SEED 1 LB/ACRE)
SWITCH GRASS *(PANICUM VIRGATUM)* (SEED 2 BLS/ACRE)
BANK STABILIZATION (LOWER, MOIST AREAS)
TREES/SHRUBS
RED OSIER DOGWOOD *(CORNUS SERICEA)*
WILLOW *(SALIX DISCOLOR OR SALIX INTERIOR)* (USE AS WHIPS IN EMBANKMENT)
BLACK WILLOW *(SALIX NIGRA)*
HERBACEOUS
CHAIRMAKER'S RUSH *(SCIRPUS AMERICANUS)* (PLUGS)
CAREX SPECIES *(C. VULPINOIDEA, DEPENDS ON NURSERY STOCK)* (PLUGS)
RICE CUT GRASS *(LEERSIA ORYZOIDES)* (PLUGS)
EMERGENT WETLANDS (LOW ENERGY AREAS OF CHANNEL)
HERBACEOUS
RIVER BULRUSH *(SCIRPUS FLUVIATILIS)* (PLUGS OR POTS)
COMMON BURREED *(SPARGANIUM EURYCARPUM)* (PLUGS OR POTS)
ARROW HEAD *(SAGITTARIA LATIFOLIA)* (POTS)
COMMON RUSH *(JUNCUS EFFUSUS)* (PLUGS OR POTS)

ERTEC BANK STABILIZATION SYSTEM (PHOTOS 28 & 30)

LUNKERS (PHOTO 26)

ROCK RIFFLES

LUNKERS (PHOTOS 28 & 30)

J–HOOKS (TYP.), SEE DETAIL 3/7

ROCK RIFFLES

ERTEC BANK STABILIZATION SYSTEM (SEE PHOTO 23)

LUNKERS (TYP.), (SEE PHOTO 16), SEE DETAIL 1/7

ROCK RIFFLES

INSTALL ENGINEERED FLOOD PLAIN B (SEE DRAWING C–5) (SEE DETAIL 6 ON DRAWING C–7 FOR THE TYPICAL PLANTING SCHEDULE)

ROCK RIFFLES

REMOVE CONCRETE RUBBLE, REPAIR ERODED STREAM BANK (SEE FIGURE 6–9, SEE PHOTO 16)

ERTEC BANK STABILIZATION SYSTEM, (SEE PHOTO 15)

ERTEC BANK STABILIZATION SYSTEM, (SEE PHOTO 15)

REMOVE ACCUMULATED SEDIMENT FROM STREAM BANK, STABILIZE CHANNEL BANK WITH ERTEC BANK STABILIZATION SYSTEM (SEE PHOTO 8)

ROCK RIFFLES

REPLACE DAMAGED SHEETING IN KIND (SEE PHOTO 4)

INSTALL ENGINEERED FLOOD PLAIN C (SEE DRAWING C–6) (SEE DETAIL 6 ON DRAWING C–7 FOR THE TYPICAL PLANTING SCHEDULE)

N

LEGEND

- ENGINEERED SIDE CHANNEL FLOOD PLAINS
- LUNKERS
- ROOT WADS
- LOG VANES
- J–HOOKS
- ERTEC BANK STABILIZATION

0 50 100

SCALE: 1" = 50'

MATCHLINE A

DRAWN BY BH	DATE 7/27/11	
CHECKED BY RLS	DATE 7/27/11	
REVISED BY	DATE	
SCALE 1" = 50'		

NAVFAC

SITE PLAN (SHEET 2 OF 2)
PROPOSED REMEDIAL ACTION PLAN
NS GREAT LAKES
GREAT LAKES, ILLONOIS

CONTRACT NO. N62467–04–D–0055	
OWNER NO. 474	
APPROVED BY RFD	DATE 3/15/12
DRAWING NO. C–3	SIZE D / REV. 0

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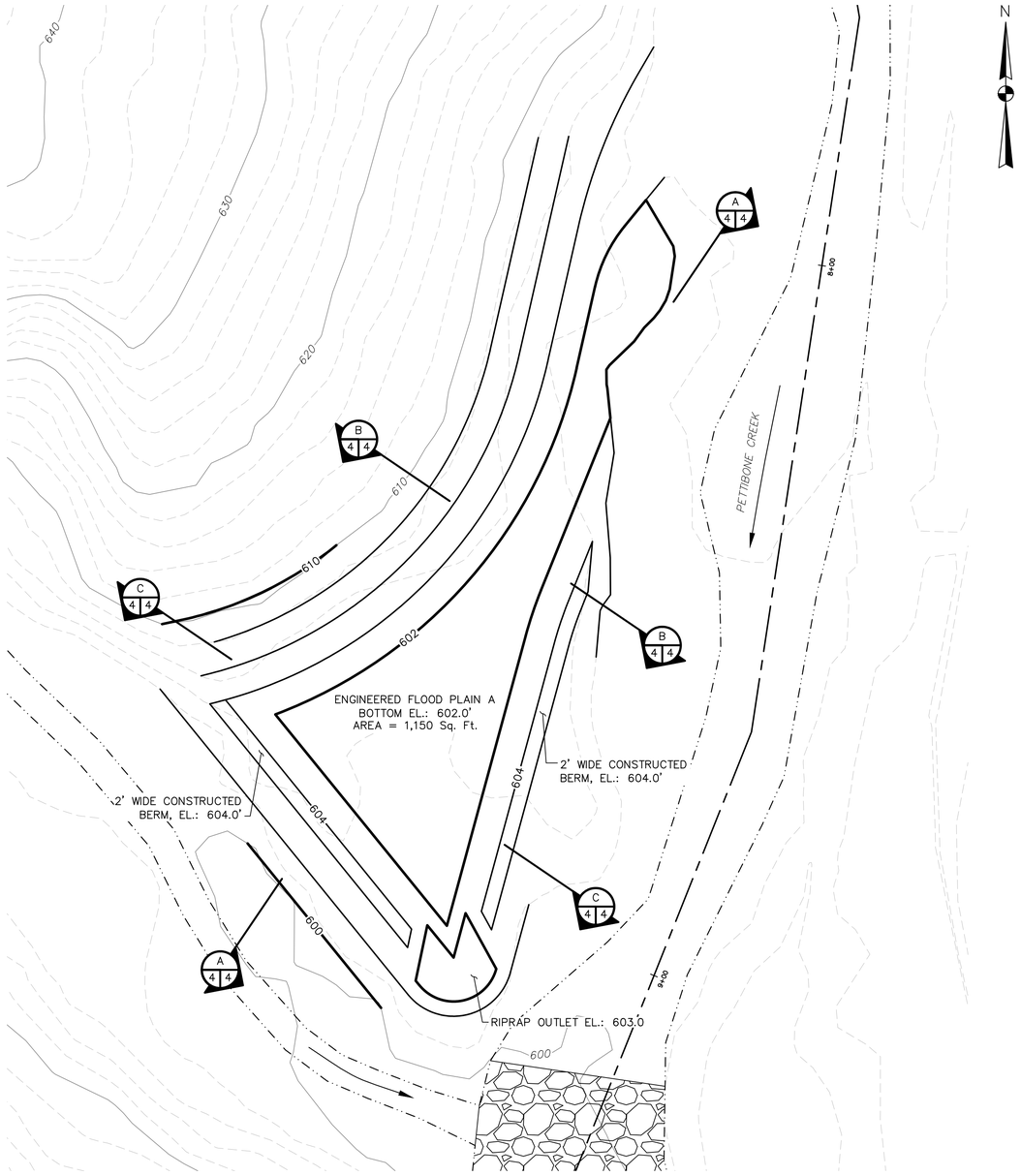
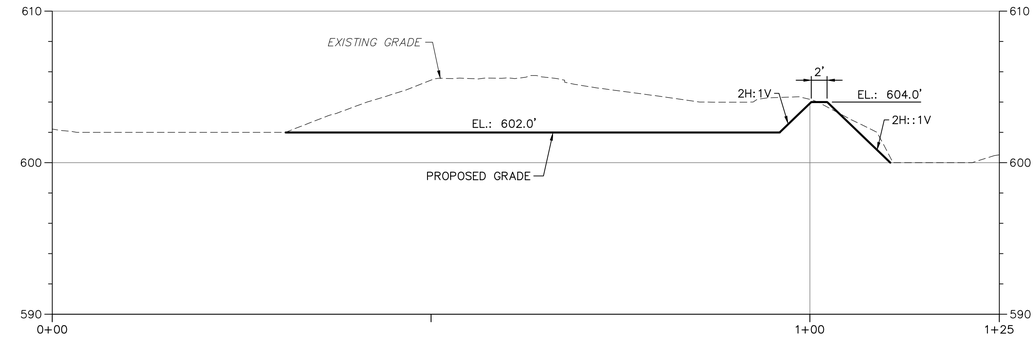


PLAN VIEW

SCALE: 1" = 10'

0 10 20

SCALE: 1" = 10'



SECTION A 4 4

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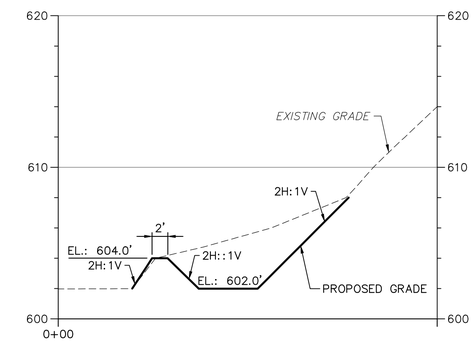
VERT: 1" = 5'



SECTION B 4 4

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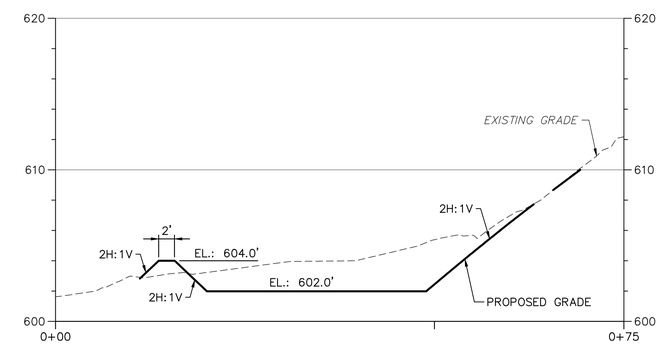
VERT: 1" = 5'



SECTION C 4 4

SCALE: HORIZ: 1" = 10'
VERT: 1" = 5'

0 10 20
HORIZONTAL SCALE: 1" = 10'

0 5 10
VERTICAL SCALE: 1" = 5'

DRAWN BY BH	DATE 7/27/11	ENGINEERED FLOOD PLAIN A PROPOSED REMEDIAL ACTION PLAN NS GREAT LAKES GREAT LAKES, ILLONOIS	CONTRACT NO. N62467–04–D–0055
CHECKED BY RLS	DATE 7/27/11		OWNER NO. 474
REVISED BY	DATE		APPROVED BY RFD / DATE 3/15/12
SCALE AS NOTED			DRAWING NO. C–4 / SIZE D / REV. 0

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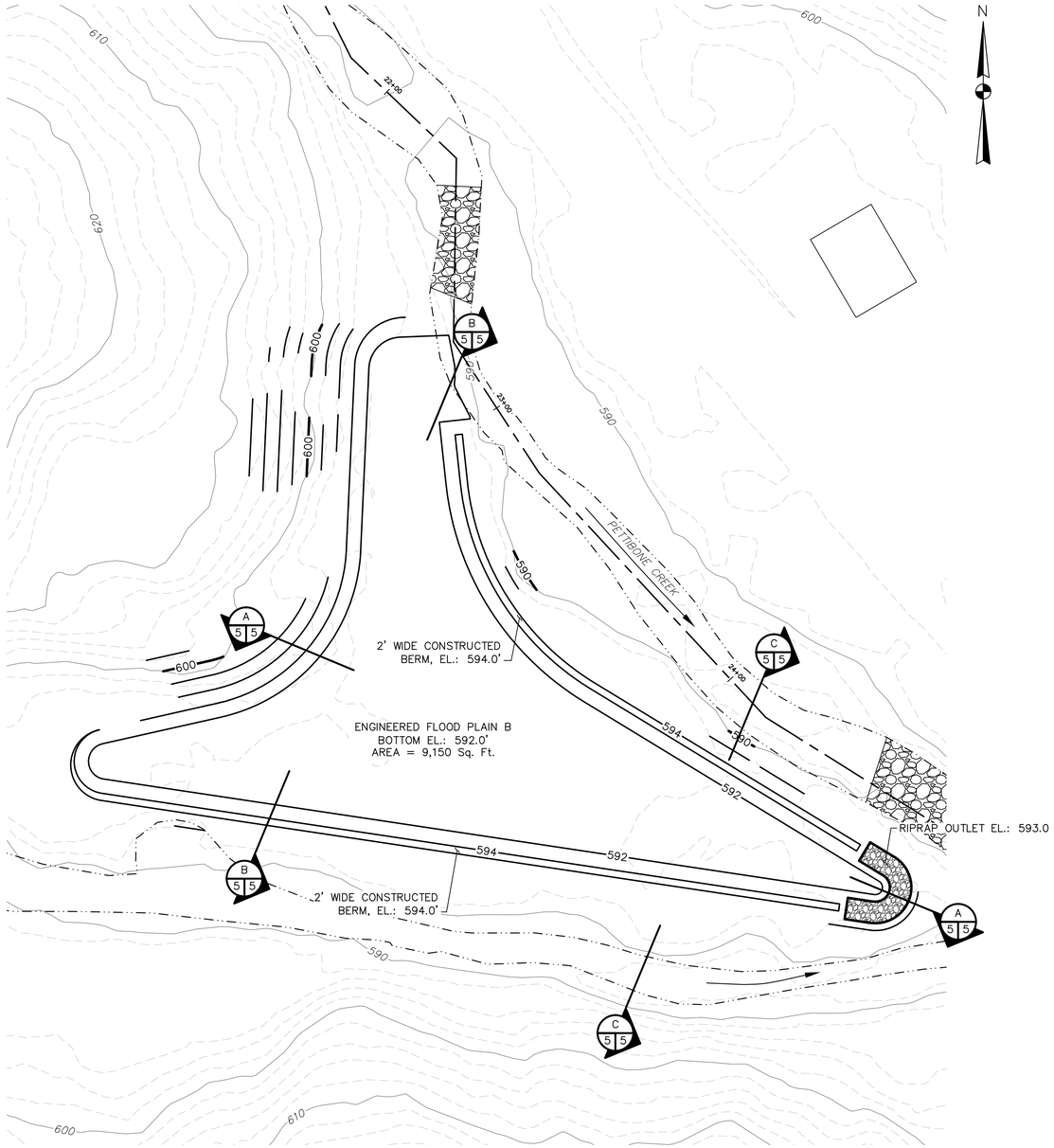
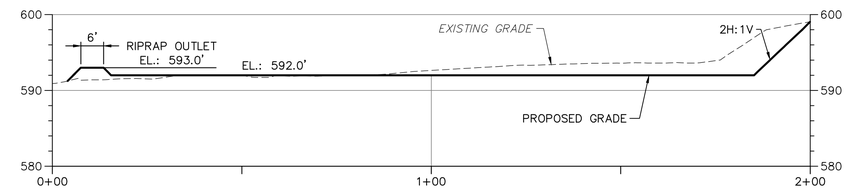


PLAN VIEW

SCALE: 1' = 20'

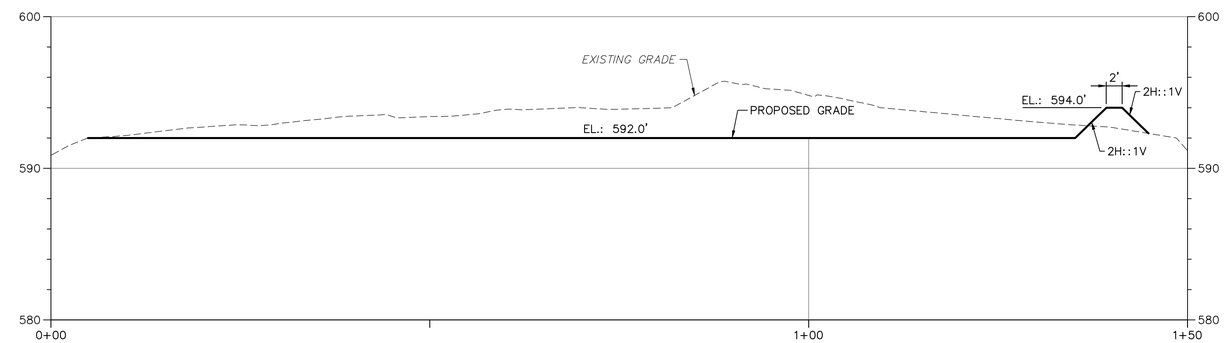
0 20 40

SCALE: 1" = 20'



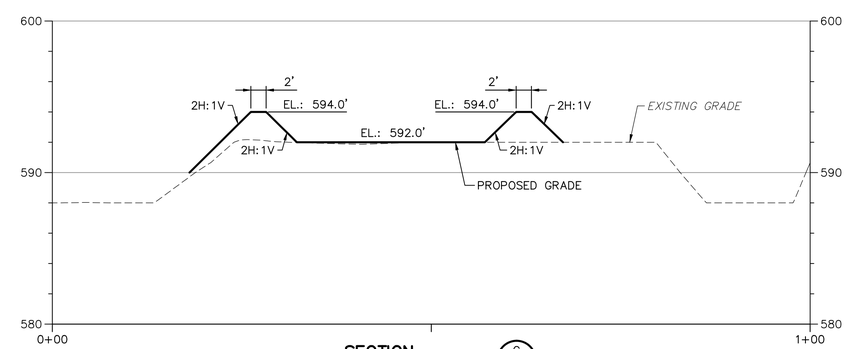
SECTION A 5 5

SCALE: HORIZ: 1" = 20'
VERT: 1" = 10'



SECTION B 5 5

SCALE: HORIZ: 1" = 10'
VERT: 1" = 5'



SECTION C 5 5

SCALE: HORIZ: 1" = 10'
VERT: 1" = 5'

0 10 20
HORIZONTAL SCALE: 1" = 10'

0 5 10
VERTICAL SCALE: 1" = 5'

DRAWN BY BH	DATE 7/27/11	ENGINEERED FLOOD PLAIN B PROPOSED REMEDIAL ACTION PLAN NS GREAT LAKES GREAT LAKES, ILLONOIS	CONTRACT NO. N62467-04-D-0055
CHECKED BY RLS	DATE 7/27/11		OWNER NO. 474
REVISED BY	DATE		APPROVED BY RFD / DATE 3/15/12
SCALE AS NOTED			DRAWING NO. C-5 / SIZE D / REV. 0

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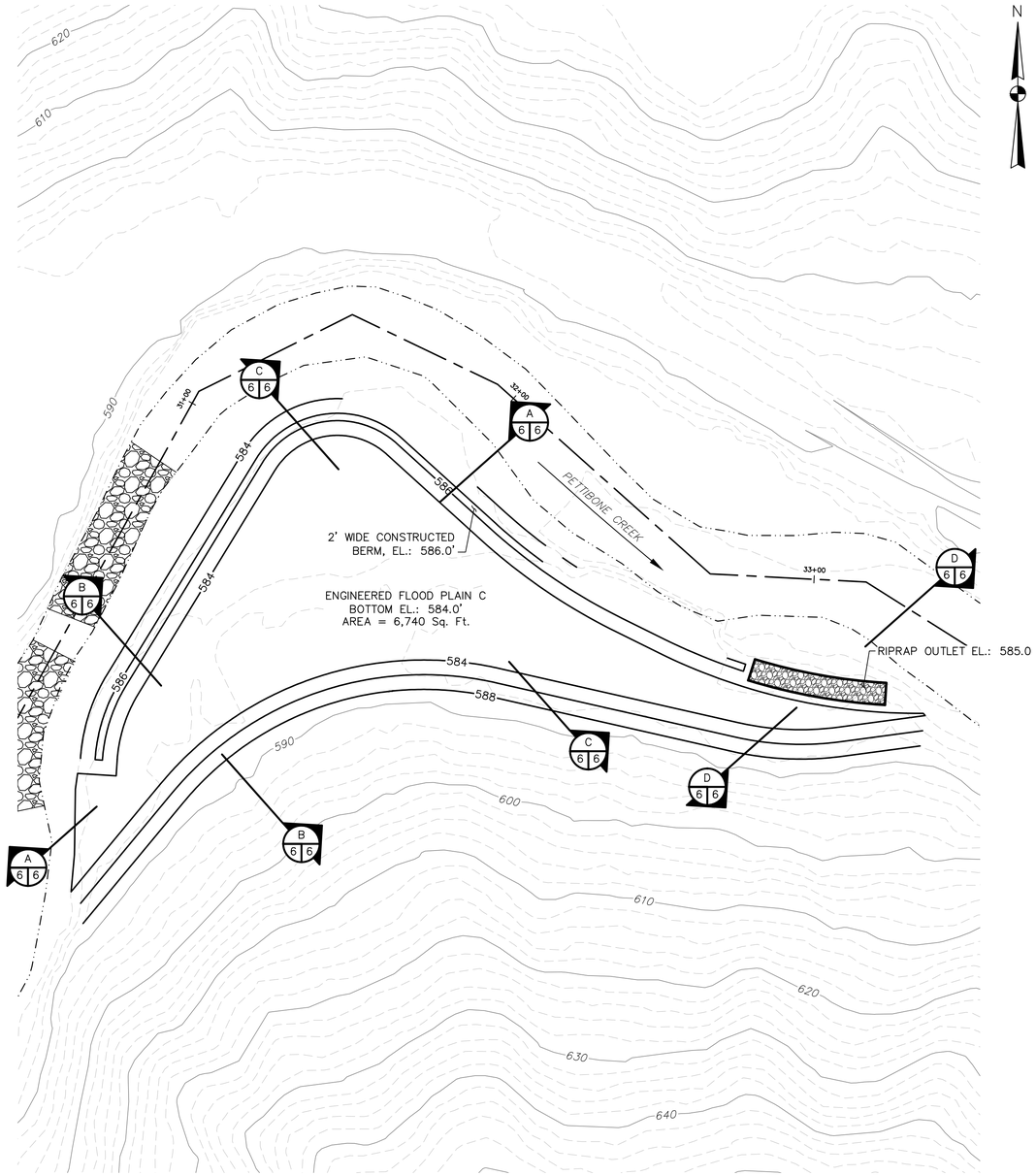
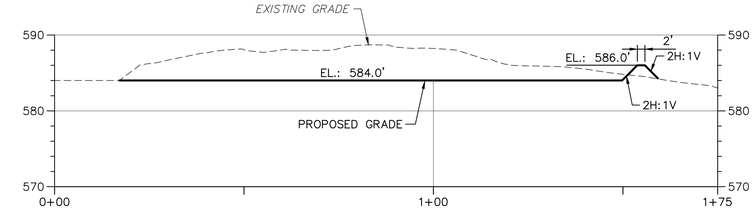


PLAN VIEW

SCALE: 1" = 20'

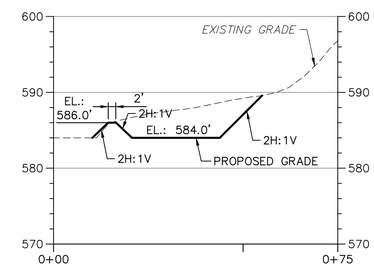
0 20 40

SCALE: 1" = 20'



SECTION A 6 6

SCALE: HORIZ: 1" = 20'
VERT: 1" = 10'



SECTION B 6 6

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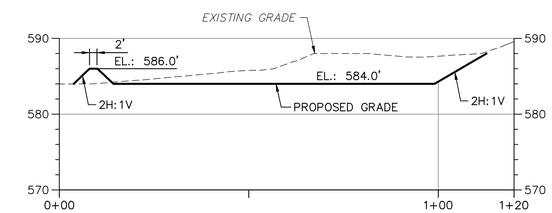
VERT: 1" = 10'



SECTION C 6 6

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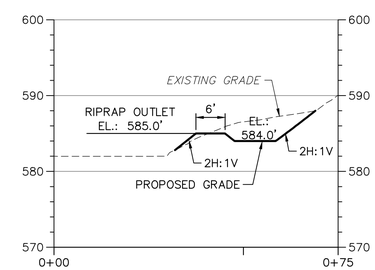
VERT: 1" = 10'



SECTION D 6 6

SCALE: HORIZ: 1" = 20'
VERT: 1" = 10'

0 20 40
HORIZONTAL SCALE: 1" = 20'

0 10 20
VERTICAL SCALE: 1" = 10'

DRAWN BY BH	DATE 7/27/11	ENGINEERED FLOOD PLAIN C PROPOSED REMEDIAL ACTION PLAN NS GREAT LAKES GREAT LAKES, ILLONOIS
CHECKED BY RLS	DATE 7/27/11	
REVISED BY	DATE	
SCALE AS NOTED		

NAVFAC

CONTRACT NO. N62467–04–D–0055	
OWNER NO. 474	
APPROVED BY RFD	DATE 3/15/12
DRAWING NO. C–6	SIZE D / REV. 0

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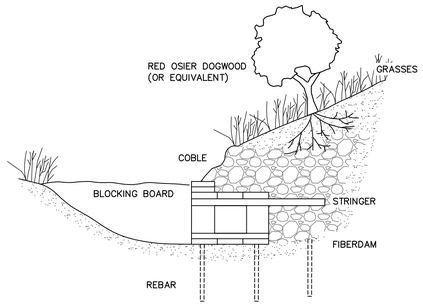
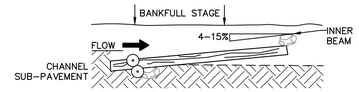
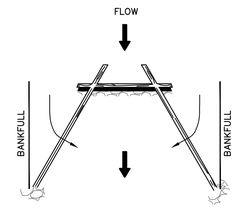


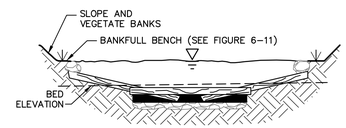
LUNKER DETAIL (1/7)
NOT TO SCALE



PROFILE



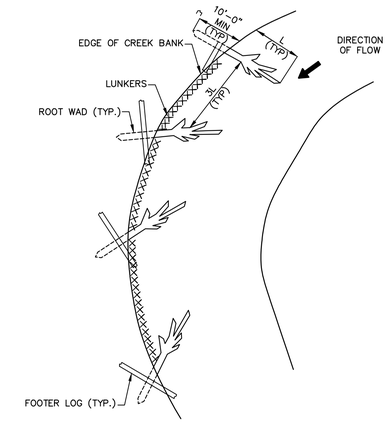
PLAN



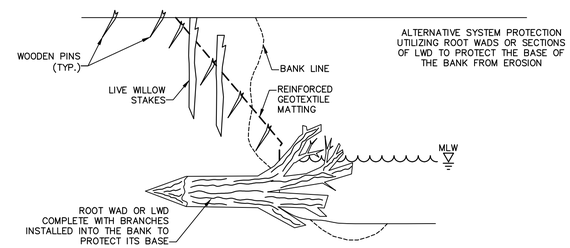
CROSS–SECTION

LEGEND:
- HEADER ROCK
- HEADER LOG
- FOOTER LOG
- VEGETATION

LOG–VANE DETAIL (4/7)
NOT TO SCALE

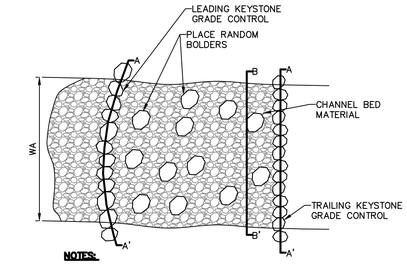


PLAN



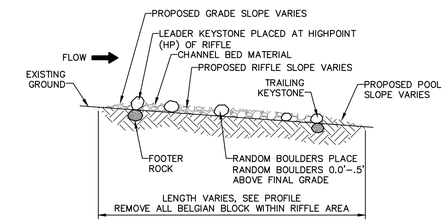
CROSS–SECTION

ROOT–WAD DETAIL (2/7)
NOT TO SCALE

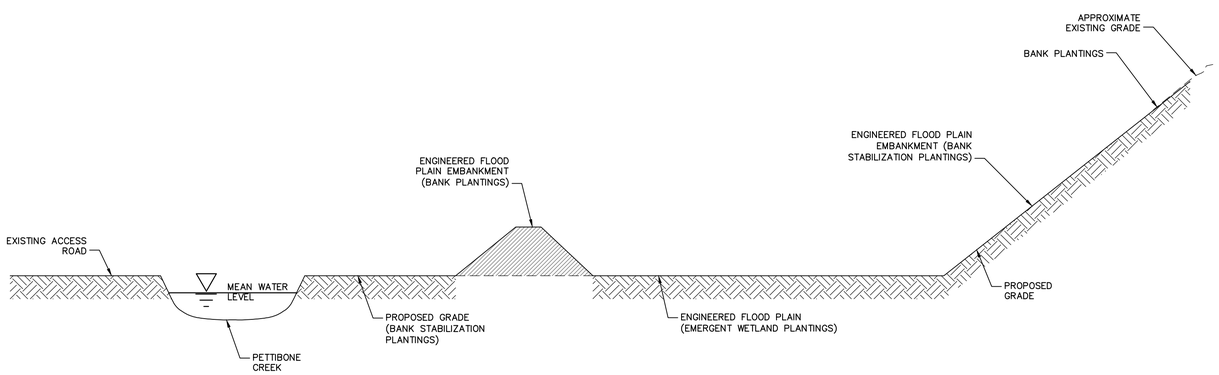


NOTES:
1. TRAILING KEYSTONE MAYBE REPLACED BY ROCK CROSS VANES.
2. PLACE FOUR RANDOM BOULDERS PER 100 SQUARE FEET OF RIFFLE AREA.

PLAN VIEW

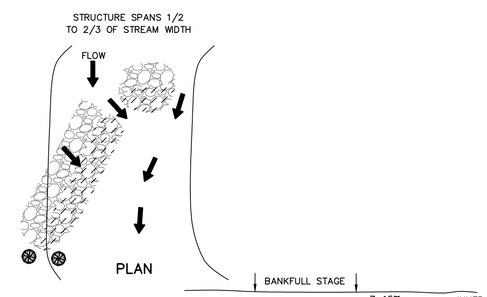


PROFILE VIEW

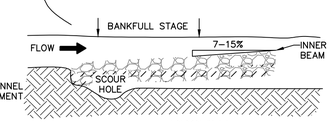


NOTES:
1. SEE PLANTING SCHEDULE ON DRAWINGS C–1, C–2, AND C–3.

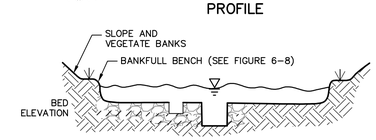
TYPICAL PLANTING SCHEDULE – ENGINEERED FLOOD PLANS (6/7)
NOT TO SCALE



PLAN



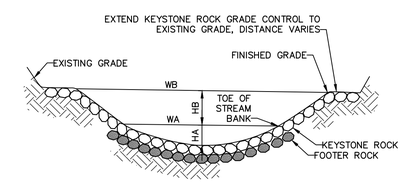
PROFILE



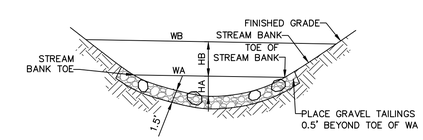
CROSS–SECTION

LEGEND:
- HEADER ROCK
- FOOTER ROCK
- VEGETATION

J–HOOK DETAIL (3/7)
NOT TO SCALE



SECTION A–A'



NOTES:
1. PLACE RANDOM BOULDERS 0–6' ABOVE FINAL GRADE RANDOM BOULDERS MAY BE PLACED IN STREAM BANKS.

SECTION B–B'

ROCK RIFFLE STRUCTURE (5/7)
NOT TO SCALE

DRAWN BY BH	DATE 7/29/11	CONSTRUCTION DETAILS PROPOSED REMEDIAL ACTION PLAN NS GREAT LAKES GREAT LAKES, ILLONOIS
CHECKED BY RLS	DATE 7/29/11	CONTRACT NO. N62467–04–D–0055
REVISED BY	DATE	OWNER NO. 474
SCALE AS NOTED		APPROVED BY RFD — DATE 3/15/12
		DRAWING NO. C–7 — SIZE D — REV. 0

NAVFAC

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APPENDIX A

SITE PHOTOGRAPHS

Photograph 1: Pettibone Creek culvert discharge onto Naval Station Great Lakes

Photograph 2: Access Road along Pettibone Creek

Photograph 3: Access Road along Pettibone Creek with steam lines

Photograph 4: Stormwater Outfall

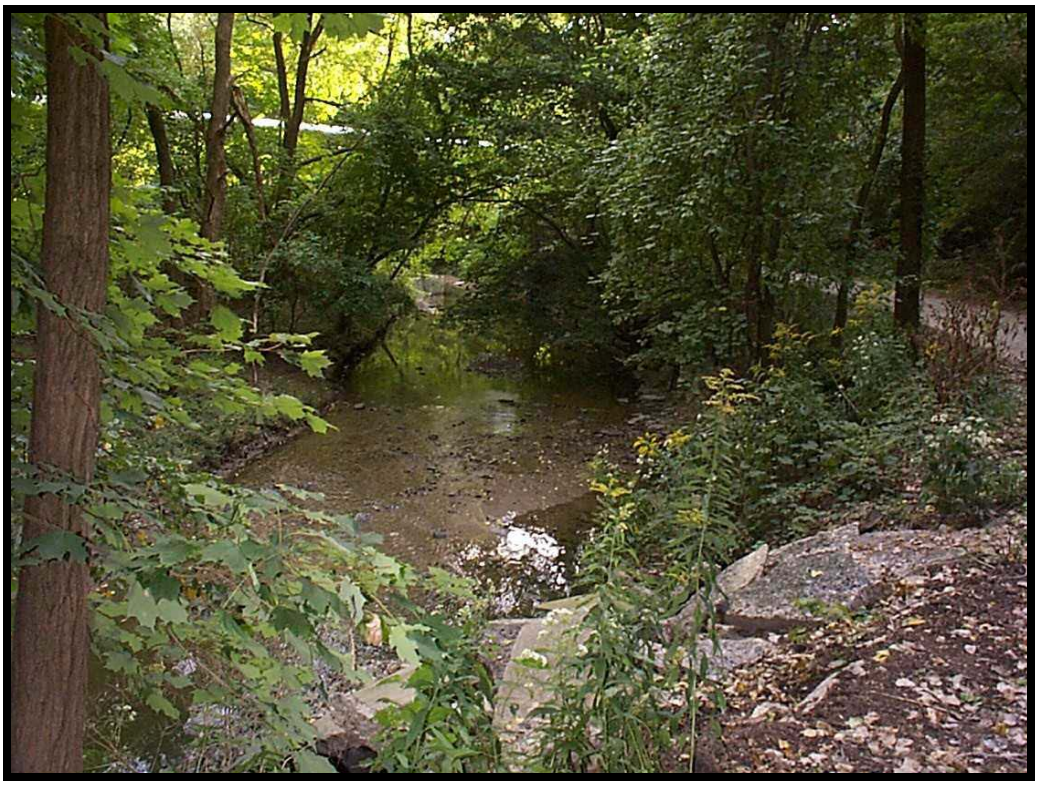
Photograph 5: Pettibone Creek with Stormwater Outfalls

Photograph 6: Pettibone Creek with sediment and rock

Photograph 7: Pettibone Creek with rock

Photograph 8: Pettibone Creek with rock and debris

Photograph 9: Pettibone Creek with retaining wall



Photograph 10: Pettibone Creek with sediment

Photograph 11: Pettibone Creek with sediment and stormwater outfall

Photograph 12: Pettibone Creek discharge into Boat Basin

APPENDIX B

INVESTIGATION INFORMATION

B.1 2001 RI RESULTS

B.2 DECEMBER 2008 INVESTIGATION RESULTS

B.3 DECEMBER 2008 SAMPLE LOGS

B.4 DECEMBER 2008 DATA VALIDATION LETTERS

B.1 2001 RI RESULTS

Appendix B-1
Site 17 - Pettibone Creek RAP
2001 RI Sediment Results
Naval Station Great Lakes
Great Lakes, Illinois

Location	NTC17PCSD01	NTC17PCSD01	NTC17PCSD02	NTC17PCSD02	NTC17PCSD03	NTC17PCSD03	NTC17PCSD04	NTC17PCSD04
Sample Number	NTC17PCSD0101	NTC17PCSD0102	NTC17PCSD0201	NTC17PCSD0201-D	NTC17PCSD0301	NTC17PCSD0301-D	NTC17PCSD0401	NTC17PCSD0402
Sample Depth Inrterval (ft)	0.13	1	0.13	0.13	0.13	0.13	0.13	1
Sample Date	20010924	20010924	20010924	20010924	20010924	20010924	20010924	20010924
Semivolatile Organics	**PRG (ug/kg)**							
ANTHRACENE	960	**4000**	**1600**	930	810	410	**2300**	120 J	910
BENZALDEHYDE	4							**1500**	
BENZO(A)ANTHRACENE	1800	**11000**	**4100**	**2400**	**2000**	1400	**7200**	560	**2400**
BENZO(A)PYRENE	2500	**11000**	**4000**	2300	1900	1500	**6900**	570	2300
BENZO(B)FLUORANTHENE	2000	**12000**	**4100**	**2400**	**2000**	1500	**7200**	650	**2400**
BENZO(G,H,I)PERYLENE	NV	7500 J	2600	1600	1300	1200	4900	530	2100
CAPROLACTAM	NV							370 U	
CARBAZOLE	400							150 J	
CHRYSENE	2800	**12000**	**4200**	2400	2000	1500	**7400**	600	2400
FLUORANTHENE	9920	**33000**	**13000**	7400	6300	4600	**22000**	1500	6700
FLUORENE	640	**2400 J**	**840**	570 J	490	320 J	**1700**	62 J	340 J
INDENO(1,2,3-CD)PYRENE	1600	**5800 J**	1600	940	800	680	**4500**	430	1200
PHENANTHRENE	2880	**24000**	**8500**	**4800**	**4200**	2600	**16000**	730	**4300**
PYRENE	2200	**27000**	**9700**	**5500**	**4700**	**3400**	**17000**	1200	**5100**
TOTAL PAHS	35000	**156000**	**56670**	32540	27665	20009	**101100**	7302	31680
Pesticides/PCBs	**PRG (ug/kg)**							
4,4'-DDD	20	**25 J**	3.8	7.2 J	5 J	**63**	**82**	**120**	**180**
4,4'-DDE	15	**36 J**	8.5	**66**	**46**	**110**	**180**	**130**	**240**
4,4'-DDT	7	**32 J**	**9.5**	**51**	**38**	**190**	**320**	**240**	**580**
TOTAL DDT	572	93	21.8	124.2	89	363	**582**	490	**1000**
AROCLOR-1254	676	300 J	92	110	120	200	200	290	380
AROCLOR-1260	676	39 UR	36 U	49	61	150	110	140	320
TOTAL PCBS	NV	300	92	159	181	350	310	430	700
ENDOSULFAN I	0.5	2 U	1.8 U	18 U	9 U	21 U	21 U	19 U	87 U
ENDOSULFAN II	0.5	**12 J**	**2.8**	18 U	**1.9 J**	**4.1 J**	**6 J**	**7.4 J**	87 U
Inorganics	**PRG (mg/kg)**							
COPPER	149	**368**	**370**	**477**	**428**	**222**	**230**	**181**	**577**
LEAD	128	**322 J**	**187**	**144**	**240**	**213**	**152**	**181**	**435**
MERCURY	1.06	0.94 J	0.31	0.17	0.39	0.25	0.25	0.32	0.87
ZINC	459	**1140 J**	**2620**	**1390**	**2830**	**774**	**934**	**836**	**2410**

Appendix B-1
Site 17 - Pettibone Creek RAP
2001 RI Sediment Results
Naval Station Great Lakes
Great Lakes, Illinois

Location		NTC17PCSD05	NTC17PCSD06	NTC17PCSD07	NTC17PCSD08	NTC17PCSD08	NTC17PCSD09	NTC17PCSD10	NTC17PCSD10
Sample Number		NTC17PCSD0501	NTC17PCSD0601	NTC17PCSD0701	NTC17PCSD0801	NTC17PCSD0802	NTC17PCSD0901	NTC17PCSD1001	NTC17PCSD1002
Sample Depth Inrterval (ft)		0.13	0.13	0.13	0.13	1	0.13	0.13	1
Sample Date		20010924	20010924	20010924	20010924	20010924	20010924	20010924	20010924
Semivolatile Organics	**PRG (ug/kg)**								
ANTHRACENE	960	320 J	58 J	75 J	73 J	800	61 J	820 J	160 J
BENZALDEHYDE	4								
BENZO(A)ANTHRACENE	1800	1000	440	470	430	**2800**	390	**2000**	620
BENZO(A)PYRENE	2500	1100	460	530	470	**2900**	470	2100 J	630 J
BENZO(B)FLUORANTHENE	2000	1200	490	580	510	**3200**	460	**2100**	690
BENZO(G,H,I)PERYLENE	NV	930	230	430	420	2300	360	1500 J	520 J
CAPROLACTAM	NV								
CARBAZOLE	400								
CHRYSENE	2800	1000	480	530	470	**3000**	410	2100	670
FLUORANTHENE	9920	3000	1000	1200	1100	8200	950	5900	1700
FLUORENE	640	190 J	40 J	56 J	74 J	450	46 J	440	120 J
INDENO(1,2,3-CD)PYRENE	1600	590	270	380	370	1600	270	990 J	430
PHENANTHRENE	2880	1700	460	670	630	**4600**	490	**3900**	1000
PYRENE	2200	**2300**	890	1000	940	**6100**	810	**4400**	1400
TOTAL PAHS	35000	13950	5088	6231	5757	**37970**	4977	27542	8290
Pesticides/PCBs	**PRG (ug/kg)**								
4,4'-DDD	20	**150 J**	3.7	2.3	4.7	14	4.4	7.5	15
4,4'-DDE	15	**200 J**	5.1	4.3	11	**22**	**20**	**20**	15
4,4'-DDT	7	**1800**	4.9	5.6	**7.5**	**15**	**17**	**18**	**11 J**
TOTAL DDT	572	**2150**	13.7	12.2	23.2	51	41.4	45.5	41
AROCLOR-1254	676	160	37 U	37 U	40 U	45 U	40 U	43 U	43 U
AROCLOR-1260	676	110	37 U	37 U	40 U	45 U	40 U	43 U	70
TOTAL PCBS	NV	270	37	37	40	45	40	43	70
ENDOSULFAN I	0.5	210 U	1.9 U	1.9 U	2 U	2.3 U	4.1 U	2.2 U	2.2 U
ENDOSULFAN II	0.5	210 U	**0.52 J**	**0.58 J**	**0.55 J**	**0.9 J**	4.1 U	**0.82 J**	**2.6 J**
Inorganics	**PRG (mg/kg)**								
COPPER	149	**225**	129	72.5	43.1	55.8	42.6	40.0	39.4
LEAD	128	117	123	76.7	73.0	71.9	30.8	68.3 J	**139 J**
MERCURY	1.06	0.17	0.09	0.04	0.05	0.12	0.31	0.07 J	0.07 J
ZINC	459	**1030**	**899**	**538**	192	171	126	183 J	178 J

Appendix B-1
Site 17 - Pettibone Creek RAP
2001 RI Sediment Results
Naval Station Great Lakes
Great Lakes, Illinois

Location		NTC17PCSD11	NTC17PCSD11	NTC17PCSD12	NTC17PCSD12	NTC17PCSD13	NTC17PCSD14	NTC17PCSD14	NTC17PCSD14
Sample Number		NTC17PCSD1101	NTC17PCSD1102	NTC17PCSD1201	NTC17PCSD1202	NTC17PCSD1301	NTC17PCSD1401	NTC17PCSD1401-D	NTC17PCSD1402
Sample Depth Inrterval (ft)		0.13	1	0.13	1	0.13	0.13	0.13	1
Sample Date		20010923	20010923	20010923	20010923	20010923	20010923	20010923	20010923
Semivolatile Organics	**PRG (ug/kg)**								
ANTHRACENE	960	**1100**	310	120 J	67	600	110 J	800	290
BENZALDEHYDE	4						370 U		
BENZO(A)ANTHRACENE	1800	**2900**	950	340	230	**2000**	440	**2100**	500
BENZO(A)PYRENE	2500	**2700**	1200	300	230	1900	410	2000	410
BENZO(B)FLUORANTHENE	2000	**2800**	1000	300	270	1900	440	**2100**	380
BENZO(G,H,I)PERYLENE	NV	1500	1100	200	170	1300	260	1300	230
CAPROLACTAM	NV						370 U		
CARBAZOLE	400						**720**		
CHRYSENE	2800	**2900**	950	360	240	1900	430	2100	430
FLUORANTHENE	9920	8400	2700	1000	600	5200	1200	6100	1300
FLUORENE	640	**850**	160	110 J	47 J	280 J	80 J	380 J	150 J
INDENO(1,2,3-CD)PYRENE	1600	1500	590	170	170	920	170	1200	140 J
PHENANTHRENE	2880	**6400**	1800	820	360	**3100**	720	**4100**	1000
PYRENE	2200	**6600**	2100	850	480	**4200**	930	**4700**	1000
TOTAL PAHS	35000	**39250**	13420	4720	2994	24400	5466	28080	6060
Pesticides/PCBs	**PRG (ug/kg)**								
4,4'-DDD	20	**58**	**76**	**73**	**48**	**100**	**100**	**83**	**180**
4,4'-DDE	15	**110**	**160**	**53**	**51**	**110**	**150**	**120**	**200**
4,4'-DDT	7	**170**	**190**	**160**	**55**	**150**	**190**	**140**	**190**
TOTAL DDT	572	338	426	286	154	360	440	343	570
AROCLOR-1254	676	37 U	**790**	35 U	150	140	200	140	40 U
AROCLOR-1260	676	46	40 U	35 U	47	41	43	51	40 U
TOTAL PCBS	NV	46	790	35	577	181	243	191	40
ENDOSULFAN I	0.5	19 U	41 U	**1.1 J**	7.3 U	18 U	38 U	20 U	41 U
ENDOSULFAN II	0.5	19 U	41 U	18 U	**1.9 J**	18 U	38 U	20 U	41 U
Inorganics	**PRG (mg/kg)**								
COPPER	149	123	**182**	127	**200**	**197**	123	**191**	**268**
LEAD	128	120	**154**	**142**	**161**	**155**	108	103	**177**
MERCURY	1.06	0.45	0.14	0.13	0.28	0.22	**4.7**	0.18	0.1
ZINC	459	**570**	**1260**	**1110**	**1520**	**856**	**810**	**1300**	**2180**

Appendix B-1
Site 17 - Pettibone Creek RAP
2001 RI Sediment Results
Naval Station Great Lakes
Great Lakes, Illinois

Location	NTC17PCSD15	NTC17PCSD16	NTC17PCSD17	NTC17PCSD17	NTC17PCSD18	NTC17PCSD18	NTC17PCSD19	NTC17PCSD19
Sample Number	NTC17PCSD1501	NTC17PCSD1601	NTC17PCSD1701	NTC17PCSD1702	NTC17PCSD1801	NTC17PCSD1802	NTC17PCSD1901	NTC17PCSD1901-D
Sample Depth Inrterval (ft)	0.13	0.13	0.13	1	0.13	1	0.13	0.13
Sample Date	20010923	20010923	20010922	20010922	20010922	20010922	20010922	20010922
Semivolatile Organics	**PRG (ug/kg)**							
ANTHRACENE	960	37	63 J	160	87	280	410	290	110 J
BENZALDEHYDE	4		410 U			350 U			
BENZO(A)ANTHRACENE	1800	150	240	530	340	630	1000	760	710
BENZO(A)PYRENE	2500	130	240	500	300	510	940	790	710
BENZO(B)FLUORANTHENE	2000	150	220	510	310	550	930	790	710
BENZO(G,H,I)PERYLENE	NV	70	170	320	200	320	600	540 J	520
CAPROLACTAM	NV		410 U			57 J			
CARBAZOLE	400		130 J			380			
CHRYSENE	2800	150	230	490	330	590	1000	740	740
FLUORANTHENE	9920	380	650	1300	900	1700	3100	2000 J	2100
FLUORENE	640	21 J	65 J	40 J	73 J	110 J	250 J	120 J	120 J
INDENO(1,2,3-CD)PYRENE	1600	70	100	180	130	190	460	320 J	370
PHENANTHRENE	2880	210	430	590	610	1100	2200	1300	1200
PYRENE	2200	310	500	980	720	1300	**2300**	1500	1600
TOTAL PAHS	35000	1769	3038	5920	4180	7580	13720	9590	9346
Pesticides/PCBs	**PRG (ug/kg)**								
4,4'-DDD	20	**73**	**78**	**30**	**59**	**110**	**190**	**170**	**120**
4,4'-DDE	15	**68**	**130**	**46**	**150**	**130**	**250**	**210**	**140**
4,4'-DDT	7	**92**	**170**	**110**	**160**	**150**	**220**	**230**	**170**
TOTAL DDT	572	233	378	186	369	390	**660**	**610**	430
AROCLOR-1254	676	97	120	69	37 U	35 U	**930**	440	220
AROCLOR-1260	676	51	53	36 U	51	55	37 U	110	460
TOTAL PCBS	NV	148	173	69	51	55	930	550	680
ENDOSULFAN I	0.5	19 U	43 U	9.3 U	38 U	36 U	75 U	42 U	21 U
ENDOSULFAN II	0.5	19 U	43 U	**1.8 J**	38 U	36 U	75 U	42 U	**15 J**
Inorganics	**PRG (mg/kg)**								
COPPER	149	**189**	141	**206**	138	**194**	139	118	76.2
LEAD	128	106	**130**	**135**	77.1	**162**	110	109	66.8
MERCURY	1.06	0.16	0.12	0.08	0.1	0.12	0.1	0.61	0.11
ZINC	459	**2120**	**797**	**1210**	**799**	**1290**	**821**	377 J	**565**

Appendix B-1
Site 17 - Pettibone Creek RAP
2001 RI Sediment Results
Naval Station Great Lakes
Great Lakes, Illinois

	Location	NTC17PCSD20	NTC17PCSD20	NTC17PCSD21	NTC17PCSD22	NTC17PCSD22	NTC17PCSD23	NTC17PCSD23	NTC17PCSD24
	Sample Number	NTC17PCSD2001	NTC17PCSD2002	NTC17PCSD2101	NTC17PCSD2201	NTC17PCSD2201-D	NTC17PCSD2301	NTC17PCSD2302	NTC17PCSD2401
	Sample Depth Inrterval (ft)	0.13	1	0.13	0.13	0.13	0.13	1	0.13
	Sample Date	20010922	20010922	20010922	20010922	20010922	20010922	20010922	20010922
Semivolatile Organics	**PRG (ug/kg)**								
ANTHRACENE	960	100	54	120	240	88	150	390	400
BENZALDEHYDE	4			360 U			420 U		
BENZO(A)ANTHRACENE	1800	450	270	380	990	360	470	790	930
BENZO(A)PYRENE	2500	470	240	330	970	320	470	770	840
BENZO(B)FLUORANTHENE	2000	480	240	340	1000	320	450	730	870
BENZO(G,H,I)PERYLENE	NV	340	170	230	650	200	85 U	460	610 J
CAPROLACTAM	NV			360 U			420 U		
CARBAZOLE	400			75 J			250 J		
CHRYSENE	2800	450	240	350	1000	350	450	730	890
FLUORANTHENE	9920	1200	580	940	2800	950	1300	2400	2800
FLUORENE	640	92	22 J	77	180	73 J	76 J	240	170 J
INDENO(1,2,3-CD)PYRENE	1600	230	120	140	460	150	230	300	390 J
PHENANTHRENE	2880	670	270	500	1600	520	730	1900	1800
PYRENE	2200	940	500	720	2100	740	1000	1800	2000
TOTAL PAHS	35000	5722	2846	4345	12601	4282	5586	10920	12200
Pesticides/PCBs	**PRG (ug/kg)**								
4,4'-DDD	20	**50**	**81**	**51**	**88**	**86**	**89**	**45**	**78**
4,4'-DDE	15	**68**	**68**	**42**	**90**	**87**	**91**	**40**	**89**
4,4'-DDT	7	**65**	**73**	**62**	**81**	**110**	**81**	**90**	**93**
TOTAL DDT	572	183	222	155	259	283	261	175	260
AROCLOR-1254	676	400	78	56	110	38 U	42 U	39 U	41 U
AROCLOR-1260	676	40 U	37 U	36 U	41	39	42 U	39 U	41 U
TOTAL PCBS	NV	400	78	56	151	39	42	39	41
ENDOSULFAN I	0.5	21 U	19 U	9.2 U	20 U	19 U	22 U	10 U	21 U
ENDOSULFAN II	0.5	21 U	19 U	**1.1 J**	20 U	19 U	22 U	10 U	21 U
Inorganics	**PRG (mg/kg)**								
COPPER	149	35.1	120	79.6	**199**	41.1	50.3	**167**	**151**
LEAD	128	44.2	83.6	45.5	104	57.1	57.6	**159**	60.3
MERCURY	1.06	0.04	0.1	0.06	0.09	0.13	0.09	0.15	0.09
ZINC	459	166	**560**	362	**672**	179	279	**1240**	376 J

B.2 DECEMBER 2008 INVESTIGATION RESULTS

APPENDIX B.2
TABEL B-1

DECEMBER 2008 INVESTIGATION ANALYTICAL RESULTS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES, ILLINOIS

Sample Number Sample Date Sample interval (feet below surface)	NTC17PCSD40 12/8/2008 1.0 - 1.5	NTC17PCSD41 12/8/2009 0.5 - 1.0	NTC17PCSD42 12/9/2008 0.25 - 0.75	NTC17PCSD43 12/9/2008 1.0 - 1.5	NTC17PCSD44 12/9/2008 0.25 - 0.75	NTC17PCSD45 12/9/2008 0.25 - 0.75	NTC17PCSD46 12/9/2008 1.0 - 1.5	NTC17PCSD47 12/9/2008 2.0 - 2.5	NTC17PCSD48 12/9/2008 2.5 - 3.0	NTC17PCSD49 12/9/2008 0.75 - 1.25
Polynuclear Aromatic Hydrocarbons (ug/kg)										
2-METHYLNAPHTHALENE	4 U	2.3 J	7.2	4.2	5	7.5	5.1	20	7.6	3.3 J
ACENAPHTHENE	4 U	4 U	11	3.5 J	11	3.9 U	3.8 U	3.8 U	4.8	1.9 J
ACENAPHTHYLENE	4 U	4 U	4.2 U	4.1 U	4.2 U	3.9 U	3.8 U	3.8 U	4 U	4.4 U
ANTHRACENE	4 U	3 J	71	12	66	3.9 U	3.8 U	3.8 U	20	7.8
BENZO(A)ANTHRACENE	4 U	4 U	220	67	260	3.9 U	3.8 U	3.8 U	33	37
BENZO(A)PYRENE	4 U	4 U	200	62	180	3.9 U	3.8 U	3.8 U	24	37
BENZO(B)FLUORANTHENE	4 U	4 U	240	74	200 J	3.9 U	3.8 U	3.8 U	20	34
BENZO(G,H,I)PERYLENE	1.8 J	5.5	120	38	100	3.8 J	4.4	3.2 J	12	21
BENZO(K)FLUORANTHENE	4 U	4 U	64	20	58	3.9 U	3.8 U	3.8 U	6.4	10
CHRYSENE	4 U	4 U	170	56	200 J	3.9 U	3.8 U	3.8 U	29	39
DIBENZO(A,H)ANTHRACENE	4 U	4 U	27 J	8.1	26	3.9 U	3.8 U	3.8 U	4 U	4.2 J
FLUORANTHENE	3.1 J	9.3	550	150	620 J	7.6	3.8 U	5.7	69	82
FLUORENE	4 U	2.9 J	18	6.3	19	3.9 U	3.8 U	3.8 U	9.7	2.8 J
INDENO(1,2,3-CD)PYRENE	4 U	4 U	100	30	88	3.9 U	3.8 U	3.8 U	4 U	17
NAPHTHALENE	4 U	4 U	6.5	4.1 U	4.8	3.9 U	3.8 U	6.2	4 U	4.4 U
PHENANTHRENE	3.9 J	18	310	110	320 J	18	16	24	78	52
PYRENE	4.4	4 U	440	130	460 J	7.7	3.8 U	3.8 U	59	68
BAP EQUIVALENT-HALFND	4 U	4 U	283.81	87.456	261.58	3.9 U	3.8 U	3.8 U	31.593	50.139
BAP EQUIVALENT-POS	4 U	4 U	283.81	87.456	261.58	3.9 U	3.8 U	3.8 U	29.393	50.139
HIGH MOLECULAR WEIGHT PAHS	9.3	14.8	2131	635.1	2192	19.1	4.4	8.9	252.4	349.2
LOW MOLECULAR WEIGHT PAHS	3.9	26.2	423.7	136	425.8	25.5	21.1	50.2	120.1	67.8
TOTAL PAHS	13.2	41	2554.7	771.1	2617.8	44.6	25.5	59.1	372.5	417
Pesticides/PCBs (ug/kg)										
4,4'-DDD	6.1 J	13 J	2.4 J	0.83 UJ	2.1 J	0.78 UJ	0.76 UJ	0.76 UJ	3.8 J	19 J
4,4'-DDE	0.92 J	7.4 J	8.4 J	0.83 UJ	14 J	0.78 UJ	0.76 UJ	0.76 UJ	1.2 J	68 J
4,4'-DDT	0.79 UJ	3.9 J	5 J	0.83 UJ	13 J	0.78 UJ	0.76 UJ	0.76 UJ	1.4 J	19 J
ALDRIN	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
ALPHA-BHC	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
ALPHA-CHLORDANE	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
AROCLOR-1016	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ	20 UJ	19 UJ	19 UJ	20 UJ	22 UJ
AROCLOR-1221	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ	20 UJ	19 UJ	19 UJ	20 UJ	22 UJ
AROCLOR-1232	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ	20 UJ	19 UJ	19 UJ	20 UJ	22 UJ
AROCLOR-1242	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ	20 UJ	19 UJ	19 UJ	20 UJ	22 UJ
AROCLOR-1248	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ	20 UJ	19 UJ	19 UJ	20 UJ	22 UJ
AROCLOR-1254	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ	20 UJ	19 UJ	19 UJ	20 UJ	22 UJ
AROCLOR-1260	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ	20 UJ	19 UJ	19 UJ	7.2 J	22 UJ
BETA-BHC	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
DELTA-BHC	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
DIELDRIN	0.79 UJ	0.8 UJ	0.84 UJ	0.83 UJ	0.83 UJ	0.78 UJ	0.76 UJ	0.76 UJ	0.8 UJ	0.89 UJ
ENDOSULFAN I	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
ENDOSULFAN II	0.79 UJ	0.8 UJ	0.84 UJ	0.83 UJ	0.27 U	0.78 UJ	0.76 UJ	0.76 UJ	0.8 UJ	0.89 UJ

APPENDIX B.2
TABEL B-1

DECEMBER 2008 INVESTIGATION ANALYTICAL RESULTS
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES, ILLINOIS

Sample Number	NTC17PCSD40	NTC17PCSD41	NTC17PCSD42	NTC17PCSD43	NTC17PCSD44	NTC17PCSD45	NTC17PCSD46	NTC17PCSD47	NTC17PCSD48	NTC17PCSD49
Sample Date	12/8/2008	12/8/2009	12/9/2008	12/9/2008	12/9/2008	12/9/2008	12/9/2008	12/9/2008	12/9/2008	12/9/2008
Sample interval (feet below surface)	1.0 - 1.5	0.5 - 1.0	0.25 - 0.75	1.0 - 1.5	0.25 - 0.75	0.25 - 0.75	1.0 - 1.5	2.0 - 2.5	2.5 - 3.0	0.75 - 1.25
Pesticides/PCBs (ug/kg) (Continued)										
ENDOSULFAN SULFATE	0.79 UJ	0.8 UJ	0.84 UJ	0.83 UJ	0.83 UJ	0.78 UJ	0.76 UJ	0.76 UJ	0.8 UJ	0.89 UJ
ENDRIN	0.79 UJ	0.8 UJ	0.84 UJ	0.83 UJ	1.5 J	0.78 UJ	0.76 UJ	0.76 UJ	0.8 UJ	2 J
ENDRIN ALDEHYDE	0.79 UJ	0.8 UJ	0.84 UJ	0.83 UJ	0.83 UJ	0.78 UJ	0.76 UJ	0.76 UJ	0.8 UJ	0.89 UJ
ENDRIN KETONE	0.79 UJ	0.8 UJ	0.84 UJ	0.83 UJ	0.83 UJ	0.78 UJ	0.76 UJ	0.76 UJ	0.8 UJ	0.89 UJ
GAMMA-BHC (LINDANE)	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.25 J	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
GAMMA-CHLORDANE	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
HEPTACHLOR	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
HEPTACHLOR EPOXIDE	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.2 R	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
METHOXYCHLOR	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.42 UJ	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
TOXAPHENE	40 UJ	40 UJ	42 UJ	41 UJ	42 UJ	39 UJ	38 UJ	38 UJ	40 UJ	44 UJ
TOTAL AROCLOR	20 U	20 U	21 U	21 U	21 U	20 U	19 U	19 U	7.2	22 U
TOTAL CHLORDANE	0.4 U	0.4 U	0.42 U	0.41 U	0.42 U	0.39 U	0.38 U	0.38 U	0.4 U	0.44 U
TOTAL DDT POS	7.02	24.3	15.8	0 U	29.1	0.78 U	0.76 U	0.76 U	6.4	106
Inorganics (mg/kg)										
COPPER	16.3	23.9	18.1	22	32.1	53.5	19.4	22.6	167	31.4
LEAD	8.9	11.4	33.6	9.9	20.6	24	9.6	11.2	103	36.6
MERCURY	0.016 U	0.028	0.061	0.023	0.038	0.015 U	0.014 U	0.015 U	0.018	0.017 U
ZINC	43.2	45.3	99.3 J	44.3 J	81.3 J	230	43.9	51	1070	97.3

U Indictated that the constituent was not detected at the reported detection limit.
J Indicated result is estimated.

APPENDIX B.2
TABLE B-2

SUMMARY OF DECEMBER 2008 POSITIVE DETECTION
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES, ILLINOIS

	SCREENING CRITERIA							ANALYTICAL RESULTS				
Sample ID Date Time Sample Interval (in ft bgs)	**TACO BACKGROUND SOIL WITHIN METROPOLITAN**	**ILLINOIS EPA UNSIEVED STREAM SEDIMENT BACKGROUND**	**ILLINOIS TACO ROUTE SPECIFIC VALUES FOR SOIL INGESTION**	**REGION 9 PRG RESIDENTIAL SOIL**	**REGION 9 PRG INDUSTRIAL SOIL**	**ECOLOGICAL SEDIMENT**	**Minimum Criteria**	NTC17PCSD40 12/8/2008 11:43 1.0-1.5	NTC17PCSD41 12/8/2008 12:25 0.5-1.0	NTC17PCSD42 12/9/2008 10:12 0.25-0.75	NTC17PCSD43 12/9/2008 10:25 1.0-1.5	NTC17PCSD44 12/9/2008 10:50 0.25-0.75
Polynuclear Aromatic Hydrocarbons (ug/kg)												
2-METHYLNAPHTHALENE	NC	NC	3100000	56000	190000	368	368	4 U	2.3 J	7.2	4.2	5
ACENAPHTHENE	NC	NC	NC	NC	NC	186	186	4 U	4 U	11	3.5 J	11
ANTHRACENE	NC	NC	23000000	22000000	100000000	85	85	4 U	3 J	71	12	66
BENZO(A)ANTHRACENE	NC	NC	900	620	2900	287	287	4 U	4 U	220	67	260
BENZO(A)PYRENE	NC	NC	**90**	**62**	290	**73**	62	4 U	4 U	**200**	62	**180**
BENZO(B)FLUORANTHENE	NC	NC	900	620	2900	886	620	4 U	4 U	240	74	200 J
BENZO(G,H,I)PERYLENE	NC	NC	3100000	56000	54000000	170	170	1.8 J	5.5	120	38	100
BENZO(K)FLUORANTHENE	NC	NC	9000	6200	29000	8860	6200	4 U	4 U	64	20	58
CHRYSENE	NC	NC	88000	62000	290000	400	400	4 U	4 U	170	56	200 J
DIBENZO(A,H)ANTHRACENE	NC	NC	90	62	290	60	60	4 U	4 U	27 J	8.1	26
FLUORANTHENE	NC	NC	3100000	2300000	30000000	2790	2790	3.1 J	9.3	550	150	620 J
FLUORENE	NC	NC	3100000	2600000	33000000	35	35	4 U	2.9 J	18	6.3	19
INDENO(1,2,3-CD)PYRENE	NC	NC	900	620	2900	2500	620	4 U	4 U	100	30	88
NAPHTHALENE	NC	NC	3100000	56000	190000	340	340	4 U	4 U	6.5	4.1 U	4.8
PHENANTHRENE	NC	NC	3100000	56000	54000000	810	810	3.9 J	18	310	110	320 J
PYRENE	NC	NC	2300000	2300000	54000000	**350**	350	4.4	4 U	**440**	130	**460 J**
BAP EQUIVALENT-HALFND	NC	NC	NC	NC	NC	NC	NC	4 U	4 U	283.81	87.456	261.58
BAP EQUIVALENT-POS	NC	NC	NC	NC	NC	NC	NC	4 U	4 U	283.81	87.456	261.58
HIGH MOLECULAR WEIGHT PAHS	NC	NC	NC	NC	NC	**1700**	1700	9.3	14.8	**2131**	635.1	**2192**
LOW MOLECULAR WEIGHT PAHS	NC	NC	NC	NC	NC	552	552	3.9	26.2	423.7	136	425.8
TOTAL PAHS	NC	NC	NC	NC	NC	4000	4000	13.2	41	2554.7	771.1	2617.8
Pesticides/PCBs (ug/kg)												
4,4'-DDD	NC	NC	3000	2400	17000	**2**	2	**6.1 J**	**13 J**	**2.4 J**	0.83 UJ	**2.1 J**
4,4'-DDE	NC	NC	2000	1700	12000	**2**	2	0.92 J	**7.4 J**	**8.4 J**	0.83 UJ	**14 J**
4,4'-DDT	NC	NC	2000	1700	12000	**1**	1	0.79 UJ	**3.9 J**	**5 J**	0.83 UJ	**13 J**
AROCLOR-1260	NC	NC	1000	220	1000	**5**	5	20 UJ	20 UJ	21 UJ	21 UJ	21 UJ
ENDRIN	NC	NC	23000	18000	260000	19	16	0.79 UJ	0.8 UJ	0.84 UJ	0.83 UJ	1.5 J
GAMMA-BHC (LINDANE)	NC	NC	500	440	2900	0.39	0.39	0.4 UJ	0.4 UJ	0.42 UJ	0.41 UJ	0.25 J
TOTAL AROCLOR	NC	NC	NC	NC	NC	50	50	20 U	20 U	21 U	21 U	21 U
TOTAL DDT POS	NC	NC	NC	NC	NC	**7**	7	**7.02**	**24.3**	**15.8**	0 U	**29.1**
Inorganics (mg/kg)												
COPPER	**19.6**	**38**	2900	2900	76000	**16**	16	**16.3**	**23.9**	**18.1**	**22**	**32.1**
LEAD	**36**	**28**	400	400	750	**31**	28	8.9	11.4	**33.6**	9.9	20.6
MERCURY	0.06	0.07	23	23	610	0.2	0.06	0.016 U	0.028	**0.061**	0.023	0.038
ZINC	**95**	**80**	23000	23000	100000	**120**	80	43.2	45.3	**99.3 J**	44.3 J	**81.3 J**

ft - feet
bgs - below ground surface
U - Parameter not detected at indicated detection limit
J - Estimated value
R - Rejected
NC - No Criteria

Notes
1) Underscored criteria indicates the most conservative screening value.
2) Shaded criteria indicates one or more resluts exceeds that criteria.
3) Shaded data indicates that the analytical results exceeds one or more of the criterion.
4) Shaded parameter indicates that one or more analytical results exceed one or more of the criterion.

APPENDIX B.2
TABLE B-2

SUMMARY OF DECEMBER 2008 POSITIVE DETECTION
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES, ILLINOIS

	SCREENING CRITERIA							ANALYTICAL RESULTS				
Sample ID Date Time Sample Interval (in ft bgs)	**TACO BACKGROUND SOIL WITHIN METROPOLITAN**	**ILLINOIS EPA UNSIEVED STREAM SEDIMENT BACKGROUND**	**ILLINOIS TACO ROUTE SPECIFIC VALUES FOR SOIL INGESTION**	**REGION 9 PRG RESIDENTIAL SOIL**	**REGION 9 PRG INDUSTRIAL SOIL**	**ECOLOGICAL SEDIMENT**	**Minimum Criteria**	NTC17PCSD45 12/9/2008 11:05 0.25-0.75	NTC17PCSD46 12/9/2008 11:21 1.0-1.5	NTC17PCSD47 12/9/2008 11:31 2.0-2.5	NTC17PCSD48 12/9/2008 11:55 2.5-3.0	NTC17PCSD49 12/9/2008 12:10 0.75-1.25
Polynuclear Aromatic Hydrocarbons (ug/kg)												
2-METHYLNAPHTHALENE	NC	NC	3100000	56000	190000	368	368	7.5	5.1	20	7.6	3.3 J
ACENAPHTHENE	NC	NC	NC	NC	NC	186	186	3.9 U	3.8 U	3.8 U	4.8	1.9 J
ANTHRACENE	NC	NC	23000000	22000000	100000000	85	85	3.9 U	3.8 U	3.8 U	20	7.8
BENZO(A)ANTHRACENE	NC	NC	900	620	2900	287	287	3.9 U	3.8 U	3.8 U	33	37
BENZO(A)PYRENE	NC	NC	**90**	**62**	290	**73**	62	3.9 U	3.8 U	3.8 U	24	37
BENZO(B)FLUORANTHENE	NC	NC	900	620	2900	886	620	3.9 U	3.8 U	3.8 U	20	34
BENZO(G,H,I)PERYLENE	NC	NC	3100000	56000	54000000	170	170	3.8 J	4.4	3.2 J	12	21
BENZO(K)FLUORANTHENE	NC	NC	9000	6200	29000	8860	6200	3.9 U	3.8 U	3.8 U	6.4	10
CHRYSENE	NC	NC	88000	62000	290000	400	400	3.9 U	3.8 U	3.8 U	29	39
DIBENZO(A,H)ANTHRACENE	NC	NC	90	62	290	60	60	3.9 U	3.8 U	3.8 U	4 U	4.2 J
FLUORANTHENE	NC	NC	3100000	2300000	30000000	2790	2790	7.6	3.8 U	5.7	69	82
FLUORENE	NC	NC	3100000	2600000	33000000	35	35	3.9 U	3.8 U	3.8 U	9.7	2.8 J
INDENO(1,2,3-CD)PYRENE	NC	NC	900	620	2900	2500	620	3.9 U	3.8 U	3.8 U	4 U	17
NAPHTHALENE	NC	NC	3100000	56000	190000	340	340	3.9 U	3.8 U	6.2	4 U	4.4 U
PHENANTHRENE	NC	NC	3100000	56000	54000000	810	810	18	16	24	78	52
PYRENE	NC	NC	2300000	2300000	54000000	**350**	350	7.7	3.8 U	3.8 U	59	68
BAP EQUIVALENT-HALFND	NC	NC	NC	NC	NC	NC	NC	3.9 U	3.8 U	3.8 U	31.593	50.139
BAP EQUIVALENT-POS	NC	NC	NC	NC	NC	NC	NC	3.9 U	3.8 U	3.8 U	29.393	50.139
HIGH MOLECULAR WEIGHT PAHS	NC	NC	NC	NC	NC	**1700**	1700	19.1	4.4	8.9	252.4	349.2
LOW MOLECULAR WEIGHT PAHS	NC	NC	NC	NC	NC	552	552	25.5	21.1	50.2	120.1	67.8
TOTAL PAHS	NC	NC	NC	NC	NC	4000	4000	44.6	25.5	59.1	372.5	417
Pesticides/PCBs (ug/kg)												
4,4'-DDD	NC	NC	3000	2400	17000	**2**	2	0.78 UJ	0.76 UJ	0.76 UJ	**3.8 J**	**19 J**
4,4'-DDE	NC	NC	2000	1700	12000	**2**	2	0.78 UJ	0.76 UJ	0.76 UJ	1.2 J	**68 J**
4,4'-DDT	NC	NC	2000	1700	12000	**1**	1	0.78 UJ	0.76 UJ	0.76 UJ	**1.4 J**	**19 J**
AROCLOR-1260	NC	NC	1000	220	1000	**5**	5	20 UJ	19 UJ	19 UJ	**7.2 J**	22 UJ
ENDRIN	NC	NC	23000	18000	260000	19	16	0.78 UJ	0.76 UJ	0.76 UJ	0.8 UJ	2 J
GAMMA-BHC (LINDANE)	NC	NC	500	440	2900	0.39	0.39	0.39 UJ	0.38 UJ	0.38 UJ	0.4 UJ	0.44 UJ
TOTAL AROCLOR	NC	NC	NC	NC	NC	50	50	20 U	19 U	19 U	7.2	22 U
TOTAL DDT POS	NC	NC	NC	NC	NC	**7**	7	0.78 U	0.76 U	0.76 U	6.4	**106**
Inorganics (mg/kg)												
COPPER	**19.6**	**38**	2900	2900	76000	**16**	16	**53.5**	**19.4**	**22.6**	**167**	**31.4**
LEAD	**36**	**28**	400	400	750	**31**	28	24	9.6	11.2	**103**	**36.6**
MERCURY	0.06	0.07	23	23	610	0.2	0.06	0.015 U	0.014 U	0.015 U	0.018	0.017 U
ZINC	**95**	**80**	23000	23000	100000	**120**	80	**230**	43.9	51	**1070**	**97.3**

ft - feet
bgs - below ground surface
U - Parameter not detected at indicated detection limit
J - Estimated value
R - Rejected
NC - No Criteria

Notes
1) Underscored criteria indicates the most conservative screening value.
2) Shaded criteria indicates one or more resluts exceeds that criteria.
3) Shaded data indicates that the analytical results exceeds one or more of the criterion.
4) Shaded parameter indicates that one or more analytical results exceed one or more of the criterion.

B.3 DECEMBER 2008 SAMPLE LOGS

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

roject Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD40	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD23	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/8/08	11:41	Hand auger	NA	1	grey	Native soil: SILT with little sand and clay about 1' bgs

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/8/08	11:43	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/8/08	11:43	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

:o Notes

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD41	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD21	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/8/08	12:23	Hand auger	NA	1	grey	Native soil at 0.5' bgs SILT with little clay and sand

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/8/08	12:25	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/8/08	12:25	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD42	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD19	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	10:11	Hand auger	NA	1	brown	Native Soil at ~0.25' bgs

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	10:12	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/9/08	10:12	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Start Report

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING L

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD43	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD New Location	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	10:24	Hand auger	NA	1	grey	Native CLAY with little silt at ~1' bgs.

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	10:25	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/9/08	10:25	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

·oject Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD44	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD14	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	10:45	Hand auger	NA	1	brown	Sample collect from southern edge of the creek.

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	10:50	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	3	Glass - Clear	4 oz. wide-mouth w/Teflon cap	MS/MSD	ED00000091-6
✓	12/9/08	10:50	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	3	Glass - Clear	4 oz. wide-mouth w/Teflon cap	MS/MSD	ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

1S/MSD

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD45	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD13	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	11:03	Hand auger	NA	1	grey	Native soil at ~ 0.25' bgs

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	11:05	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/9/08	11:05	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

roject Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD46	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD11	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	11:13	Trowel	NA	1	grey	Native at ~1' bgs

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	11:21	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/9/08	11:21	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD47	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD08	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	11:27	Hand auger	NA	1	grey	Native material ~2' bgs

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	11:31	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/9/08	11:31	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

roject Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD48	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD03	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	11:46	Hand auger	NA	1	grey	Native soil at ~2.5' bgs

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	11:55	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/9/08	11:55	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Tetra Tech NUS, Inc.

SEDIMENT SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**Sample ID #**	NTC17PCSD49	**Created By**	John Wright
TtNUS Project #	112G00936	**Sample Location ID**	NTC17PCSD01	**Created Date**	12/7/08
Task/Contract #	0468	**Sampled By**	Charlie Warino	**Modified By**	Shannon Hill
WBS Code #		**Concentration**	Not known	**Modified Date**	12/15/08
QA Sample Type				**Printed By**	John Wright
Status	Complete			**Printed Date**	1/9/09

Sample Collection Records

Date	Time	Method	Monitor (ppm)	Depth (ft)	Color	Description
12/9/08	12:08	Trowel	NA	1	brown	Native Soil at ~0.75' bgs

Analysis Records

Collected	Date	Time	Analysis / Method	Description of Analysis	Preservative	Count	Type	Requirements	Comments	Chain#
✓	12/9/08	12:10	SW-846 6010B	Metals (Copper, Lead, Zinc, Mercury)	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✓	12/9/08	12:10	SW-846 8270C/8081/8082	PAHs/Pesticides /PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		ED00000091-6
✗			SW-846 8270C	PAHs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		
✗			SW-846 8081/8082	Pesticides/PCBs	4°C	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap		

General Observations and Notes

No Notes

- End of Report -

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-IDW-01	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**		**Created Date**	12/2/08
Task/Contract #	0468	**QA Sample Type**	Other	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/3/08	14:50	SW-846 8260B	VOCs	2	Glass - Clear	Other	AQ	4°C	4 oz jar	ED00000091-3
✓	12/3/08	14:50	SW-846 6010B	Metals (Total)	2	Glass - Clear	Other	AQ	4°C	4 oz jars	ED00000091-3

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-TB120208	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**		**Created Date**	12/2/08
Task/Contract #	0468	**QA Sample Type**	Trip Blank	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/2/08	08:00	NONE		1	Glass - Clear	40ml vials	AQ	4°C/HCL	Trip blank for VOCs	ED00000091-1

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

roject Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-FD120308-01	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**	NTC19SB15-SO-0406	**Created Date**	12/3/08
Task/Contract #	0468	**QA Sample Type**	Field Duplicate	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/3/08	00:00	SW-846 8260B	VOCs	3	Other	Other	AQ	4°C	En Core samplers	ED00000091-2
✓	12/3/08	00:00	SW-846 8270C	PAHs	1	Glass - Clear	Other	AQ	4°C	4oz jars	ED00000091-2
✓	12/3/08	00:00	SW-846 6010B	Metals (Total)	1	Glass - Clear	Other	AQ	4°C	4oz jar	ED00000091-2

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-FD120308-03	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**	NTC19SB17-SO-0002	**Created Date**	12/3/08
Task/Contract #	0468	**QA Sample Type**	Field Duplicate	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/3/08	00:00	SW-846 8260B	VOCs	3	Other	Other	AQ	4°C	En Core samplers 5 gramz	ED00000091-2
✓	12/3/08	00:00	SW-846 8270C	PAHs	1	Glass - Clear	Other	AQ	4°C	4 oz jar	ED00000091-2
✓	12/3/08	00:00	SW-846 6010B	Metals (Total)	1	Glass - Clear	Other	AQ	4°C	4 oz jar	ED00000[illegible] 2

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

roject Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-FD120308-02	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**	NTC19SB16-SO-0103	**Created Date**	12/3/08
Task/Contract #	0468	**QA Sample Type**	Field Duplicate	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/3/08	00:00	SW-846 8260B	VOCs	3	Other	Other	AQ	4°C	En Core samples 5 gram	ED00000091-2
✓	12/3/08	00:00	SW-846 8270C	PAHs	1	Glass - Clear	Other	AQ	4°C	4 oz jar	ED00000091-2
✓	12/3/08	00:00	SW-846 6010B	Metals (Total)	1	Glass - Clear	Other	AQ	4°C	4 oz jar	ED00000091-2

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-TB120308	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**		**Created Date**	12/3/08
Task/Contract #	0468	**QA Sample Type**	Trip Blank	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/16/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/3/08	08:00	NONE		2	Glass - Clear	40ml vials	AQ	4°C/HCL	VOC Trip Blank	ED00000091-2

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

roject Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-RB120308-01	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**		**Created Date**	12/3/08
Task/Contract #	0468	**QA Sample Type**	Rinsate Blank	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/3/08	17:00	SW-846 8260B	VOCs	3	Glass - Clear	40ml vials	AQ	4°C/HCL		ED00000091-2
✓	12/3/08	17:00	SW-846 8270C	PAHs	1	Glass - Clear	1L	AQ	4°C		ED00000091-2
✓	12/3/08	17:00	SW-846 6010B	Metals (Total)	1	Plastic - PE	250ml	AQ	4°C/HNO3		ED00000091-2

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-SB120308-01	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**		**Created Date**	12/3/08
Task/Contract #	0468	**QA Sample Type**	Source Water Blank	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/3/08	17:10	SW-846 8260B	VOCs	3	Glass - Clear	40ml vials	AQ	4°C/HCL		ED00000091-2
✓	12/3/08	17:10	SW-846 8270C	PAHs	1	Glass - Amber	1L	AQ	4°C		ED00000091-2
✓	12/3/08	17:10	SW-846 6010B	Metals (Total)	1	Plastic - PE	250ml	AQ	4°C/HNO3		ED00000091-2

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19FD120808-01	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**	NTC19-MW01-1208	**Created Date**	12/8/08
Task/Contract #	0468	**QA Sample Type**	Field Duplicate	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✗			SW-846 6010B	Metals (Total)	1	Plastic - PE	250ml	AQ	4°C/HNO3		
✓	12/8/08	00:00	SW-846 6010B	Metals (Total)	1	Plastic - PE	500ml	AQ	4°C/HNO3		ED00000091-5
✓	12/8/08	00:00	SW-846 8260B	VOCs	3	Glass - Clear	40ml vials	AQ	4°C/HCL		ED00000091-5
✓	12/8/08	00:00	SW-846 6010B - Filtered	Metals (Dissolved)	1	Plastic - PE	500ml	AQ	4°C/HNO3		ED00000091-5
✗		00:00	SW-846 6010B - Filtered	Metals (Dissolved)	1	Plastic - PE	250ml	AQ	4°C/HNO3		
✓	12/8/08	00:00	SW-846 8270C	PAHs	2	Glass - Amber	1L	AQ	4°C		ED00000091-5
✗		00:00	SW-846 8260B	VOCs	3	Glass - Clear	40ml vials	AQ	4°C/HCL		

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-TB120809	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**		**Created Date**	12/8/08
Task/Contract #	0468	**QA Sample Type**	Trip Blank	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/8/08	08:00	SW-846 8260B	VOCs	2	Glass - Clear	40ml vials	AQ	4°C/HCL		ED00000091-5

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

roject Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC19-IDW02	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**		**Created Date**	12/8/08
Task/Contract #	0468	**QA Sample Type**	Other	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✓	12/8/08	19:45	SW-846 6010B	Metals (Total)	4	Glass - Amber	1L	AQ	4°C	Misc. IDW Analysis: Flash Point	ED00000091-5

Tetra Tech NUS, Inc.

QUALITY CONTROL SAMPLING LOG

RI Field Investigation - GREAT LAKES NTC

Project Information

Facility Name	GREAT LAKES NTC	**QC Sample ID #**	NTC17PCFD10	**Created By**	Shannon Hill
TtNUS Project #	112G00936	**Corresponding Sample ID**	NTC17PCSD42	**Created Date**	12/9/08
Task/Contract #	0468	**QA Sample Type**	Field Duplicate	**Modified By**	Shannon Hill
WBS Code #		**Sample Location**	QC	**Modified Date**	12/15/08
Status	Complete	**Sampled By**	Shannon Hill	**Printed By**	John Wright
		Concentration	Not known	**Printed Date**	1/9/09

Log Entries

Collected	Date	Time	Analysis / Method	Description of Analysis	Count	Type	Requirements	Matrix	Preservative	Comments	Chain of Custody #
✗		00:00	SW-846 8270C	PAHs	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap	AQ	4°C		
✗		00:00	NONE	Pesticides/PCBs	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap	AQ	4°C		
✓	12/9/08	00:00	NONE	Metals (Copper, Lead, Zinc, Mercury)	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap	AQ	4°C		ED00000091-6
✓	12/9/08	00:00	NONE	PAHs/Pesticides /PCBs	1	Glass - Clear	4 oz. wide-mouth w/Teflon cap	AQ	4°C		ED00000091-6

B.4 DECEMBER 2008 DATA VALIDATION LETTERS

Tetra Tech NUS **INTERNAL CORRESPONDENCE**

TO:	**B. DAVIS**	**DATE:**	**FEBRUARY 18, 2009**
FROM:	**LEIGH A. CIOFANI**	**COPIES:**	**DV FILE**

SUBJECT: **ORGANIC DATA VALIDATION / VERIFICATION- PAH / PEST/PCB**
CTO 474, NTC GREAT LAKES
SAMPLE DELIVERY GROUP (SDG) GL004

SAMPLES: 11 / Sediment / PAH / PEST/PCB

NTC17PCFD10*	NTC17PCSD40*	NTC17PCSD41*
NTC17PCSD42*	NTC17PCSD43*	NTC17PCSD44*
NTC17PCSD45	NTC17PCSD46	NTC17PCSD47
NTC17PCSD48	NTC17PCSD49	

* - Indicates that sample received a full validation

OVERVIEW

The sample set for CTO 474 NTC Great Lakes, SDG GL004, consists of eleven (11) sediment environmental samples. One field duplicate pair is associated with this SDG: NTC17PCSD42 / NTC17PCFD10. Only the first six samples (approximately 50%) received a full validation; the remaining samples received a cursory review.

Samples were analyzed for polynuclear aromatic hydrocarbons (PAH) and pesticides/polychlorinated biphenyls (PEST/PCB).

The samples were collected by Tetra Tech NUS on December 08, 2008 and analyzed by Empirical Laboratories, LLC. All analyses were conducted in accordance with SW-846 Methods 8270C SIM, 8081A, and 8082 analysis and reporting protocols. The samples receiving full validation were validated with regard to the following parameters:

*	• Data Completeness
	• Holding Times
*	• GC/MS Tuning
	• Initial/Continuing Calibrations
	• Laboratory Method/Field Blank Results
	• Surrogate Recoveries
*	• Blank Spike/Blank Spike Duplicate Results
	• Matrix Spike/Matrix Spike Duplicate Results
*	• Internal Standards
	• Field Duplicate Precision
*	• Compound Quantitation
	• Compound Identification
	• Detection Limits

The samples receiving a cursory review were evaluated only for data completeness, holding times, laboratory method/field blank results, field duplicate precision, and detection limits.

The symbol (*) indicates that quality control criteria were met for this parameter. Problems affecting data quality

are discussed below; documentation supporting these findings is presented in Appendix C. Qualified Analytical results are presented in Appendix A. Results as reported by the laboratory are presented in Appendix B.

PAH

The matrix spike and matrix spike duplicate (MS/MSD) samples NTC17PCSD44MS and NTC17PCSD44MSD were analyzed more than 12 hours after the last DFTPP injection. No action was taken on this basis. All environmental samples were analyzed within the 12-hour limit.

The continuing calibration run on 12/20/08 at 03:25 on instrument BNA4 had a percent difference result that was outside of the ±25% acceptance range for benzo(a)anthracene. Samples NTC17PCSD46, NTC17PCSD47, NTC17PCSD48, and NTC17PCSD49 were affected. No qualification was made because the affected samples only received a cursory review.

The MS/MSD performed on sample NTC17PCSD44 had MS percent recoveries that were greater than the laboratory upper acceptance limit for benzo(b)fluoranthene, phenanthrene, and pyrene. The MSD percent recoveries were less than the laboratory lower acceptance limit for chrysene, fluoranthene (<10%) and pyrene (<10%). Positive results for these analytes were qualified as estimated (J) in the original unspiked sample NTC17PCSD44 only.

The field duplicate pair NTC17PCSD42 / NTC17PCFD10 had a percent difference that exceeded the quality control limit of 50% for dibenzo(a,h)anthracene. The positive and non-detected results for dibenzo(a,h)anthracene were qualified as estimated (J and UJ, respectively) in the field duplicate pair samples only.

The project action limit for naphthalene was 0.55 ug/kg in the laboratory scope of work. The method detection limits for naphthalene exceeded the project action limit in all samples as follows:

Sample	MDL	Units
NTC17PCFD10	2.9	UG/KG
NTC17PCSD40	2.8	UG/KG
NTC17PCSD41	2.8	UG/KG
NTC17PCSD42	2.9	UG/KG
NTC17PCSD43	2.9	UG/KG
NTC17PCSD44	2.9	UG/KG
NTC17PCSD45	2.7	UG/KG
NTC17PCSD46	2.6	UG/KG
NTC17PCSD47	2.7	UG/KG
NTC17PCSD48	2.8	UG/KG
NTC17PCSD49	3.1	UG/KG

Positive results between the method detection limit (MDL) and the reporting limit were qualified as estimated (J) due to uncertainty near the detection limit.

PEST/PCB

All pesticide and PCB samples were extracted 42 days after sample collection. Therefore, these samples are all 28 days outside of the 14-day extraction holding time limit. The samples were analyzed 44 days after sample collection, which is 4 days outside of the 40-day analysis holding time limit. Positive and non-detected results were qualified as estimated (J and UJ) in all samples on this basis.

Toxaphene was run as a single-component analyte in the initial calibration analysis. All results were non-detected, so the laboratory did not perform continuing calibration for toxaphene. However, the the Department of Defense (DoD) document entitled "Quality Systems Manual (QSM) for Environmental Laboratories" (January 2006) requires that continuing calibration verifications be run for all target analytes. Therefore, all non-detected toxaphene results were qualified as estimated (UJ) in samples receiving full validations.

The continuing calibration run on 01/21/09 at 07:43 on instrument ECD3 had percent difference results that were outside of the ±15% acceptance range for alpha-BHC and gamma-BHC on the primary column only. All samples were affected. No action was taken for alpha-BHC because this compound was non-detected in all samples and the secondary column was compliant. One positive result for gamma-BHC in sample NTC17PCSD44 was reported from the primary column. This result was qualified as estimated (J) due to calibration noncompliance.

The continuing calibration run on 01/21/09 at 16:41 on instrument ECD3 had an average percent difference result that was outside of the ±15% acceptance range for Aroclor-1016 on both columns. All samples were affected. Non-detected results for Aroclor-1016 in all samples receiving full validations (NTC17PCFD10, NTC17PCSD40, NTC17PCSD41, NTC17PCSD42, NTC17PCSD43, and NTC17PCSD44) were qualified as estimated (UJ) on this basis.

The continuing calibration run on 01/21/09 at 16:41 on instrument ECD3 had percent difference results that were outside of the ±15% acceptance range for delta-BHC and 4,4-DDD on both columns. All samples were affected. The non-detected results for delta-BHC were qualified as estimated (UJ), and the positive and non-detected results for 4,4-DDD were qualified as estimated (J and UJ, respectively) in the full validation samples only (NTC17PCFD10, NTC17PCSD40, NTC17PCSD41, NTC17PCSD42, NTC17PCSD43, and NTC17PCSD44). The 4,4'-DDD result in sample NTC17PCFD10 was qualified as unusable (R) due to percent difference between columns.

The continuing calibration run on 01/21/09 at 16:41 on instrument ECD3 had percent difference results that were outside of the ±15% acceptance range for alpha-BHC, gamma-BHC, beta-BHC, heptachlor epoxide, endrin aldehyde, and endrin ketone on the primary column only. All samples were affected. No results were qualified for alpha-BHC, beta-BHC, endrin aldehyde, and endrin ketone, as results for these analytes were non-detected in all samples and the secondary column was compliant. The positive results for gamma-BHC and heptachlor epoxide in sample NTC17PCSD44, both reported from the primary column, were qualified as estimated (J) on this basis. However, the heptachlor epoxide result in this sample was qualified as unusable (R) due to percent difference between columns.

The continuing calibration run on 01/21/09 at 16:41 on instrument ECD3 had percent difference results that were outside of the ±15% acceptance range for 4,4'-DDE on the secondary column only. In samples receiving a full validation, the positive results for 4,4'-DDE reported from the primary column (NTC17PCFD10, NTC17PCSD40, NTC17PCSD41, and NTC17PCSD44) were qualified as estimated (J) on this basis.

The continuing calibration run on 01/21/09 at 16:59 on instrument ECD3 had average percent difference results that were outside of the ±15% acceptance range for Aroclor-1016 on both columns. All samples were affected. Non-detected results for this compound were qualified as estimated (UJ) on this basis in the samples receiving full validations (NTC17PCFD10, NTC17PCSD40, NTC17PCSD41, NTC17PCSD42, NTC17PCSD43, and NTC17PCSD44). Additionally, this calibration had an average percent difference result for Aroclor-1260 that was outside of the ±15% acceptance range for Aroclor-1260 on the secondary column only. No action was necessary because results for this compound were non-detected in the aforementioned samples that received a full validation.

The following analyte was detected in the method blank at the following maximum concentration:

Analyte	Maximum Concentration	Action Level
Endosulfan II	0.36 ug/kg	1.8 ug/kg

An action level of 5X the maximum concentration was used to evaluate sample data for blank contamination. Sample aliquot, percent solids, and dilution factors, if applicable, were taken into consideration in evaluating for blank contamination. The endosulfan II result for sample NTC17PCSD44 was qualified as non-detected (U) due to blank contamination.

The surrogate recovery for decachlorobiphenyl (DCB) was greater than the laboratory upper acceptance limit for sample NTC17PCSD41 on the primary column only. No action was necessary because the secondary column was compliant.

The surrogate recovery for tetrachloro-m-xylene (TCMX) was greater than the laboratory upper acceptance limit for sample NTC17PCSD45 on the primary column only. No action was necessary because the secondary column was compliant and this sample only received a cursory validation.

The following full validation samples had results exceeding the quality control limit of 25% for percent difference between columns:

Sample	Analyte	% Difference	Qualifier
NTC17PCSD40	4,4'-DDE	35.1 %	J
NTC17PCFD10	4,4'-DDD	111.3%	R
NTC17PCSD42	4,4'-DDD	70.4%	J
NTC17PCSD44	Endosulfan II	63.6%	J*
	Gamma-BHC	39.0%	J
	Heptachlor epoxide	149.6	R
NTC17PCSD48	4,4'-DDE	28.1%	NA-cursory
	4,4'-DDT	44.3%	NA-cursory

* Previously qualified as non-detected (U) due to blank contamination

Analytes with percent difference results greater than 25% but less than 100% were qualified as estimated (J). Analytes with percent difference results greater than 100% were qualified as unusable (R). Analytes in sample NTC17PCSD48 were not qualified on this basis because that sample was given a cursory review.

Positive results detected between the MDL and the reporting limit were qualified as estimated (J) due to uncertainty near the detection limit.

Notes

According to the laboratory sample documentation, one jar for sample NTC17PCSD44 was broken during shipment.

EXECUTIVE SUMMARY

Laboratory Performance Issues: The PAH fraction had calibration noncompliance (no qualification) and detection limits for naphthalene that were greater than project action limits. The Pest/PCB fraction had holding time noncompliance, calibration noncompliance, method blank contamination, surrogate recovery noncompliance (no qualification), and percent difference between columns that exceeded the acceptance limit.

Other Factors Affecting Data Quality: Some results were qualified due to MS/MSD recovery noncompliance

in the PAH fraction. One analyte was qualified due to field duplicate imprecision in the PAH fraction. Some positive results in both fractions were qualified due to uncertainty near the detection limit.

The data for these analyses were reviewed with reference to the EPA Functional Guidelines for Organic Data Validation (10/99), and the Department of Defense (DoD) document entitled "Quality Systems Manual (QSM) for Environmental Laboratories" (January 2006). The text of this report has been formulated to address only those problem areas affecting data quality.

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Attachments:

Appendix A – Qualified Analytical Results
Appendix B – Results as Reported by the Laboratory
Appendix C – Support Documentation

APPENDIX A

QUALIFIED ANALYTICAL RESULTS

Data Validation Qualifier Codes:

A = Lab Blank Contamination
B = Field Blank Contamination
C = Calibration Noncompliance (e.g. % RSDs, %Ds, ICVs, CCVs, RRFs, etc.)
C01 = GC/MS Tuning Noncompliance
D = MS/MSD Recovery Noncompliance
E = LCS/LCSD Recovery Noncompliance
F = Lab Duplicate Imprecision
G = Field Duplicate Imprecision
H = Holding Time Exceedance
I = ICP Serial Dilution Noncompliance
J = GFAA PDS - GFAA MSA's $r < 0.995$
K = ICP Interference - includes ICS % R Noncompliance
L = Instrument Calibration Range Exceedance
M = Sample Preservation Noncompliance
N = Internal Standard Noncompliance
N01 = Internal Standard Recovery Noncompliance Dioxins
N02 = Recovery Standard Noncompliance Dioxins
N03 = Clean-up Standard Noncompliance Dioxins
O = Poor Instrument Performance (e.g. base-line drifting)
P = Uncertainty near detection limit (< 2 x IDL for inorganics and <CRQL for organics)
Q = Other problems (can be any number of issues; e.g. poor chromatography,interferences, etc.)
R = Surrogates Recovery Noncompliance
S = Pesticide/PCB Resolution
T = % Breakdown Noncompliance for DDT and Endrin
U = % Difference between columns/detectors >25% for positive results determined via GC/HPLC
V = Non-linear calibrations; correlation coefficient $r < 0.995$
W = EMPC result
X = Signal to noise response drop
Y = Percent solids <30%
Z = Uncertainty at 2 sigma deviation is greater than sample activity

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PAH

nsample	NTC17PCFD10	nsample	NTC17PCSD40	nsample	NTC17PCSD41
samp_date	12/8/2008	samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-03	lab_id	0812143-01	lab_id	0812143-02
qc_type	NM	qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG	units	UG/KG
Pct_Solids	80.8	Pct_Solids	84.3	Pct_Solids	83.1
DUP_OF:	NTC17PCSD42	DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	7.3		
ACENAPHTHENE	14		
ACENAPHTHYLENE	4.1	U	
ANTHRACENE	72		
BENZO(A)ANTHRACENE	280		
BENZO(A)PYRENE	210		
BENZO(B)FLUORANTHENE	210		
BENZO(G,H,I)PERYLENE	110		
BENZO(K)FLUORANTHENE	67		
CHRYSENE	230		
DIBENZO(A,H)ANTHRACENE	4.1	UJ	G
FLUORANTHENE	560		
FLUORENE	20		
INDENO(1,2,3-CD)PYRENE	94		
NAPHTHALENE	8.8		
PHENANTHRENE	340		
PYRENE	480		

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	4	U	
ACENAPHTHENE	4	U	
ACENAPHTHYLENE	4	U	
ANTHRACENE	4	U	
BENZO(A)ANTHRACENE	4	U	
BENZO(A)PYRENE	4	U	
BENZO(B)FLUORANTHENE	4	U	
BENZO(G,H,I)PERYLENE	1.8	J	P
BENZO(K)FLUORANTHENE	4	U	
CHRYSENE	4	U	
DIBENZO(A,H)ANTHRACENE	4	U	
FLUORANTHENE	3.1	J	P
FLUORENE	4	U	
INDENO(1,2,3-CD)PYRENE	4	U	
NAPHTHALENE	4	U	
PHENANTHRENE	3.9	J	P
PYRENE	4.4		

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	2.3	J	P
ACENAPHTHENE	4	U	
ACENAPHTHYLENE	4	U	
ANTHRACENE	3	J	P
BENZO(A)ANTHRACENE	4	U	
BENZO(A)PYRENE	4	U	
BENZO(B)FLUORANTHENE	4	U	
BENZO(G,H,I)PERYLENE	5.5		
BENZO(K)FLUORANTHENE	4	U	
CHRYSENE	4	U	
DIBENZO(A,H)ANTHRACENE	4	U	
FLUORANTHENE	9.3		
FLUORENE	2.9	J	P
INDENO(1,2,3-CD)PYRENE	4	U	
NAPHTHALENE	4	U	
PHENANTHRENE	18		
PYRENE	4	U	

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PAH

nsample	NTC17PCSD42	nsample	NTC17PCSD43	nsample	NTC17PCSD44
samp_date	12/8/2008	samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-04	lab_id	0812143-05	lab_id	0812143-06
qc_type	NM	qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG	units	UG/KG
Pct_Solids	79.3	Pct_Solids	80.5	Pct_Solids	80.2
DUP_OF:		DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	7.2		
ACENAPHTHENE	11		
ACENAPHTHYLENE	4.2	U	
ANTHRACENE	71		
BENZO(A)ANTHRACENE	220		
BENZO(A)PYRENE	200		
BENZO(B)FLUORANTHENE	240		
BENZO(G,H,I)PERYLENE	120		
BENZO(K)FLUORANTHENE	64		
CHRYSENE	170		
DIBENZO(A,H)ANTHRACENE	27	J	G
FLUORANTHENE	550		
FLUORENE	18		
INDENO(1,2,3-CD)PYRENE	100		
NAPHTHALENE	6.5		
PHENANTHRENE	310		
PYRENE	440		

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	4.2		
ACENAPHTHENE	3.5	J	P
ACENAPHTHYLENE	4.1	U	
ANTHRACENE	12		
BENZO(A)ANTHRACENE	67		
BENZO(A)PYRENE	62		
BENZO(B)FLUORANTHENE	74		
BENZO(G,H,I)PERYLENE	38		
BENZO(K)FLUORANTHENE	20		
CHRYSENE	56		
DIBENZO(A,H)ANTHRACENE	8.1		
FLUORANTHENE	150		
FLUORENE	6.3		
INDENO(1,2,3-CD)PYRENE	30		
NAPHTHALENE	4.1	U	
PHENANTHRENE	110		
PYRENE	130		

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	5		
ACENAPHTHENE	11		
ACENAPHTHYLENE	4.2	U	
ANTHRACENE	66		
BENZO(A)ANTHRACENE	260		
BENZO(A)PYRENE	180		
BENZO(B)FLUORANTHENE	200	J	D
BENZO(G,H,I)PERYLENE	100		
BENZO(K)FLUORANTHENE	58		
CHRYSENE	200	J	D
DIBENZO(A,H)ANTHRACENE	26		
FLUORANTHENE	620	J	D
FLUORENE	19		
INDENO(1,2,3-CD)PYRENE	88		
NAPHTHALENE	4.8		
PHENANTHRENE	320	J	D
PYRENE	460	J	D

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PAH

nsample	NTC17PCSD45	nsample	NTC17PCSD46	nsample	NTC17PCSD47
samp_date	12/8/2008	samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-07	lab_id	0812143-08	lab_id	0812143-09
qc_type	NM	qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG	units	UG/KG
Pct_Solids	85.2	Pct_Solids	87.9	Pct_Solids	87.1
DUP_OF:		DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	7.5		
ACENAPHTHENE	3.9	U	
ACENAPHTHYLENE	3.9	U	
ANTHRACENE	3.9	U	
BENZO(A)ANTHRACENE	3.9	U	
BENZO(A)PYRENE	3.9	U	
BENZO(B)FLUORANTHENE	3.9	U	
BENZO(G,H,I)PERYLENE	3.8	J	P
BENZO(K)FLUORANTHENE	3.9	U	
CHRYSENE	3.9	U	
DIBENZO(A,H)ANTHRACENE	3.9	U	
FLUORANTHENE	7.6		
FLUORENE	3.9	U	
INDENO(1,2,3-CD)PYRENE	3.9	U	
NAPHTHALENE	3.9	U	
PHENANTHRENE	18		
PYRENE	7.7		

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	5.1		
ACENAPHTHENE	3.8	U	
ACENAPHTHYLENE	3.8	U	
ANTHRACENE	3.8	U	
BENZO(A)ANTHRACENE	3.8	U	
BENZO(A)PYRENE	3.8	U	
BENZO(B)FLUORANTHENE	3.8	U	
BENZO(G,H,I)PERYLENE	4.4		
BENZO(K)FLUORANTHENE	3.8	U	
CHRYSENE	3.8	U	
DIBENZO(A,H)ANTHRACENE	3.8	U	
FLUORANTHENE	3.8	U	
FLUORENE	3.8	U	
INDENO(1,2,3-CD)PYRENE	3.8	U	
NAPHTHALENE	3.8	U	
PHENANTHRENE	16		
PYRENE	3.8	U	

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	20		
ACENAPHTHENE	3.8	U	
ACENAPHTHYLENE	3.8	U	
ANTHRACENE	3.8	U	
BENZO(A)ANTHRACENE	3.8	U	
BENZO(A)PYRENE	3.8	U	
BENZO(B)FLUORANTHENE	3.8	U	
BENZO(G,H,I)PERYLENE	3.2	J	P
BENZO(K)FLUORANTHENE	3.8	U	
CHRYSENE	3.8	U	
DIBENZO(A,H)ANTHRACENE	3.8	U	
FLUORANTHENE	5.7		
FLUORENE	3.8	U	
INDENO(1,2,3-CD)PYRENE	3.8	U	
NAPHTHALENE	6.2		
PHENANTHRENE	24		
PYRENE	3.8	U	

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PAH

nsample	NTC17PCSD48	nsample	NTC17PCSD49
samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-10	lab_id	0812143-11
qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG
Pct_Solids	83.0	Pct_Solids	74.8
DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	7.6		
ACENAPHTHENE	4.8		
ACENAPHTHYLENE	4	U	
ANTHRACENE	20		
BENZO(A)ANTHRACENE	33		
BENZO(A)PYRENE	24		
BENZO(B)FLUORANTHENE	20		
BENZO(G,H,I)PERYLENE	12		
BENZO(K)FLUORANTHENE	6.4		
CHRYSENE	29		
DIBENZO(A,H)ANTHRACENE	4	U	
FLUORANTHENE	69		
FLUORENE	9.7		
INDENO(1,2,3-CD)PYRENE	4	U	
NAPHTHALENE	4	U	
PHENANTHRENE	78		
PYRENE	59		

Parameter	Result	Val Qual	Qual Code
2-METHYLNAPHTHALENE	3.3	J	P
ACENAPHTHENE	1.9	J	P
ACENAPHTHYLENE	4.4	U	
ANTHRACENE	7.8		
BENZO(A)ANTHRACENE	37		
BENZO(A)PYRENE	37		
BENZO(B)FLUORANTHENE	34		
BENZO(G,H,I)PERYLENE	21		
BENZO(K)FLUORANTHENE	10		
CHRYSENE	39		
DIBENZO(A,H)ANTHRACENE	4.2	J	P
FLUORANTHENE	82		
FLUORENE	2.8	J	P
INDENO(1,2,3-CD)PYRENE	17		
NAPHTHALENE	4.4	U	
PHENANTHRENE	52		
PYRENE	68		

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PEST/PCB

nsample	NTC17PCFD10	nsample	NTC17PCSD40	nsample	NTC17PCSD41
samp_date	12/8/2008	samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-03	lab_id	0812143-01	lab_id	0812143-02
qc_type	NM	qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG	units	UG/KG
Pct_Solids	80.8	Pct_Solids	84.3	Pct_Solids	83.1
DUP_OF:	NTC17PCSD42	DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	4	R	U
4,4'-DDE	11	J	CH
4,4'-DDT	6	J	H
ALDRIN	0.41	UJ	H
ALPHA-BHC	0.41	UJ	H
ALPHA-CHLORDANE	0.41	UJ	H
AROCLOR-1016	21	UJ	CH
AROCLOR-1221	21	UJ	H
AROCLOR-1232	21	UJ	H
AROCLOR-1242	21	UJ	H
AROCLOR-1248	21	UJ	H
AROCLOR-1254	21	UJ	H
AROCLOR-1260	21	UJ	H
BETA-BHC	0.41	UJ	H
DELTA-BHC	0.41	UJ	CH
DIELDRIN	0.82	UJ	H
ENDOSULFAN I	0.41	UJ	H
ENDOSULFAN II	0.82	UJ	H
ENDOSULFAN SULFATE	0.82	UJ	H
ENDRIN	0.82	UJ	H
ENDRIN ALDEHYDE	0.82	UJ	H
ENDRIN KETONE	0.82	UJ	H
GAMMA-BHC (LINDANE)	0.41	UJ	H
GAMMA-CHLORDANE	0.41	UJ	H
HEPTACHLOR	0.41	UJ	H
HEPTACHLOR EPOXIDE	0.41	UJ	H
METHOXYCHLOR	0.41	UJ	H
TOXAPHENE	41	UJ	CH

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	6.1	J	CH
4,4'-DDE	0.92	J	CHU
4,4'-DDT	0.79	UJ	H
ALDRIN	0.4	UJ	H
ALPHA-BHC	0.4	UJ	H
ALPHA-CHLORDANE	0.4	UJ	H
AROCLOR-1016	20	UJ	CH
AROCLOR-1221	20	UJ	H
AROCLOR-1232	20	UJ	H
AROCLOR-1242	20	UJ	H
AROCLOR-1248	20	UJ	H
AROCLOR-1254	20	UJ	H
AROCLOR-1260	20	UJ	H
BETA-BHC	0.4	UJ	H
DELTA-BHC	0.4	UJ	CH
DIELDRIN	0.79	UJ	H
ENDOSULFAN I	0.4	UJ	H
ENDOSULFAN II	0.79	UJ	H
ENDOSULFAN SULFATE	0.79	UJ	H
ENDRIN	0.79	UJ	H
ENDRIN ALDEHYDE	0.79	UJ	H
ENDRIN KETONE	0.79	UJ	H
GAMMA-BHC (LINDANE)	0.4	UJ	H
GAMMA-CHLORDANE	0.4	UJ	H
HEPTACHLOR	0.4	UJ	H
HEPTACHLOR EPOXIDE	0.4	UJ	H
METHOXYCHLOR	0.4	UJ	H
TOXAPHENE	40	UJ	CH

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	13	J	CH
4,4'-DDE	7.4	J	CH
4,4'-DDT	3.9	J	H
ALDRIN	0.4	UJ	H
ALPHA-BHC	0.4	UJ	H
ALPHA-CHLORDANE	0.4	UJ	H
AROCLOR-1016	20	UJ	CH
AROCLOR-1221	20	UJ	H
AROCLOR-1232	20	UJ	H
AROCLOR-1242	20	UJ	H
AROCLOR-1248	20	UJ	H
AROCLOR-1254	20	UJ	H
AROCLOR-1260	20	UJ	H
BETA-BHC	0.4	UJ	H
DELTA-BHC	0.4	UJ	CH
DIELDRIN	0.8	UJ	H
ENDOSULFAN I	0.4	UJ	H
ENDOSULFAN II	0.8	UJ	H
ENDOSULFAN SULFATE	0.8	UJ	H
ENDRIN	0.8	UJ	H
ENDRIN ALDEHYDE	0.8	UJ	H
ENDRIN KETONE	0.8	UJ	H
GAMMA-BHC (LINDANE)	0.4	UJ	H
GAMMA-CHLORDANE	0.4	UJ	H
HEPTACHLOR	0.4	UJ	H
HEPTACHLOR EPOXIDE	0.4	UJ	H
METHOXYCHLOR	0.4	UJ	H
TOXAPHENE	40	UJ	CH

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PEST/PCB

nsample	NTC17PCSD42	nsample	NTC17PCSD43	nsample	NTC17PCSD44
samp_date	12/8/2008	samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-04	lab_id	0812143-05	lab_id	0812143-06
qc_type	NM	qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG	units	UG/KG
Pct_Solids	79.3	Pct_Solids	80.5	Pct_Solids	80.2
DUP_OF:		DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	2.4	J	CHU
4,4'-DDE	8.4	J	H
4,4'-DDT	5	J	H
ALDRIN	0.42	UJ	H
ALPHA-BHC	0.42	UJ	H
ALPHA-CHLORDANE	0.42	UJ	H
AROCLOR-1016	21	UJ	CH
AROCLOR-1221	21	UJ	H
AROCLOR-1232	21	UJ	H
AROCLOR-1242	21	UJ	H
AROCLOR-1248	21	UJ	H
AROCLOR-1254	21	UJ	H
AROCLOR-1260	21	UJ	H
BETA-BHC	0.42	UJ	H
DELTA-BHC	0.42	UJ	CH
DIELDRIN	0.84	UJ	H
ENDOSULFAN I	0.42	UJ	H
ENDOSULFAN II	0.84	UJ	H
ENDOSULFAN SULFATE	0.84	UJ	H
ENDRIN	0.84	UJ	H
ENDRIN ALDEHYDE	0.84	UJ	H
ENDRIN KETONE	0.84	UJ	H
GAMMA-BHC (LINDANE)	0.42	UJ	H
GAMMA-CHLORDANE	0.42	UJ	H
HEPTACHLOR	0.42	UJ	H
HEPTACHLOR EPOXIDE	0.42	UJ	H
METHOXYCHLOR	0.42	UJ	H
TOXAPHENE	42	UJ	CH

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	0.83	UJ	CH
4,4'-DDE	0.83	UJ	H
4,4'-DDT	0.83	UJ	H
ALDRIN	0.41	UJ	H
ALPHA-BHC	0.41	UJ	H
ALPHA-CHLORDANE	0.41	UJ	H
AROCLOR-1016	21	UJ	CH
AROCLOR-1221	21	UJ	H
AROCLOR-1232	21	UJ	H
AROCLOR-1242	21	UJ	H
AROCLOR-1248	21	UJ	H
AROCLOR-1254	21	UJ	H
AROCLOR-1260	21	UJ	H
BETA-BHC	0.41	UJ	H
DELTA-BHC	0.41	UJ	CH
DIELDRIN	0.83	UJ	H
ENDOSULFAN I	0.41	UJ	H
ENDOSULFAN II	0.83	UJ	H
ENDOSULFAN SULFATE	0.83	UJ	H
ENDRIN	0.83	UJ	H
ENDRIN ALDEHYDE	0.83	UJ	H
ENDRIN KETONE	0.83	UJ	H
GAMMA-BHC (LINDANE)	0.41	UJ	H
GAMMA-CHLORDANE	0.41	UJ	H
HEPTACHLOR	0.41	UJ	H
HEPTACHLOR EPOXIDE	0.41	UJ	H
METHOXYCHLOR	0.41	UJ	H
TOXAPHENE	41	UJ	CH

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	2.1	J	CH
4,4'-DDE	14	J	CH
4,4'-DDT	13	J	H
ALDRIN	0.42	UJ	H
ALPHA-BHC	0.42	UJ	H
ALPHA-CHLORDANE	0.42	UJ	H
AROCLOR-1016	21	UJ	CH
AROCLOR-1221	21	UJ	H
AROCLOR-1232	21	UJ	H
AROCLOR-1242	21	UJ	H
AROCLOR-1248	21	UJ	H
AROCLOR-1254	21	UJ	H
AROCLOR-1260	21	UJ	H
BETA-BHC	0.42	UJ	H
DELTA-BHC	0.42	UJ	CH
DIELDRIN	0.83	UJ	H
ENDOSULFAN I	0.42	UJ	H
ENDOSULFAN II	0.27	U	A
ENDOSULFAN SULFATE	0.83	UJ	H
ENDRIN	1.5	J	H
ENDRIN ALDEHYDE	0.83	UJ	H
ENDRIN KETONE	0.83	UJ	H
GAMMA-BHC (LINDANE)	0.25	J	CHPU
GAMMA-CHLORDANE	0.42	UJ	H
HEPTACHLOR	0.42	UJ	H
HEPTACHLOR EPOXIDE	0.2	R	U
METHOXYCHLOR	0.42	UJ	H
TOXAPHENE	42	UJ	CH

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PEST/PCB

nsample	NTC17PCSD45	nsample	NTC17PCSD46	nsample	NTC17PCSD47
samp_date	12/8/2008	samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-07	lab_id	0812143-08	lab_id	0812143-09
qc_type	NM	qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG	units	UG/KG
Pct_Solids	85.2	Pct_Solids	87.9	Pct_Solids	87.1
DUP_OF:		DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	0.78	UJ	H
4,4'-DDE	0.78	UJ	H
4,4'-DDT	0.78	UJ	H
ALDRIN	0.39	UJ	H
ALPHA-BHC	0.39	UJ	H
ALPHA-CHLORDANE	0.39	UJ	H
AROCLOR-1016	20	UJ	H
AROCLOR-1221	20	UJ	H
AROCLOR-1232	20	UJ	H
AROCLOR-1242	20	UJ	H
AROCLOR-1248	20	UJ	H
AROCLOR-1254	20	UJ	H
AROCLOR-1260	20	UJ	H
BETA-BHC	0.39	UJ	H
DELTA-BHC	0.39	UJ	H
DIELDRIN	0.78	UJ	H
ENDOSULFAN I	0.39	UJ	H
ENDOSULFAN II	0.78	UJ	H
ENDOSULFAN SULFATE	0.78	UJ	H
ENDRIN	0.78	UJ	H
ENDRIN ALDEHYDE	0.78	UJ	H
ENDRIN KETONE	0.78	UJ	H
GAMMA-BHC (LINDANE)	0.39	UJ	H
GAMMA-CHLORDANE	0.39	UJ	H
HEPTACHLOR	0.39	UJ	H
HEPTACHLOR EPOXIDE	0.39	UJ	H
METHOXYCHLOR	0.39	UJ	H
TOXAPHENE	39	UJ	H

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	0.76	UJ	H
4,4'-DDE	0.76	UJ	H
4,4'-DDT	0.76	UJ	H
ALDRIN	0.38	UJ	H
ALPHA-BHC	0.38	UJ	H
ALPHA-CHLORDANE	0.38	UJ	H
AROCLOR-1016	19	UJ	H
AROCLOR-1221	19	UJ	H
AROCLOR-1232	19	UJ	H
AROCLOR-1242	19	UJ	H
AROCLOR-1248	19	UJ	H
AROCLOR-1254	19	UJ	H
AROCLOR-1260	19	UJ	H
BETA-BHC	0.38	UJ	H
DELTA-BHC	0.38	UJ	H
DIELDRIN	0.76	UJ	H
ENDOSULFAN I	0.38	UJ	H
ENDOSULFAN II	0.76	UJ	H
ENDOSULFAN SULFATE	0.76	UJ	H
ENDRIN	0.76	UJ	H
ENDRIN ALDEHYDE	0.76	UJ	H
ENDRIN KETONE	0.76	UJ	H
GAMMA-BHC (LINDANE)	0.38	UJ	H
GAMMA-CHLORDANE	0.38	UJ	H
HEPTACHLOR	0.38	UJ	H
HEPTACHLOR EPOXIDE	0.38	UJ	H
METHOXYCHLOR	0.38	UJ	H
TOXAPHENE	38	UJ	H

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	0.76	UJ	H
4,4'-DDE	0.76	UJ	H
4,4'-DDT	0.76	UJ	H
ALDRIN	0.38	UJ	H
ALPHA-BHC	0.38	UJ	H
ALPHA-CHLORDANE	0.38	UJ	H
AROCLOR-1016	19	UJ	H
AROCLOR-1221	19	UJ	H
AROCLOR-1232	19	UJ	H
AROCLOR-1242	19	UJ	H
AROCLOR-1248	19	UJ	H
AROCLOR-1254	19	UJ	H
AROCLOR-1260	19	UJ	H
BETA-BHC	0.38	UJ	H
DELTA-BHC	0.38	UJ	H
DIELDRIN	0.76	UJ	H
ENDOSULFAN I	0.38	UJ	H
ENDOSULFAN II	0.76	UJ	H
ENDOSULFAN SULFATE	0.76	UJ	H
ENDRIN	0.76	UJ	H
ENDRIN ALDEHYDE	0.76	UJ	H
ENDRIN KETONE	0.76	UJ	H
GAMMA-BHC (LINDANE)	0.38	UJ	H
GAMMA-CHLORDANE	0.38	UJ	H
HEPTACHLOR	0.38	UJ	H
HEPTACHLOR EPOXIDE	0.38	UJ	H
METHOXYCHLOR	0.38	UJ	H
TOXAPHENE	38	UJ	H

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: PEST/PCB

nsample	NTC17PCSD48	nsample	NTC17PCSD49
samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-10	lab_id	0812143-11
qc_type	NM	qc_type	NM
units	UG/KG	units	UG/KG
Pct_Solids	83.0	Pct_Solids	74.8
DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	3.8	J	H
4,4'-DDE	1.2	J	H
4,4'-DDT	1.4	J	H
ALDRIN	0.4	UJ	H
ALPHA-BHC	0.4	UJ	H
ALPHA-CHLORDANE	0.4	UJ	H
AROCLOR-1016	20	UJ	H
AROCLOR-1221	20	UJ	H
AROCLOR-1232	20	UJ	H
AROCLOR-1242	20	UJ	H
AROCLOR-1248	20	UJ	H
AROCLOR-1254	20	UJ	H
AROCLOR-1260	7.2	J	HP
BETA-BHC	0.4	UJ	H
DELTA-BHC	0.4	UJ	H
DIELDRIN	0.8	UJ	H
ENDOSULFAN I	0.4	UJ	H
ENDOSULFAN II	0.8	UJ	H
ENDOSULFAN SULFATE	0.8	UJ	H
ENDRIN	0.8	UJ	H
ENDRIN ALDEHYDE	0.8	UJ	H
ENDRIN KETONE	0.8	UJ	H
GAMMA-BHC (LINDANE)	0.4	UJ	H
GAMMA-CHLORDANE	0.4	UJ	H
HEPTACHLOR	0.4	UJ	H
HEPTACHLOR EPOXIDE	0.4	UJ	H
METHOXYCHLOR	0.4	UJ	H
TOXAPHENE	40	UJ	H

Parameter	Result	Val Qual	Qual Code
4,4'-DDD	19	J	H
4,4'-DDE	68	J	H
4,4'-DDT	19	J	H
ALDRIN	0.44	UJ	H
ALPHA-BHC	0.44	UJ	H
ALPHA-CHLORDANE	0.44	UJ	H
AROCLOR-1016	22	UJ	H
AROCLOR-1221	22	UJ	H
AROCLOR-1232	22	UJ	H
AROCLOR-1242	22	UJ	H
AROCLOR-1248	22	UJ	H
AROCLOR-1254	22	UJ	H
AROCLOR-1260	22	UJ	H
BETA-BHC	0.44	UJ	H
DELTA-BHC	0.44	UJ	H
DIELDRIN	0.89	UJ	H
ENDOSULFAN I	0.44	UJ	H
ENDOSULFAN II	0.89	UJ	H
ENDOSULFAN SULFATE	0.89	UJ	H
ENDRIN	2	J	H
ENDRIN ALDEHYDE	0.89	UJ	H
ENDRIN KETONE	0.89	UJ	H
GAMMA-BHC (LINDANE)	0.44	UJ	H
GAMMA-CHLORDANE	0.44	UJ	H
HEPTACHLOR	0.44	UJ	H
HEPTACHLOR EPOXIDE	0.44	UJ	H
METHOXYCHLOR	0.44	UJ	H
TOXAPHENE	44	UJ	H

Tetra Tech NUS **INTERNAL CORRESPONDENCE**

TO:	**R. DAVIS**	**DATE:**	**FEBRUARY 5, 2009**
FROM:	**LEANNE M. GANSER**	**COPIES:**	**DV FILE**

SUBJECT: **50/50 FULL/CURSORY INORGANIC DATA VALIDATION – METALS AND PERCENT SOLIDS**
NTC GREAT LAKES CTO 474
SAMPLE DELIVERY GROUP (SDG) – GL004

SAMPLES: Full Validation/6/Solid/

NTC17PCFD10	NTC17PCSD40	NTC17PCSD41
NTC17PCSD42	NTC17PCSD43	NTC17PCSD44

Cursory Validation/5/Solid/

NTC17PCSD45	NTC17PCSD46	NTC17PCSD47
NTC17PCSD48	NTC17PCSD49	

Overview

The sample set for NTC Great Lakes CTO 474, SDG GL004, consists of eleven (11) sediment environmental samples. One field duplicate pair was included within this SDG: NTC17PCSD42 / NTC17PCFD10.

All samples were analyzed for copper, lead, mercury, and zinc and percent solids. The samples were collected by Tetra Tech NUS on December 8-9, 2008 and analyzed by Empirical Laboratories. Metals analyses were conducted using SW-846 methods 6010B and 7471A. Percent solids analyses were conducted using standard method 2540B.

These data were evaluated based on the following parameters:

* • Data Completeness
* • Holding Times
* • Initial and Continuing Calibrations
• Laboratory Method / Preparation Blanks
* • ICP Interference Analysis
* • Laboratory Control Sample Results
* • Matrix Spike / Matrix Spike Duplicate Results
* • Laboratory Duplicate Results
* • Field Duplicate Results
• ICP Serial Dilution Results
* • Detection Limits
* • Analyte Quantitation

* - All quality control criteria were met for this parameter.

Qualified (if applicable) analytical results are summarized in Appendix A. Results as reported by the laboratory are presented in Appendix B. Appendix C contains the documentation to support the findings as discussed in this validation report.

Laboratory Method / Preparation Blanks

The following contaminants were detected in the laboratory method/preparation blanks at the following maximum concentrations:

Analyte	Maximum Concentration	Action Level
Lead[1]	1.6 ug/L	1.6 mg/kg

(1) Maximum concentration affecting samples NTC17PCSD40, NTC17PCSD41, and NTC17PCFD10.

An action level of 5X the maximum contaminant level has been used to evaluate sample data for blank contamination. Sample aliquot and dilution factors, if applicable, were taken into consideration when evaluating for blank contamination. No action was taken as all results for lead were greater than the blank action level.

ICP Serial Dilution Results

The serial dilution percent difference (%D) for zinc was >10% affecting samples in the 12/17/08 preparation batch. Positive results for zinc were qualified as estimated, "J" in samples NTC17PCSD42, NTC17PCSD43, and NTC17PCSD44.

Notes

The original nondetected results on the EDD were reported to the method reporting limit. The nondetected results reported on the EDD were amended to reflect the method detection limits (MDL) as reported on the Form 1s.

Sample NTC17PCFD10 was reported on the chain of custody as an aqueous QC sample; however, NTC17PCFD10 was a sediment field duplicate sample, corresponding to sample NTC17PCSD42.

Executive Summary

Laboratory Performance: Lead was present in a laboratory blank. ICP serial dilution %D for zinc exceeded the quality control limit.

Other Factors Affecting Data Quality: None.

The data for these analyses were reviewed with reference to the "National Functional Guidelines for Inorganic Review", October 2004 and the Department of Defense (DoD) document entitled "Quality Systems Manual (QSM) for Environmental Laboratories" (January 2006).

The text of this report has been formulated to address only those problem areas affecting data quality.

Tetra Tech NUS
Leanne M. Ganser
Environmental Scientist

Tetra Tech NUS
Joseph A. Samchuck
Quality Assurance Officer

Attachments:

1. Appendix A - Qualified Analytical Results
2. Appendix B - Results as reported by the Laboratory
3. Appendix C - Support Documentation

APPENDIX A
QUALIFIED ANALYTICAL RESULTS

Data Validation Qualifier Codes:

A = Lab Blank Contamination
B = Field Blank Contamination
C = Calibration Noncompliance (e.g. % RSDs, %Ds, ICVs, CCVs, RRFs, etc.)
C01 = GC/MS Tuning Noncompliance
D = MS/MSD Recovery Noncompliance
E = LCS/LCSD Recovery Noncompliance
F = Lab Duplicate Imprecision
G = Field Duplicate Imprecision
H = Holding Time Exceedance
I = ICP Serial Dilution Noncompliance
J = GFAA PDS-GFAA MSA's r < 0.995 / ICP PDS Recovery Noncompliance
K = ICP Interference - includes ICS % R Noncompliance
L = Instrument Calibration Range Exceedance
M = Sample Preservation Noncompliance
N = Internal Standard Noncompliance
N01 = Internal Standard Recovery Noncompliance Dioxins
N02 = Recovery Standard Noncompliance Dioxins
N03 = Clean-up Standard Noncompliance Dioxins
O = Poor Instrument Performance (e.g. base-line drifting)
P = Uncertainty near detection limit (< 2 x IDL for inorganics and <CRQL for organics)
Q = Other problems (can encompass a number of issues; e.g. chromatography,interferences, etc.)
R = Surrogates Recovery Noncompliance
S = Pesticide/PCB Resolution
T = % Breakdown Noncompliance for DDT and Endrin
U = % Difference between columns/detectors >25% for positive results determined via GC/HPLC
V = Non-linear calibrations; correlation coefficient r < 0.995
W = EMPC result
X = Signal to noise response drop
Y = Percent solids <30%
Z = Uncertainty at 2 sigma deviation is greater than sample activity

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: M

nsample	NTC17PCFD10	nsample	NTC17PCSD40	nsample	NTC17PCSD41
samp_date	12/8/2008	samp_date	12/8/2008	samp_date	12/8/2008
lab_id	0812143-03	lab_id	0812143-01	lab_id	0812143-02
qc_type	NM	qc_type	NM	qc_type	NM
units	MG/KG	units	MG/KG	units	MG/KG
Pct_Solids	80.8	Pct_Solids	84.3	Pct_Solids	83.1
DUP_OF:	NTC17PCSD42	DUP_OF:		DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	21		
LEAD	34		
MERCURY	0.039		
ZINC	100		

Parameter	Result	Val Qual	Qual Code
COPPER	16.3		
LEAD	8.9		
MERCURY	0.016	U	
ZINC	43.2		

Parameter	Result	Val Qual	Qual Code
COPPER	23.9		
LEAD	11.4		
MERCURY	0.028		
ZINC	45.3		

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: M

nsample	NTC17PCSD42
samp_date	12/8/2008
lab_id	0812143-04
qc_type	NM
units	MG/KG
Pct_Solids	79.3
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	18.1		
LEAD	33.6		
MERCURY	0.061		
ZINC	99.3	J	I

nsample	NTC17PCSD43
samp_date	12/8/2008
lab_id	0812143-05
qc_type	NM
units	MG/KG
Pct_Solids	80.5
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	22		
LEAD	9.9		
MERCURY	0.023		
ZINC	44.3	J	I

nsample	NTC17PCSD44
samp_date	12/8/2008
lab_id	0812143-06
qc_type	NM
units	MG/KG
Pct_Solids	80.2
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	32.1		
LEAD	20.6		
MERCURY	0.038		
ZINC	81.3	J	I

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: M

nsample	NTC17PCSD45
samp_date	12/8/2008
lab_id	0812143-07
qc_type	NM
units	MG/KG
Pct_Solids	85.2
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	53.5		
LEAD	24		
MERCURY	0.015	U	
ZINC	230		

nsample	NTC17PCSD46
samp_date	12/8/2008
lab_id	0812143-08
qc_type	NM
units	MG/KG
Pct_Solids	87.9
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	19.4		
LEAD	9.6		
MERCURY	0.014	U	
ZINC	43.9		

nsample	NTC17PCSD47
samp_date	12/8/2008
lab_id	0812143-09
qc_type	NM
units	MG/KG
Pct_Solids	87.1
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	22.6		
LEAD	11.2		
MERCURY	0.015	U	
ZINC	51		

PROJ_NO: 01021

SDG: GL004 MEDIA: SEDIMENT DATA FRACTION: M

nsample	NTC17PCSD48
samp_date	12/8/2008
lab_id	0812143-10
qc_type	NM
units	MG/KG
Pct_Solids	83.0
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	167		
LEAD	103		
MERCURY	0.018		
ZINC	1070		

nsample	NTC17PCSD49
samp_date	12/8/2008
lab_id	0812143-11
qc_type	NM
units	MG/KG
Pct_Solids	74.8
DUP_OF:	

Parameter	Result	Val Qual	Qual Code
COPPER	31.4		
LEAD	36.6		
MERCURY	0.017	U	
ZINC	97.3		

Sample Calculation

Analysis Report 12/17/08 11:01:09 PM page 1

Method: TESTING Sample Name: 0812143-02,TS,TETRA Operator: RGB
Run Time: 12/17/08 22:54:52 Sample NTC17P(SD41 sample weight = g
Comment: 200.7 / 6010B Lab reported result = 11.4 mg/kg sample volume = 0.2 L
Mode: CONC Corr. Factor: 1 % solids = 83.1

47.366 ppb @ 0.2 L @ 1/0.831 =

Elem	Ag3280	Al3082	As1890	B_2496	Ba4934	Be3130	Ca3179
Units	ppb	ppb	ppb	ppb	ppb	ppb	ppm
Avge	-.36823	39987.	34.260	66.351	177.73	2.6800	H336.98
SDev	.15654	53.	1.899	.408	.27	.0444	.28
%RSD	42.513	.13363	5.5420	.61480	.15080	1.6550	.08337
#1	-.54371	39971.	33.308	65.921	177.46	2.6493	H337.19
#2	-.24293	39944.	33.026	66.733	177.75	2.6599	H337.09
#3	-.31805	40047.	36.447	66.399	177.99	2.7308	H336.67
Errors	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass	LC High
High	2000.0	500000.	10000.	50000.	5000.0	10000.	100.00
Low	-1.0000	-50.000	-3.0000	-10.000	-5.0000	-1.0000	-1.0000

11.4 mg/kg

Elem	Cd2265	Co2286	Cr2677	Cu3247	Fe2714	K_7664	Mg2790
Units	ppb	ppb	ppb	ppb	ppb	ppm	ppm
Avge	1.2211	42.697	69.061	99.260	83385.	11.667	178.45
SDev	.0979	.259	.208	.217	110.	.045	.05
%RSD	8.0155	.60642	.30153	.21881	.13145	.38329	.02715
#1	1.2869	42.457	68.915	99.177	83431.	11.702	178.44
#2	1.1086	42.972	69.300	99.096	83464.	11.617	178.50
#3	1.2678	42.663	68.969	99.506	83260.	11.684	178.41
Errors	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass
High	10000.	10000.	10000.	10000.	500000.	100.00	500.00
Low	-1.0000	-5.0000	-2.0000	-5.0000	-30.000	-1.0000	-1.0000

Elem	Mn2576	Mo2020	Na3302	Ni2316	Pb2203	Se1960	Sb2068
Units	ppb	ppb	ppm	ppb	ppb	ppb	ppb
Avge	2540.0	16.788	1.3807	103.15	47.366	-2.4638	.48725
SDev	2.8	.415	.0535	.54	1.621	1.9754	3.5197
%RSD	.10850	2.4703	3.8725	.52222	3.4225	80.176	722.36
#1	2540.7	17.005	1.3612	103.23	45.891	L-4.6521	-3.2744
#2	2542.4	17.049	1.4412	102.57	47.107	-1.9271	1.0357
#3	2537.0	16.310	1.3397	103.64	49.102	-.81225	3.7005
Errors	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass
High	10000.	10000.	100.00	10000.	10000.	10000.	10000.
Low	-3.0000	-5.0000	-1.0000	-5.0000	-3.0000	-3.0000	-10.000

Elem	Sn1899	Ti3349	Tl1908	V_2924	Zn2062	2203/1	2203/2
Units	ppb	ppb	ppb	ppb	ppb	ppb	ppb
Avge	12.215	878.78	1.2339	86.656	187.95	45.586	48.254
SDev	1.804	1.37	.4770	.079	1.74	2.348	1.480
%RSD	14.773	.15620	38.657	.09149	.92534	5.1499	3.0676
#1	10.496	878.15	1.3959	86.648	188.70	42.927	47.369
#2	12.054	880.35	.69703	86.739	189.19	46.456	47.430
#3	14.094	877.83	1.6088	86.581	185.96	47.374	49.963
Errors	LC Pass	LC Pass	LC Pass	LC Pass	LC Pass	NOCHECK	NOCHECK

APPENDIX C

RESIDUAL RISK ASSESSMENT INFORMATION

TECHNICAL MEMORANDUM

RISK EVALUATION OF REMEDIAL ALTERNATIVES

SITE 17 – PETTIBONE CREEK

NAVAL STATION GREAT LAKES GREAT LAKES, ILLINOIS

April 2011

DRAFT

TECHNICAL MEMORANDUM

Risk Evaluation of Remedial Alternatives at Site 17 – Pettibone Creek; Naval Station Great Lakes; Great Lakes, Illinois

PREPARED FOR:	NAVFAC Midwest
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DATE:	19 April 2011

1.0 Objective and Summary

The purpose of this technical memorandum is to complete a human health and ecological risk evaluation of remedial alternatives (RERA) to evaluate the level of risk reduction expected to be achieved by completing the proposed remedial action for Site 17 – Pettibone Creek at Naval Station Great Lakes located in Great Lakes, Illinois.

The proposed action includes excavation of contaminated sediment within the North Branch of Pettibone Creek and Pettibone Creek Proper (hereto referred as Pettibone Creek) to a depth reaching native sediment (approximately 6 inches to 1 foot), and stream restoration/engineering controls to prevent further degradation, erosion and sedimentation in Pettibone Creek and the Boat Basin.

The proposed remedy shall address the following site-specific remedial action objective (RAO):

- Reduce ecological risk associated with: (1) benthic invertebrate exposure to contaminated sediments and (2) exposure of piscivorous birds to contaminated sediment via ingestion of fish and aquatic organisms.

In order to evaluate the efficacy of the proposed action, this RERA will evaluate the risk reduction realized by comparison of the post-action residual risk (represented by chemical concentrations in native sediment) to current levels of risk (represented by chemical concentrations in surface sediment).

1.1 Results Summary

The human health and ecological RERA results are summarized below in Tables 1.1 and 1.2, respectively. More detailed RERA results are discussed in the Section 3.0 and presented in Exhibits 1 and 2.

1.1.1 Human Health RERA

The estimated human health risks associated with exposure to chemicals of potential concern (COPCs) in native sediment from Pettibone Creek for both the adult and adolescent recreational users are either less than or within U.S. Environmental Protection Agency (USEPA) target levels and are less than the risks calculated in the RI-RA HHRA. Therefore, the proposed action will sufficiently accomplish risk reduction.

TABLE 1.1 POTENTIAL HUMAN HEALTH RISK REDUCTION FOR PETTIBONE CREEK

Receptor and Exposure Scenario	RI-RA HHRA		Expected Post-Remediation	
	ILCR	HI	ILCR	HI
Adult Recreational User				
Contact with sediment in the North Branch	8E-06	0.031	4E-07	NA
Ingestion of fish[1]	2E-04	6.6	3E-05	0.8
Adolescent Recreational User				
Contact with sediment in the North Branch	3E-06	0.032	4E-07	NA

RI-RA HHRA – Remedial Investigation Risk Assessment Human Health Risk Assessment
ILCR – Incremental lifetime cancer risk
HI – Hazard index
NA – Not applicable. HIs were not calculated because only potentially carcinogenic chemicals exceeded screening values.
1. In the RI HHRA, it is assumed that there is no recreational fishing in Pettibone Creek. The RI HHRA ingestion of fish scenario is for ingestion of fish caught in the Boat Basin. The post-remediation calculations for this scenario assume that native sediment in the North Branch of Pettibone Creek could be transported to the Boat Basin where fish would be exposed and accumulate concentrations of chemicals.

1.1.2 Ecological RERA

The estimated ecological risks associated with exposure to chemicals of concern (COCs) in native sediment from Pettibone Creek for the benthic invertebrate endpoint and the piscivorous bird endpoint indicate environmental effects quotients (EEQs) will be much less than EEQs calculated in the RI-RA. Therefore, significant risk reduction will be accomplished by implementing the proposed action.

TABLE 1.2 POTENTIAL ECOLOGICAL RISK REDUCTION FOR PETTIBONE CREEK

Receptor	Chemicals of Concern	RI-RA ERA EEQ[1]	Expected Post Remediation EEQ
Benthic invertebrates	PAHs	2.3 to 1,364	0.03 to 2.5
	4,4'-DDT	1800	19
	4,4'-DDE	105	34
	4,4'-DDD	85	9.5
	Endosulfan II	80	NC
	Copper	30	10.5
	Lead	10	3.2
	Mercury	24	0.3
	zinc	18	9.1
Piscivorous Birds	4,4'-DDT	43	1.1
	4,4'-DDE	94	11.7

RI RA ERA – Remedial Investigation-Risk Assessment Ecological Risk Assessment
NC – Not calculated. This chemical was not detected in 2008
1. EEQ – Environmental Effects Quotient calculated by dividing chemical concentration or chronic daily intake by appropriate sediment benchmarks/toxicity reference values. Benthic Invertebrate EEQs calculated using Screening Values from RI Table 7-2 and maximum sediment concentrations. Piscivorous Bird EEQs are calculated using mean sediment concentrations, average inputs, and using the LOAEL.

1.2 Conclusions

The results of the human health RERA indicate that risks associated with exposure to COPCs in native sediment from the North Branch of Pettibone Creek for both adult and adolescent recreational users are either less than or within USEPA target levels and have been reduced from the risks calculated in the RI-RA HHRA.

The results of the ecological RERA indicate that risks associated with exposure to COCs in native sediment from the North Branch of Pettibone Creek for both the benthic invertebrate endpoint and the piscivorous bird endpoint are significantly less than risks calculated in the RI-RA for the current surface sediment.

Therefore, the proposed action will result in site wide risk reduction.

1.3 Report Organization

This Technical Memorandum is organized as follows:

Section 2.0 presents a description of the site, brief site history and the Conceptual Site Model (CSM; 2.1).

Section 3.0 presents the human health and ecological Risk Evaluation of Remedial Alternatives (RERA) including Data Analysis (3.1), Exposure Assessment (3.2), Toxicity Assessment (3.3), and Risk Characterization (3.4). The RERA presents the human health and ecological risk evaluation of sediments remaining assuming the proposed remedy removes Pettibone Creek sediment to a depth reaching native material.

Section 4.0 presents the conclusions of the human health and ecological RERA.

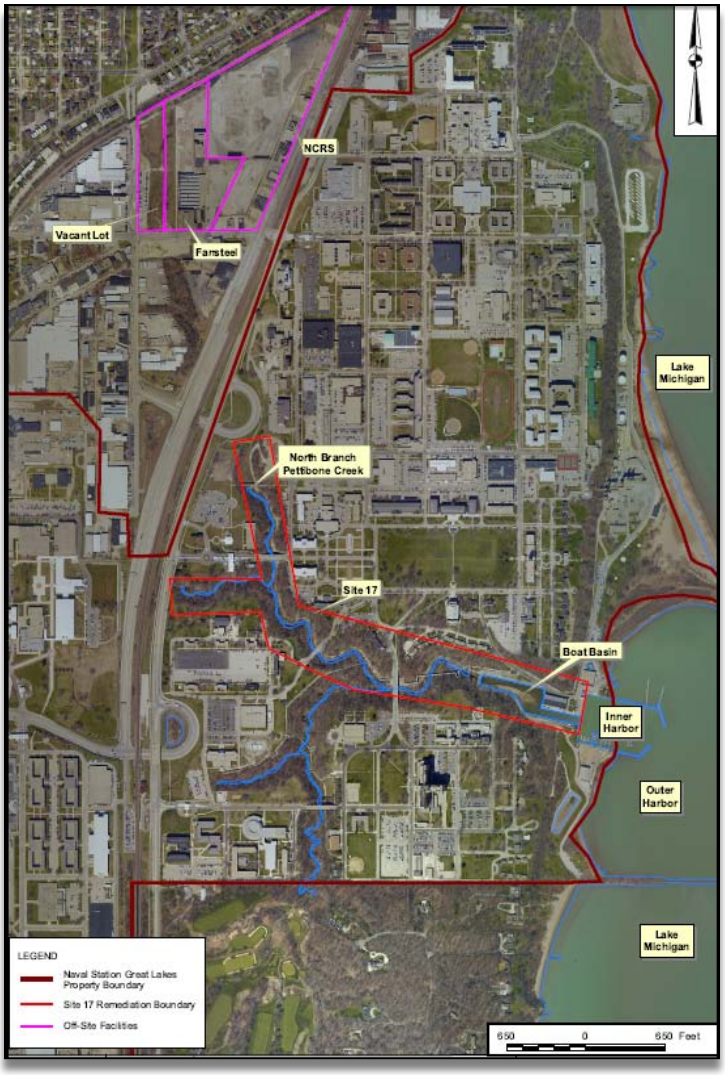
Section 5.0 presents the references cited in this Technical Memorandum.

Exhibits 1 and 2 present detailed RERA results.

Attachments 1 and 2 provide supporting information for the human health and ecological risk assessments respectively.

2.0 Site Description

FIGURE 2.1 NAVAL STATION GREAT LAKES AND SITE 17 SITE MAP



Naval Station Great Lakes covers 1,632 acres of Lake County, which is located in northeastern Illinois, north of the City of Chicago along the western shore of Lake Michigan. The Naval Station fronts 1.5 miles of Lake Michigan shoreline, and since 1911 has provided facilities and support to training activities and a variety of military commands and includes the Navy's only boot camp (See Figure 2.1). A variety of land uses currently surround Naval Station Great Lakes, including urbanized and industrial areas to the north, industrial use to the west, and a mixture of public use land and residential neighborhoods to the south.

During an IAS performed in 1986, the Navy identified 14 potentially contaminated areas where hazardous material may have been released in the environment at the Naval Station (Rogers, Golden, & Halpern and BCM Eastern Inc., 1996). In addition, many sampling events have been conducted since the 1970s within the industrialized (non-Navy property) areas upstream of Naval Station Great Lakes. To investigate these areas within and upstream of the Naval Station, the Navy developed a team of representatives from the Illinois Environmental Protection Agency (Illinois EPA), Naval Facilities Engineering Command Southeast and its consultant Tetra Tech, and the Naval Station Great Lakes Environmental Department. The investigations were conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986, and its governing regulations, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300, and the National Environmental Policy Act (NEPA).

Site 17 consists of the North and South Branches of Pettibone Creek, Pettibone Creek proper and the Boat Basin (see Figure 2.2).

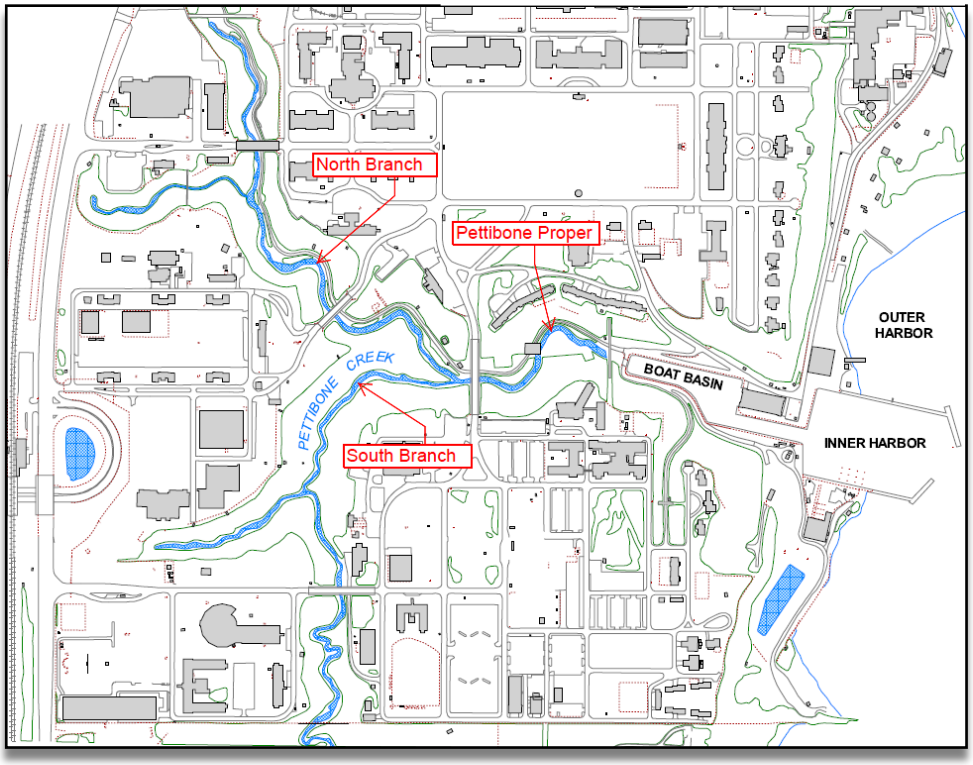
The North Branch originates in the City of North Chicago near Commonwealth Avenue, flows south under Martin Luther King Jr. Drive and a parking area, resurfaces north of Sheridan Road, flows below Sheridan Road, resurfaces on Naval Station Great Lakes property, and flows south and east through Naval Station Great Lakes until it enters the Boat Basin and then discharges to Lake Michigan.

The Boat Basin is approximately 850 feet long and measures approximately 100 feet wide near the discharge of Pettibone Creek, 225 feet in the center, and 60 feet as it empties into Lake Michigan. The water depth in the Boat Basin ranges from several inches to 5 feet. Boats are docked at the opening of the Boat Basin near the Inner Harbor. Because of sedimentation, the Boat Basin has become too shallow for vessels to dock. Intermittent (or occasional) recreational fishing occurs in the Boat Basin, depending upon water depth and conditions.

The South Branch originates in a residential area southwest of Naval Station Great Lakes, flows northward through the Shore Acres Golf Course Country Club, and enters Naval Station Great Lakes near the intersection of G Street and 3rd Street. Flow continues northward on Naval Station Great Lakes property where it joins with flow from the North Branch.

This technical memorandum focuses on the North Branch of Pettibone Creek and Pettibone Creek Proper [hereto known as Pettibone Creek]. The South Branch of Pettibone Creek has been eliminated as an area of concern and may be indicative of background locations (TTNUS, 2005). The Boat Basin is being handled separately by an installation Operations and Maintenance sediment removal action.

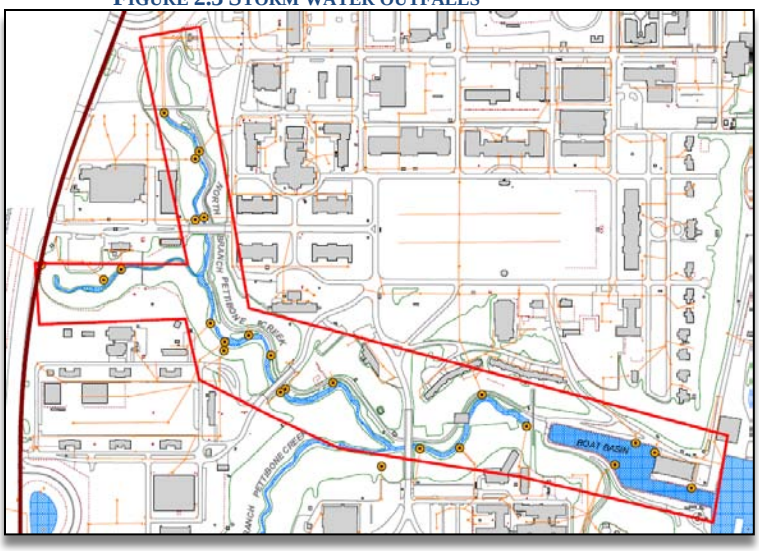
FIGURE 2.2 SITE 17 LOCATION MAP



2.1 Conceptual Site Model (CSM)

The North Branch of Pettibone Creek ranges between 15 and 30 feet in width and several inches to 2 feet in depth. It receives storm water inputs from a large section of the City of North Chicago and from Naval Station Great Lakes. Because of the industrial and urban nature of this watershed, Pettibone Creek is subject to flash flooding and associated erosive forces during storm events. As a result, Pettibone Creek has severe erosion and sedimentation problems. Figure 2.3 presents Pettibone Creek within the limits of Naval Station Great Lakes property along with storm drain locations that discharge to Pettibone Creek.

FIGURE 2.3 STORM WATER OUTFALLS

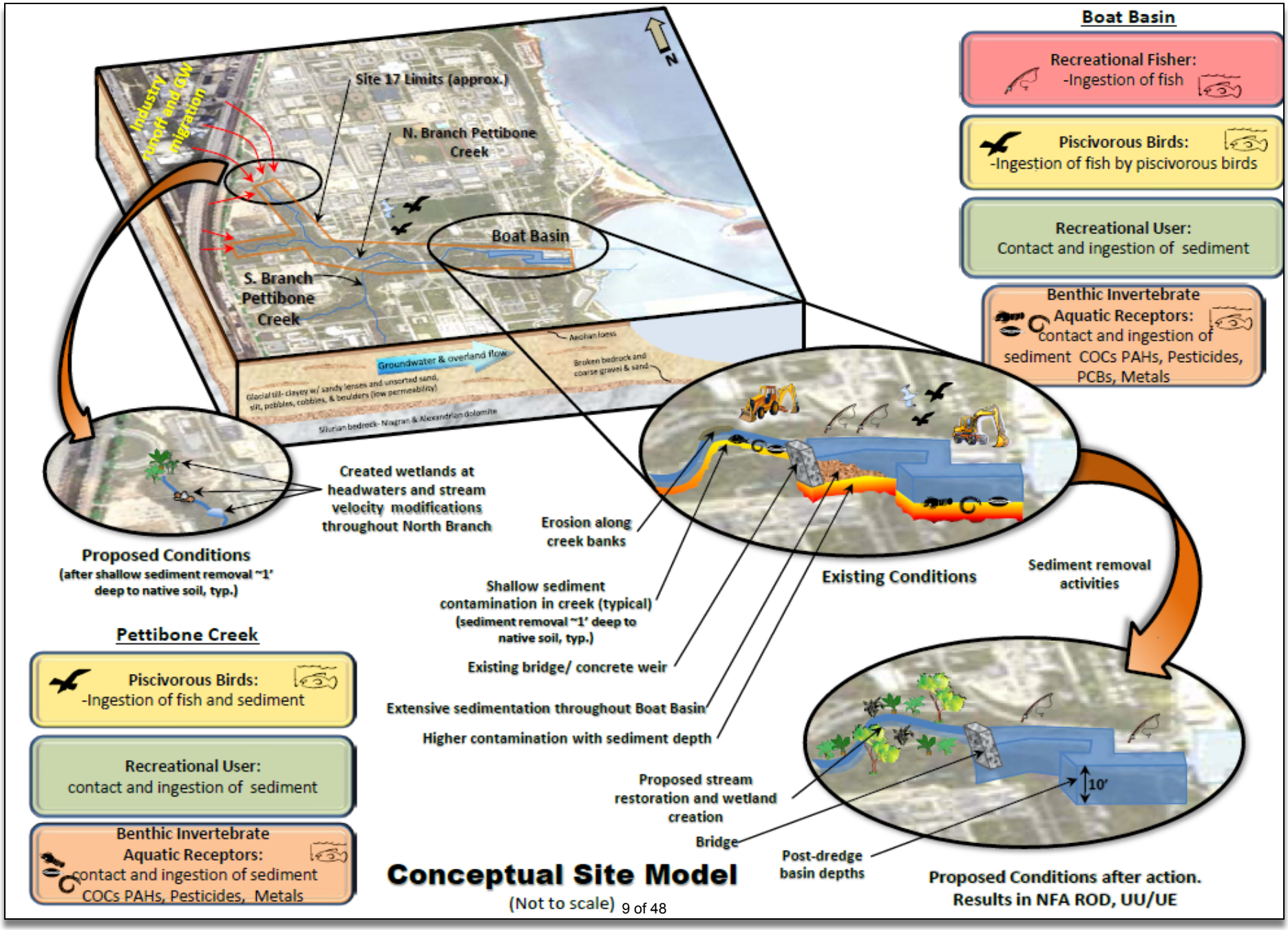


Pettibone Creek is a stream that collects runoff from urban and industrialized areas both within and adjacent to Naval Station Great Lakes property and has been receiving urban and industrial area storm water runoff since the development of this portion of Lake County. Therefore, early investigations of Site 17 included studies of abandoned industrial facilities in the City of North Chicago located upstream of Naval Station Great Lakes. These facilities [Fansteel, North Chicago Refiners and Smelters (NCRS), and a Vacant Lot] were turn-of-the-century manufacturing facilities that produced tantalum mill products, nonferrous metals, and zinc oxide. The United States Environmental Protection Agency (USEPA) Region 5 investigated these facilities for volatile organic compound (VOC), semivolatile organic compound (SVOC), pesticide, polychlorinated biphenyl (PCB), and metal contamination. These former industrial areas are identified on Figure 2.1.

The Watershed Contaminated Source Document (WCSD) indicated that non-Navy upstream industrial sources clearly appear to be the primary sources of the environmental contaminants (PAHs, pesticides, PCBs, and metals) detected in the sediments of Site 17 (TTNUS, 2003a). Predominant metal contaminants in the Site 17 sediments (e.g., copper, lead, and zinc) were also identified as significant environmental contaminants in sediment samples collected upstream and offsite of Site 17 during past environmental investigations. Consequently, the industrial sources upstream of Site 17 have contributed to the contaminant load detected in the Pettibone Creek Watershed. Various transport and release mechanisms including (e.g. overland run-off, erosion, storm water outfall and culvert conveyances) serve as the primary pathway for non-Navy contamination and other anthropogenic chemicals to reach Pettibone Creek. Storm water discharges and overland run-off from Naval Station, Great Lakes to Site 17 may have contributed pollutants to the watershed, but analytical results do not suggest that a significant point source(s) from Naval Station, Great Lakes is(are) impacting the sediment quality of Pettibone Creek or the Boat Basin (TTNUS, 2003a). Current sources, transport and release mechanisms, and exposure pathways are presented on Figure 2.4. Figure 2.4 also illustrates the change in the CSM based on implementation of the proposed action.

Due to the contamination found upstream of Naval Station Great Lakes and the types of industrial activities performed on Naval Station Great Lakes property, future associated activities and actions will be performed in accordance the CERCLA program, ultimately resulting in a No Further Action (NFA) Record of Decision (ROD).

Figure 2.4 Site 17 Conceptual Site Model - Existing and Proposed Conditions



3.0 Risk Evaluation of Remedial Alternative (RERA)

This technical memorandum presents a RERA assuming that sediment from the North Branch of Pettibone Creek is excavated down to the native sediment and future recreational users and ecological receptors would be exposed to chemicals in the native sediment.

A Remedial Investigation and Risk Assessment (RI-RA) was performed for the site, which included a baseline human health risk assessment (HHRA) and ecological risk assessment (ERA) (Tetra Tech, 2003b).

The HHRA concluded that there were no significant potential health hazards associated with exposure to COPCs in surface water and surface sediment under the recreational land use scenarios. This RERA presents the risk calculation results for direct exposure to native sediment in the North Branch of Pettibone Creek to ensure the post-remediation conditions are still protective of human health.

The ERA concluded that concentrations of PAHs, pesticides, and metals pose a potential unacceptable risk to benthic invertebrates and 2 pesticides pose a potential unacceptable risk to piscivorous birds exposed to chemicals in the North Branch of Pettibone Creek.

Subsequently, a Remedial Action Plan (RAP) was prepared which included the excavation and offsite disposal of contaminated sediment, to a depth reaching native sediment, located within the North Branch of Pettibone Creek (Tetra Tech, 2009). The RAP also included an analysis of native sediment in the North Branch of Pettibone Creek, to determine what the post-remediation conditions would be like in the North Branch.

Table 3.1 summarizes the previous investigations that were used to support this assessment.

TABLE 3.1 SUMMARY OF PREVIOUS INVESTIGATIONS

Previous Study/Investigation	Date	Investigation Activities
Remedial Investigation and Risk Assessment Report	2003	38 shallow sediment samples and 14 deep sediment samples were collected from Pettibone Creek and sampled for metals, PAHs, PCBs, and total organic carbon (10% were analyzed for VOCs and SVOCs). 6 surface water samples were collected and analyzed for VOCs, SVOCs, pesticides, PCBs, and metals. PAHs, pesticides, PCBs, and metals detected in sediment samples; VOCs and metals detected in surface water samples.
Watershed Contaminated Source Document	2003	Documented non-Navy, upstream sources of contamination to Pettibone Creek.
Feasibility Study	2005	Developed PRGs, identified RAOs and developed/evaluated remedial alternatives
DRAFT Remedial Action Plan	2009	Determine whether the contamination detected in sediment extends to underlying native stream bed soil and to determine the sediment layer thickness at each sampling location.

In order to make the results of this RERA comparable to the HHRA and ERA presented within the RI-RA (Tetra Tech, 2003b), many of the assumptions made in the RI-RA were also used in this assessment. However, one exception was that updated information was used in the human health RERA for screening levels, toxicity values, assessment of chemicals that are assumed to be carcinogenic via a mutagenic mode of action, and for deriving exposure point concentrations (EPCs), in order to reflect the current state of the science. These differences, and the potential impact that they have on the evaluation, are discussed in more detail below.

3.1 Data Analysis

The data used for this analysis were collected in December 2008 from the North Branch of Pettibone Creek. The December 2008 sampling event was performed to determine whether the contamination detected in sediment extended to the native stream sediment and to determine the sediment layer thickness at each sampling location (Tetra Tech, 2009).

Table 3.2 presents the native sediment data initially presented in the RAP (Tetra Tech, 2009) and used in this assessment. Figure 3.1 presents the native sediment data results for a select number of COCs.

The data collected in December 2008 were categorized by the Navy and Illinois EPA to be representative of native stream sediment throughout the North Branch of Pettibone Creek. As such, these data were used to assess both direct contact with sediment in the creek and ingestion of fish as part of this RERA.

FIGURE 3.1 2008 NATIVE SEDIMENT INVESTIGATION LOCATIONS AND RESULTS

TABLE 3.2 2008 NATIVE SEDIMENT DATA

Sample Number	NTC17PCSD49	NTC17PCSD48	NTC17PCSD47	NTC17PCSD46	NTC17PCSD45
Sample Date	12/9/2008	12/9/2008	12/9/2008	12/9/2008	12/9/2008
Sediment/Soil description	Native Soil - Brown CLAY with silt/sand	Native Soil - Gray CLAY little silt t-sand	Native Soil - Gray Silty CLAY	Native Soil - Gray CLAY little silt, sand, gravel	Native Soil - Gray CLAY little silt
Sample Interval (in ft bgs)	0.75-1.25	2.5-3.0	2.0-2.5	1.0-1.5	0.25-0.75
Semivolatile Organics (µg/kg)					
2-Methylnaphthalene	3.3 J	7.6	20	5.1	7.5
Acenaphthene	1.9 J	4.8	3.8 U	3.8 U	3.9 U
Anthracene	7.8	20	3.8 U	3.8 U	3.9 U
Benzo(a)anthracene	37	33	3.8 U	3.8 U	3.9 U
Benzo(a)pyrene	37	24	3.8 U	3.8 U	3.9 U
Benzo(b)fluoranthene	34	20	3.8 U	3.8 U	3.9 U
Benzo(g,h,i)perylene	21	12	3.2 J	4.4	3.8 J
Benzo(k)fluoranthene	10	6.4	3.8 U	3.8 U	3.9 U
Chrysene	39	29	3.8 U	3.8 U	3.9 U
Dibenz(a,h)anthracene	4.2 J	4 U	3.8 U	3.8 U	3.9 U
Fluoranthene	82	69	5.7	3.8 U	7.6
Fluorene	2.8 J	9.7	3.8 U	3.8 U	3.9 U
Indeno(1,2,3-cd)pyrene	17	4 U	3.8 U	3.8 U	3.9 U
Naphthalene	4.4 U	4 U	6.2	3.8 U	3.9 U
Phenanthrene	52	78	24	16	18
Pyrene	68	59	3.8 U	3.8 U	7.7
Total PAHs	417	372.5	59.1	25.5	44.6
Pesticides/PCBs (µg/kg)					
4,4'-DDD	19 J	3.8 J	0.76 UJ	0.76 UJ	0.78 UJ
4,4'-DDE	68 J	1.2 J	0.76 UJ	0.76 UJ	0.78 UJ
4,4'-DDT	19 J	1.4 J	0.76 UJ	0.76 UJ	0.78 UJ
Total DDT	106	6.4	0.76 U	0.76 U	0.78 U
Aroclor-1254	22 UJ	20 UJ	19 UJ	19 UJ	20 UJ
Aroclor-1260	22 UJ	7.2 J	19 UJ	19 UJ	20 UJ
Endrin	2 J	0.8 UJ	0.76 UJ	0.76 UJ	0.78 UJ
Gamma-BHC (Lindane)	0.44 UJ	0.4 UJ	0.38 UJ	0.38 UJ	0.39 UJ
Endosulfan I	0.44 UJ	0.4 UJ	0.38 UJ	0.38 UJ	0.39 UJ
Endosulfan II	0.89 UJ	0.8 UJ	0.76 UJ	0.76 UJ	0.78 UJ
Total Aroclor (Detected)	NC	7.2	19 U	19 U	20 U
Inorganics (mg/kg)					
Copper	31.4	167	22.6	19.4	53.5
Lead	36.6	103	11.2	9.6	24
Mercury	0.017 U	0.018	0.015 U	0.014 U	0.015 U
Zinc	97.3	1070	51	43.9	230

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Sample Number	NTC17PCSD44	NTC17PCSD43	NTC17PCSD42	NTC17PCSD41	NTC17PCSD40
Sample Date	12/9/2008	12/9/2008	12/9/2008	12/8/2008	12/8/2008
Sediment/Soil description	Native Soil - Brown SAND/SILT/CLAY	Native Soil - Gray CLAY little silt	Native Soil - Brown SAND/SILT/CLAY	Native Soil - Gray SILT little clay/sand	Native Soil - Gray SILT little clay/sand
Sample Interval (in ft bgs)	0.25-0.75	1.0-1.5	0.25-0.75	0.5-1.0	1.0-1.5
Semivolatile Organics (µg/kg)					
2-Methylnaphthalene	5	4.2	7.2	2.3 J	4 U
Acenaphthene	11	3.5 J	11	4 U	4 U
Anthracene	66	12	71	3 J	4 U
Benzo(a)anthracene	260	67	220	4 U	4 U
Benzo(a)pyrene	180	62	200	4 U	4 U
Benzo(b)fluoranthene	200 J	74	240	4 U	4 U
Benzo(g,h,i)perylene	100	38	120	5.5	1.8 J
Benzo(k)fluoranthene	58	20	64	4 U	4 U
Chrysene	200 J	56	170	4 U	4 U
Dibenz(a,h)anthracene	26	8.1	27 J	4 U	4 U
Fluoranthene	620 J	150	550	9.3	3.1 J
Fluorene	19	6.3	18	2.9 J	4 U
Indeno(1,2,3-cd)pyrene	88	30	100	4 U	4 U
Naphthalene	4.8	4.1 U	6.5	4 U	4 U
Phenanthrene	320 J	110	310	18	3.9 J
Pyrene	460 J	130	440	4 U	4.4
Total PAHs	2617.8	771.1	2554.7	41	13.2
Pesticides/PCBs (µg/kg)					
4,4'-DDD	2.1 J	0.83 UJ	2.4 J	13 J	6.1 J
4,4'-DDE	14 J	0.83 UJ	8.4 J	7.4 J	0.92 J
4,4'-DDT	13 J	0.83 UJ	5 J	3.9 J	0.79 UJ
Total DDT	29.1	0 U	15.8	24.3	7.02
Aroclor-1254	21 UJ	21 UJ	21 UJ	20 UJ	20 UJ
Aroclor-1260	21 UJ	21 UJ	21 UJ	20 UJ	20 UJ
Endrin	1.5 J	0.83 UJ	0.84 UJ	0.8 UJ	0.79 UJ
Gamma-BHC (Lindane)	0.25 J	0.41 UJ	0.42 UJ	0.4 UJ	0.4 UJ
Endosulfan I	0.42 UJ	0.41 UJ	0.42 UJ	0.4 UJ	0.4 UJ
Endosulfan II	0.27 U	0.83 UJ	0.84 UJ	0.8 UJ	0.79 UJ
Total Aroclor (Detected)	21 U	21 U	21 U	20 U	NC
Inorganics (mg/kg)					
Copper	32.1	22	18.1	23.9	16.3
Lead	20.6	9.9	33.6	11.4	8.9
Mercury	0.038	0.023	0.061	0.028	0.016 U
Zinc	81.3 J	44.3 J	99.3 J	45.3	43.2

J - Estimated concentration; U - Analyte not detected; NC - Value not calculated

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Since fish tissue has not been collected to support either the RI or this RERA, the chemical concentrations in fish tissue were estimated assuming a direct relationship between chemical concentrations in sediment and fish tissue. The fish tissue concentrations were estimated from the native sediment data using biota-sediment accumulation factors (BSAFs) using the following equation:

$$C_{fish} = \left(\frac{f_{lipid} \times BSAF}{\frac{f_{oc}}{C_{sed}}} \right)$$

Where:

C_{fish} = Chemical concentration in fish tissue; see Attachment 1, Table 2.2 (mg/kg)

f_{lipid} = Percent lipid in fish tissue; 3.56% North Branch

BSAF = Biota-sediment accumulation factor; chemical-specific values in Table 3.3 (unitless)

f_{oc} = Percent organic carbon in sediment; 0.642% for Boat Basin (unitless), 0.39% North Branch

C_{sed} = Chemical concentration in sediment; see Attachment 1, Table 2.1 (mg/kg)

The values shown above for the percent lipid in fish (3.56%) and fraction of organic carbon in sediment (0.642% for Boat Basin and 0.39% for the North Branch) were obtained from the RI (Tetra Tech, 2003b). The value used for fraction of organic carbon in sediment for the human health RERA was for the Boat Basin. The value used for fraction organic carbon in sediment for the ecological RERA was from the North Branch. Note that organic carbon information was not available for the 2008 analysis of native sediment in the North Branch of Pettibone Creek.

Table 3.3 presents the biota-sediment accumulation factors (BSAFs) that were used for this assessment, which were obtained from the RI so that the estimated uptake would be comparable with the RI (Tetra Tech, 2003b). As explained in the RI, this is a conservative way to estimate fish tissue concentrations and likely overestimates what fish tissue concentrations would be expected for fish living in areas with these sediment concentrations.

TABLE 3.3 BIOTA-SEDIMENT ACCUMULATION FACTORS

Chemical	BSAF	Chemical	BSAF
Acenaphthene	0.29	Phenanthrene	0.29
Anthracene	0.29	Pyrene	0.29
Benzo(a)anthracene	0.29	4,4'-DDD	0.28
Benzo(a)pyrene	0.29	4,4'-DDE	7.7
Benzo(b)fluoranthene	0.29	4,4'-DDT	1.67
Benzo(g,h,i)perylene	0.29	Aroclor-1254	1.85
Benzo(k)fluoranthene	0.29	Aroclor-1260	1.85
Chrysene	0.29	Endrin	1.8
Dibenz(a,h)anthracene	0.29	Gamma-BHC (Lindane)	1.8
Fluoranthene	0.29	Endosulfan I	1.8
Fluorene	0.29	Endosulfan II	1.8
Indeno(1,2,3-cd)pyrene	0.29	Copper	1
2-Methylnaphthalene	0.29	Lead	1
Naphthalene	0.29	Mercury	1
Phenanthrene	0.29	Zinc	1

Since native sediment in the Boat Basin was not characterized, this analysis assumed that the native sediment from the North Branch of Pettibone Creek is comparable to the native sediment in the Boat Basin.

For the human health RERA, Attachment 1, Tables 2.1 (sediment) and 2.2 (fish tissue) present the COPC selection process for this analysis. The most current version of the USEPA Regional Screening Level (RSL) table was used to select COPCs for this assessment (USEPA, 2010a). Since the RSL table does not include RSLs for fish tissue, the

USEPA RSL online calculator was used to estimate fish tissue RSLs (online at: http://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search). The default exposure assumptions were used to calculate the fish tissue RSLs. The calculated values are shown in Attachment 1, Table 2.2.

For the ecological RERA, the COPC selection process was not completed for this evaluation because the RI-RA and RAP clearly identified Chemicals of Concern (COCs) for the ecological endpoints. The ecological RERA focuses only on those chemicals indentified as COCs in the RAP (Tetra Tech, 2009).

3.2 Exposure Assessment

3.2.1 Human Health RERA

The EPCs for sediment and fish tissue are shown in Attachment 1, Tables 3.1 and 3.2, respectively. The EPCs for this evaluation were calculated in accordance with current EPA guidance (USEPA, 2002; 2010b). ProUCL Version 4.00.05 was used to determine the appropriate upper confidence limits of the mean (UCLs) to use for the EPCs (USEPA, 2010b). The only COPC that did not use a ProUCL-recommended UCL as the EPC was Aroclor-1260 in fish tissue. This is because Aroclor-1260 was only detected in one out of ten native sediment samples. Given this low detection frequency, ProUCL determined that there was insufficient data to estimate a UCL. Therefore, for Aroclor-1260 in fish tissue, the single detection (0.0072 mg/kg) was used to calculate the fish tissue EPC. Similar to the COPC selection process, the concentrations of COPCs in fish tissue were estimated from the sediment concentrations using BSAFs.

In order to make the results of these HHRA calculations comparable to the RI HHRA (Tetra Tech, 2003b) the same exposure scenarios and exposure factors were used in this assessment. It was assumed that future adult and adolescent recreational users could come into direct contact with native sediment in the North Branch of Pettibone Creek since access to the area is not restricted. It was assumed that these potential receptors could be exposed to COPCs in sediment through incidental ingestion and dermal contact. Although some fish may be present in the North Branch of Pettibone Creek, it does not support a significant fish population (TTNUS2003a). As such the recreators at the North Branch of Pettibone Creek are not assumed to regularly consume locally caught fish. Consistent with the RI-RA, it was assumed that future adult recreational users could fish in the Boat Basin, and thus be exposed to sediment COPCs that have been taken up by the sport fish that the recreators consume on a regular basis. Since the proposed remedial action involves dredging to native sediment, it was assumed that the native sediment from the North Branch of Pettibone Creek could be transported to the Boat Basin. Although the recreational fishing scenario is assumed to occur in the Boat Basin, the risk calculations assume that the fish being caught and eaten from the Boat Basin are exposed to native sediment from the North Branch of Pettibone Creek. Since the Boat Basin received sediment and runoff from other sources, the recreational fishing scenario is not intended to reflect exposure and thus risk for the Boat Basin itself; just to the potential post-remediation inputs from the North Branch of Pettibone Creek. Attachment 1, Tables 4.1 and 4.2 summarizes the specific exposure parameters used in the RI HHRA and this RERA.

3.2.2 Ecological RERA

The focus of the ecological RERA will be on the COCs indentified for the North Branch of Pettibone Creek in the 2009 RAP and on the assessment and measurement endpoints identified as having unacceptable site-related risk in the RI-RA (summarized in Table 3.4). The assessment and measurement endpoints and surrogate receptor are presented in the table below. Attachment 2, Table 1 presents the assessment endpoints, measurement endpoints, and the COCs identified in the RAP.

TABLE 3.4 SELECTED ASSESSMENT AND MEASUREMENT ENDPOINTS AND RECEPTOR SPECIES FOR ECOLOGICAL RERA

Assessment Endpoint	Measurement Endpoint	Receptor
Protection of the benthic invertebrate community	Mortality and other adverse effects (i.e., those on growth, feeding rates, and behavior) to benthic invertebrates were evaluated by comparing the measured concentrations of chemicals in the sediment to screening values designed to be protective of ecological receptors	Benthic invertebrates
Protection of piscivorous bird community	Survival, reproductive, and/or developmental effects to piscivorous birds were evaluated by comparing the ingested dose from contaminants in the surface water, sediment, and fish to NOAELs and LOAELs	Belted kingfisher

To ensure comparability with the 2003 RI-RA, the maximum detected concentration from the 2008 native sediment data was used as the exposure point concentration for the benthic invertebrate endpoint. Similarly, the mean concentration of the 2008 native sediment data was used as the exposure point concentration for the piscivorous bird endpoint to ensure comparability. Also, the same exposure assumptions used in the food chain model in the RI-RA were also used in this evaluation.

3.3 Toxicity Assessment

3.3.1 Human Health RERA

Attachment 1, Tables 5.1 and 6.1 summarize the toxicity values that were used in this assessment.

With the exception of dibenz (a,h)anthracene, the COPCs selected for this RERA were also selected as COPCs for the RI HHRA (Tetra Tech, 2003b). The toxicity values used in the RI HHRA are still considered current for the COPCs; that is, the same toxicity values were used in both the RI HHRA and this reassessment.

3.3.1.1 Evaluation of lead

The traditional risk assessment approach for evaluating noncancer effects and carcinogenic risk from exposure to chemicals involves comparison of chemical intakes to a toxicity value such as a reference dose (RfD) or cancer slope factor. This approach is inappropriate for lead because the USEPA has not established these toxicity values for lead. Blood-lead concentrations are accepted as the preferred measure of cumulative lead exposures. A blood lead level of 10 µg/dL has been identified by the Centers for Disease Control and Prevention as a level of concern in children (CDC, 2005). The USEPA recommends limiting a child's exposure to lead in soil such that there is no more than a five

percent probability of a child exceeding the 10 µg/dL blood lead level of concern (USEPA, 1994; 1998).

Guidance from the USEPA recommends 400 mg/kg as the screening level for lead-contaminated soil in a residential setting, where children are frequently present (USEPA, 1994; 1998). This value was used to screen lead out as a COPC in sediment. Applying this screening level to sediments is conservative because the screening level is based on residential exposure to soil by young children (0 to 6 year of age).

At this time, no screening level is available for exposure to lead in fish tissue. Due to the lack of toxicity values for lead, the USEPA RSL calculator does not calculate a fish tissue screening level for lead. As such, the potential health effects associated with ingesting lead from fish tissue was not evaluated in this RERA.

3.3.2 Ecological RERA

The No Observed Adverse Effect Levels (NOAELs) and Lowest Observed Adverse Effect Levels (LOAELs) identified in the RI-RA (TTNUS 2003b) were used as toxicity reference values (TRVs) for this ecological RERA. These TRVs can be found on Attachment 2, Table 4.

3.4 Risk Characterization

3.4.1 Human Health RERA Risk Characterization

The risk characterization combines the selected COPCs, the exposure assessment, and the toxicity assessment to produce a quantitative estimate of potential human health risks associated with exposure to COPCs at a site.

The risk of cancer from chemical exposure is described in terms of the probability that an exposed individual will develop cancer during his/her lifetime from that exposure. The risk estimate is calculated by multiplying the daily intake of a particular COPC over a lifetime by the cancer slope factor. Adverse noncarcinogenic health effects from exposure to a COPC are quantitatively expressed as a hazard quotient (HQ). The HQ is the ratio of a human's estimated intake of a particular chemical to the reference dose (RfD). The HQs from each chemical are summed to a total hazard index (HI) for the receptor. The calculated daily intakes, lifetime cancer risks, and HQs are presented in Attachment 1, Tables 7.1 and 7.2 for the adult and adolescent recreational users, respectively.

3.4.1.1 Adult Recreational User

The carcinogenic risk for future adult recreational user in contact with native sediment from the North Branch of Pettibone Creek (4×10^{-7}) was less than the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}. Since none of the sediment COPCs has noncarcinogenic RfDs, there is no HI calculation for this receptor.

The future adult recreational user's carcinogenic risk from ingestion of fish exposed to North Branch native sediments at the Boat Basin (3×10^{-5}) was within the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}.

The noncarcinogenic HI for future adult recreational user's exposure to COPCs from ingesting fish caught from the Boat Basin (0.8) was less than the USEPA's target HI of one.

3.4.1.2 Adolescent Recreational User

The carcinogenic risk for future adolescent recreational user in contact with native sediment from the North Branch of Pettibone Creek (1×10^{-7}) was less than the USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}.

Since none of the sediment COPCs has noncarcinogenic RfDs, there is no HI calculation for this receptor.

3.4.2 Ecological RERA Risk Characterization

The ecological risk characterization summarizes the risks to potential receptors and interprets the ecological significance of those risks. To accomplish this, risk is estimated by a generating a hazard quotient or EEQ to compare site chemical concentrations to literature values deemed protective of selected toxicity endpoints.

3.4.2.1 Benthic Invertebrate Endpoint

Table 3.2 presents the concentrations of all analyzed chemicals from the 2008 sampling event. As mentioned previously, the focus of the ecological RERA will be on the COCs indentified for the North Branch of Pettibone Creek in the RI-RA (TTNUS, 2003).

In order to evaluate risk reduction and to ensure an accurate comparison to the 2003 RI-RA, the post remediation EEQs were calculated using the screening criteria selected in Table 7-2 of the RI-RA and the maximum concentrations from the 2008 native sediment data.

Potential reduction in risk for the benthic invertebrate endpoint resulting from completion of the proposed remedial action is presented in Attachment 2, Table 2. An abbreviated, summary version is also presented earlier in this document (Table 1.2).

Additionally, concentrations of COCs from the 2008 native sediment data were compared to the preliminary remediation goals (PRGs) developed and approved for use by representatives of the Navy and Illinois EPA in the Feasibility Study (FS) (TTNUS, 2005). This comparison is presented in Attachment 2, Table 3 and summarized in Table 3.5 below. Only two pesticides (DDE and DDT) and two metals (copper and zinc) exceed their respective PRGs. Concentrations of DDE and DDT both exceed the PRGs in sample NTC17PCSD-49 and DDT also exceeds the PRG at sample NTC17PCSD-44. Concentrations of both copper and zinc exceed their respective PRGs at sample NTC17PCSD-48. The low frequency and magnitude of PRG exceedances in the native sediment indicate that there is low potential risk to the populations of benthic invertebrates in Pettibone Creek.

TABLE 3.5 COMPARISON OF 2008 NATIVE SEDIMENT DATA TO BENTHIC INVERTEBRATE PRGS AT PETTIBONE CREEK

Chemicals of Concern	PRGs[1]	Number of Sample Stations Exceeding PRGs	Sample Station Exceeding PRGs	Concentration Exceeding PRGs
Organics (µg/kg)				
PAHs	640-35,000	0	None	None
4,4'-DDD	20	0	None	None
4,4'-DDE	15	1	NTC17PCSD49	68
4,4'-DDT	7	2	NTC17PCSD49 NTC17PCSD44	19 13
Endosulfan II	0.5	0	Not Detected	none
Inorganics (mg/kg)				
Copper	149	1	NTC17PCSD48	167
Lead	128	0	None	
Mercury	1.06	0	None	
Zinc	459	1	NTC17PCSD48	1070

1. PRGs from Table 2-6 of FS (TTNUS, 2005)

These results indicate that risks associated with exposure to COCs in native sediment from the North Branch of Pettibone Creek for the benthic invertebrate endpoint are significantly less than risks associated with current surface sediment. The proposed removal action of surface sediment in the North Branch will result in a desired risk reduction for benthic invertebrates. Furthermore, stream restoration efforts following the removal action will result in habitat improvement over time, allowing accretion of sediment over existing native sediment.

3.4.2.2 Piscivorous Bird Endpoint

Attachment 2, Table 4 presents the concentrations of COCs for the piscivorous bird endpoint, the result of food-web modeling to calculate chronic daily intake (CDI), and the resulting EEQ using both the NOAEL and LOAEL. Only one pesticide (DDT) presents an EEQ greater than 1 associated with exposure to native sediment from the North Branch of Pettibone Creek.

Potential reduction in risk for the piscivorous bird endpoint is presented in Attachment 2, Table 5, assuming that the proposed action is implemented. An abbreviated, summary version is also presented earlier in this document (Table 1.2).

Additionally, mean concentrations of COCs for the piscivorous bird endpoint from the 2008 native sediment data were compared to the preliminary remediation goals (PRGs) developed and approved for use by representatives of the Navy and Illinois EPA in the Feasibility Study (FS) (TTNUS, 2005). This comparison is presented in Attachment 2, Table 6 and summarized in Table 3.6 below. The means for both DDE and DDT from the 2008 native sediment data did not exceed the PRGs. This would indicate that there is no potential for risk to the piscivorous bird endpoint from exposure to native sediment in Pettibone Creek.

TABLE 3.6 COMPARISON OF 2008 NATIVE SEDIMENT TO PISCIVOROUS BIRD PRGS AT PETTIBONE CREEK

Chemicals of Concern	PRGs (µg/kg)	Mean 2008 Native Sediment (µg/kg)
4,4'-DDE	16	10.3
4,4'-DDT	75	4.6

These results indicate that risks associated with exposure to COCs in native sediment from the North Branch of Pettibone Creek for the piscivorous bird endpoint are significantly less than risks associated with current surface sediment. The proposed removal action of surface sediment in the North Branch will result in a desired risk reduction for the piscivorous bird endpoint.

4.0 Conclusions

The results of the human health RERA indicate that risks associated with exposure to COPCs in native sediment from the North Branch of Pettibone Creek for both adult and adolescent recreational users are either less than or within USEPA target levels, indicating that no unacceptable risk exist for these scenarios.

The results of the ecological RERA indicate that risks associated with exposure to COCs in native sediment from the North Branch of Pettibone Creek for both the benthic invertebrate/aquatic receptor endpoint and the piscivorous bird endpoint are significantly less than risks associated with current surface sediment.

Therefore, the proposed action will result in site-wide risk reduction.

5.0 References

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Risk Evaluation of Remedial Alternatives at Site 17 – Pettibone Creek; Naval Station Great Lakes; Great Lakes, Illinois

Exhibits

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Exhibit 1 – Potential Human Health Risk Reduction for Pettibone Creek

Receptor	Media	Pathway	Chemical of Potential Concern	Exposure Point Concentration mg/kg	RI HHRA RME Cancer Risk	RERA RME Cancer Risk	RI HHRA RME Non-Cancer Hazard	RERA RME Non-Cancer Hazard	Cancer Slope Factor (mg/kg-day)$^{-1}$	Non-Cancer Toxicity (RfD) mg/kg-day
Current/Future Adolescent Recreator	Sediment	Ingestion	Benzo(a)anthracene	0.13	6.6E-08	1.4E-08	NA	NA	0.73	NA
			Benzo(a)pyrene	0.10	6.6E-07	1.1E-07	NA	NA	7.3	NA
			Benzo(b)fluoranthene	0.12	6.9E-08	1.3E-08	NA	NA	0.73	NA
			Benzo(k)fluoranthene	0.033	3.8E-09	3.5E-10	NA	NA	0.073	NA
			Chrysene	0.10	NA	1.1E-10	NA	NA	0.0073	NA
			Dibenzo(a,h)anthracene	0.015	NA	1.6E-08	NA	NA	7.3	NA
			Indeno(1,2,3-cd)pyrene	0.054	3.4E-08	5.7E-09	NA	NA	0.73	NA
		Dermal Contact	Benzo(a)anthracene	0.13	8.4E-08	1.8E-08	NA	NA	0.73	NA
			Benzo(a)pyrene	0.10	8.5E-07	1.4E-07	NA	NA	7.3	NA
			Benzo(b)fluoranthene	0.12	8.8E-08	1.6E-08	NA	NA	0.73	NA
			Benzo(k)fluoranthene	0.033	4.9R-09	4.5E-10	NA	NA	0.073	NA
			Chrysene	0.10	NA	1.4E-10	NA	NA	0.0073	NA
			Dibenzo(a,h)anthracene	0.015	NA	2.0E-08	NA	NA	7.3	NA
			Indeno(1,2,3-cd)pyrene	0.054	4.3E-08	7.3E-09	NA	NA	0.73	NA
Current/Future Adult Recreator	Sediment	Ingestion	Benzo(a)anthracene	0.13	9.5E-08	6.7E-09	NA	NA	0.73	NA
			Benzo(a)pyrene	0.10	9.5E-07	5.3E-08	NA	NA	7.3	NA
			Benzo(b)fluoranthene	0.12	9.9E-08	6.0E-09	NA	NA	0.73	NA
			Benzo(k)fluoranthene	0.033	5.5E-09	1.7E-10	NA	NA	0.073	NA
			Chrysene	0.10	NA	5.3E-11	NA	NA	0.0073	NA
			Dibenzo(a,h)anthracene	0.015	NA	7.6E-09	NA	NA	7.3	NA

Receptor	Media	Pathway	Chemical of Potential Concern	Exposure Point Concentration mg/kg	RI HHRA RME Cancer Risk	RERA RME Cancer Risk	RI HHRA RME Non-Cancer Hazard	RERA RME Non-Cancer Hazard	Cancer Slope Factor (mg/kg-day)$^{-1}$	Non-Cancer Toxicity (RfD) mg/kg-day
Current/Future Adult Recreator (continued)	Sediment (continued)	Ingestion (continued)	Indeno(1,2,3-cd)pyrene	0.054	4.9E-08	2.8E-09	NA	NA	0.73	NA
		Dermal Contact	Benzo(a)anthracene	0.13	3.4E-07	2.4E-08	NA	NA	0.73	NA
			Benzo(a)pyrene	0.10	3.4E-06	1.9E-07	NA	NA	7.3	NA
			Benzo(b)fluoranthene	0.12	3.6E-07	2.2E-08	NA	NA	0.73	NA
			Benzo(k)fluoranthene	0.033	2.0E-08	6.0E-10	NA	NA	0.073	NA
			Chrysene	0.10	NA	1.9E-10	NA	NA	0.0073	NA
			Dibenzo(a,h)anthracene	0.015	NA	2.7E-08	NA	NA	7.3	NA
			Indeno(1,2,3-cd)pyrene	0.054	1.7E-07	9.9E-09	NA	NA	0.73	NA
	Fish Tissue	Ingestion	Benzo(a)anthracene	0.21	NC	1.9E-06	NA	NA	0.73	NA
			Benzo(a)pyrene	0.17	NC	1.5E-05	NA	NA	7.3	NA
			Benzo(b)fluoranthene	0.19	NC	1.7E-06	NA	NA	0.73	NA
			Benzo(k)fluoranthene	0.053	NC	4.7E-08	NA	NA	0.073	NA
			Chrysene	0.17	NC	1.5E-08	NA	NA	0.0073	NA
			Dibenzo(a,h)anthracene	0.024	NC	2.1E-06	NA	NA	7.3	NA
			Indeno(1,2,3-cd)pyrene	0.087	NC	7.8E-07	NA	NA	0.73	NA
			4,4'-DDD	0.014	7.0E-07	4.1E-08	NA	NA	0.24	NA
			4,4'-DDE	1.1	2.0E-05	4.4E-06	NA	NA	0.34	NA
			4,4'-DDT	0.081	3.4E-06	3.4E-07	0.047	0.0046	0.34	0.0005
			Aroclor-1260	0.074	2.7E-05	1.8E-06	NA	NA	2.0	NA

Receptor	Media	Pathway	Chemical of Potential Concern	Exposure Point Concentration mg/kg	RI HHRA RME Cancer Risk	RERA RME Cancer Risk	RI HHRA RME Non-Cancer Hazard	RERA RME Non-Cancer Hazard	Cancer Slope Factor (mg/kg-day)$^{-1}$	Non-Cancer Toxicity (RfD) mg/kg-day
Current/Future Adult Recreator (continued)	Fish Tissue (continued)	Ingestion (continued)	Copper	574	NA	NA	0.056	0.41	NA	0.04
			Lead	257	NA	NA	NA	NA	NA	NA
			Mercury	0.19	NA	NA	0.011	0.055	NA	0.0001
			Zinc	3429	NA	NA	0.054	0.33	NA	0.3

Exhibit 2a – Potential Ecological Risk Reduction for the Benthic Invertebrate Endpoint for Pettibone Creek

Endpoint/Receptor	Chemicals of Concern	RI-RA Maximum sediment concentration (µg/kg)	RI-RA EEQ	Native Sediment Maximum concentration (µg/kg)	Native Sediment EEQ
Benthic Invertebrates and Aquatic Organisms	Anthracene	4000	47	71	0.8
	Benzo(a)anthracene	11000	38	260	0.9
	Benzo(a)pyrene	11000	151	180	2.5
	Benzo(b)fluoranthene	12000	14	240	0.3
	Benzo(g,h,i)perylene	7500	44	120	0.7
	Chrysene	12000	30	200	0.5
	Fluoranthene	33000	11.8	620	0.2
	Fluorene	2400	69	19	0.5
	Indeno(1,2,3-cd)pyrene	5800	2.3	100	0.03
	Phenanthrene	24000	30	320	0.4
	Pyrene	27000	77	460	1.3
	4,4'DDT	1800	1800	19	19
	4,4'-DDE	210	105	68	34
	4,4'-DDD	170	85	19	9.5
	Endosulfan II	12	80	0.89	NC
	Copper (mg/kg)	477	30	167	10.5
	Lead (mg/kg	322	10	103	3.2
	Mercury (mg/kg	4.7	24	0.061	0.31
	Zinc (mg/kg)	2120	18	1070	9.1

Exhibit 2b – Potential Ecological Risk Reduction for the Piscivorous Bird Endpoint for Pettibone Creek

Receptor	Chemicals of Concern	RI-RA mean sediment concentration (mg/kg)	RI-RA Sediment EEQ	Native Sediment mean concentration (mg/kg)	Native Sediment EEQ
Piscivorous Birds	4,4'DDT	1.74E-001	43	4.62E-03	1
	4,4'-DDE	8.29E-02	94	1.03E-02	12

Risk Evaluation of Remedial Alternatives at Site 17 – Pettibone Creek, Naval Station Great Lakes, Great Lakes, Illinois

Attachment 1

TABLE 1

SELECTION OF EXPOSURE PATHWAYS

Site 17 - Naval Station Great Lakes HHRA RERA Technical Memorandum

Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Sediment	Sediment	North Branch of Pettibone Creek Sediment	Recreational Users	Adult	Ingestion	Quant	Access to the study area is not limited by any physical constraints. Potential receptors may be exposed to COPCs in sediment while wading
					Dermal	Quant	
				Adolescent	Ingestion	Quant	Access to the study area is not limited by any physical constraints. Potential receptors may be exposed to COPCs in sediment while wading
					Dermal	Quant	
	Fish Tissue	Boat Basin	Recreational Users	Adult	Ingestion	Quant	Fishing is known to occur in the Boat Basin. Potential receptors may be exposed by eating fish caught at the site.

Table 2.1

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Point	CAS Number	Chemical	Minimum Concentration Qualifier	Maximum Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (1)	Background Value (2)	Screening Toxicity Value (3)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Selection or Deletion (4)
North Branch of Pettibone Creek Sediment	83-32-9	Acenaphthene	1.90E-03 J	1.10E-02	mg/kg	NTC17PCSD42 and NTC17PCSD44	5 / 10	0.0038 - 0.004	1.10E-02	NA	3.40E+02 n	NA	NA	No	BSL
	120-12-7	Anthracene	3.00E-03 J	7.10E-02	mg/kg	NTC17PCSD42	6 / 10	0.0038 - 0.004	7.10E-02	NA	1.70E+03 n	NA	NA	No	BSL
	56-55-3	Benzo(a)anthracene	3.30E-02	2.60E-01	mg/kg	NTC17PCSD44	5 / 10	0.0038 - 0.004	2.60E-01	NA	1.50E-01 c	NA	NA	Yes	ASL
	50-32-8	Benzo(a)pyrene	2.40E-02	2.00E-01	mg/kg	NTC17PCSD42	5 / 10	0.0038 - 0.004	2.00E-01	NA	1.50E-02 c	NA	NA	Yes	ASL
	205-99-2	Benzo(b)fluoranthene	2.00E-02	2.40E-01	mg/kg	NTC17PCSD42	5 / 10	0.0038 - 0.004	2.40E-01	NA	1.50E-01 c	NA	NA	Yes	ASL
	191-24-2	Benzo(g,h,i)perylene	1.80E-03 J	1.20E-01	mg/kg	NTC17PCSD42	10 / 10	NA	1.20E-01	NA	1.70E+02 n	NA	NA	No	BSL
	207-08-9	Benzo(k)fluoranthene	6.40E-03	6.40E-02	mg/kg	NTC17PCSD42	5 / 10	0.0038 - 0.004	6.40E-02	NA	1.50E+00 c	NA	NA	Yes	CSC
	218-01-9	Chrysene	2.90E-02	2.00E-01 J	mg/kg	NTC17PCSD44	5 / 10	0.0038 - 0.004	2.00E-01	NA	1.50E+01 c	NA	NA	Yes	CSC
	53-70-3	Dibenz(a,h)anthracene	4.20E-03 J	2.70E-02 J	mg/kg	NTC17PCSD42	4 / 10	0.0038 - 0.004	2.70E-02	NA	1.50E-02 c	NA	NA	Yes	ASL
	206-44-0	Fluoranthene	3.10E-03 J	6.20E-01 J	mg/kg	NTC17PCSD44	9 / 10	0.0038	6.20E-01	NA	2.30E+02 n	NA	NA	No	BSL
	86-73-7	Fluorene	2.80E-03 J	1.90E-02	mg/kg	NTC17PCSD44	6 / 10	0.0038 - 0.004	1.90E-02	NA	2.30E+02 n	NA	NA	No	BSL
	193-39-5	Indeno(1,2,3-cd)pyrene	1.70E-02	1.00E-01	mg/kg	NTC17PCSD42	4 / 10	0.0038 - 0.004	1.00E-01	NA	1.50E-01 c	NA	NA	Yes	CSC
	91-57-6	2-Methylnaphthalene	2.30E-03 J	2.00E-02	mg/kg	NTC17PCSD47	9 / 10	0.004	2.00E-02	NA	3.10E+01 n	NA	NA	No	BSL
	91-20-3	Naphthalene	4.80E-03	6.50E-03	mg/kg	NTC17PCSD42	3 / 10	0.038 - 0.0044	6.50E-03	NA	3.60E+00 c	NA	NA	No	BSL
	85-01-8	Phenanthrene	3.90E-03 J	3.20E-01	mg/kg	NTC17PCSD44	10 / 10	NA	3.20E-01	NA	1.70E+02 n	NA	NA	No	BSL
	129-00-0	Pyrene	4.40E-03 J	4.60E-01 J	mg/kg	NTC17PCSD44	7 / 10	0.0038 - 0.004	4.60E-01	NA	1.70E+02 n	NA	NA	No	BSL
	72-54-8	4,4'-DDD	2.10E-03 J	1.90E-02	mg/kg	NTC17PCSD49	6 / 10	0.00076 - 0.00083	1.90E-02	NA	2.00E+00 c	NA	NA	No	BSL
	72-55-9	4,4'-DDE	9.20E-04 J	6.80E-02 J	mg/kg	NTC17PCSD49	6 / 10	0.00076 - 0.00083	6.80E-02	NA	1.40E+00 c	NA	NA	No	BSL
	50-29-3	4,4'-DDT	1.40E-03 J	1.90E-02 J	mg/kg	NTC17PCSD49	5 / 10	0.00076 - 0.00083	1.90E-02	NA	1.70E+00 c	NA	NA	No	BSL
	11097-69-1	Aroclor-1254	ND	ND	mg/kg	NA	0 / 10	0.019 - 0.022	ND	NA	1.10E-01 n	NA	NA	No	ND
	11096-82-5	Aroclor-1260	7.20E-03 J	7.20E-03 J	mg/kg	NTC17PCSD48	1 / 10	0.019 - 0.022	7.20E-03	NA	2.20E-01 c	NA	NA	No	BSL
	72-20-8	Endrin	1.50E-03 J	2.00E-03 J	mg/kg	NTC17PCSD49	2 / 10	0.00076 - 0.00084	2.00E-03	NA	1.80E+00 n	NA	NA	No	BSL
	58-89-9	Gamma-BHC (Lindane)	2.50E-04 J	2.50E-04 J	mg/kg	NTC17PCSD44	1 / 10	0.00038 - 0.00044	2.50E-04	NA	5.20E-01 c	NA	NA	No	BSL
	115-29-7	Endosulfan I	ND	ND	mg/kg	NA	0 / 10	0.00038 - 0.00044	ND	NA	3.70E+01 n	NA	NA	No	ND
	115-29-7	Endosulfan II	ND	ND	mg/kg	NA	0 / 10	0.00027 - 0.00089	ND	NA	3.70E+01 n	NA	NA	No	ND
	7440-50-8	Copper	1.63E+01	1.67E+02	mg/kg	NTC17PCSD48	10 / 10	NA	1.67E+02	NA	3.10E+02 n	NA	NA	No	BSL
	7439-92-1	Lead	8.90E+00	1.03E+02	mg/kg	NTC17PCSD48	10 / 10	NA	1.03E+02	NA	4.00E+02 n	NA	NA	No	BSL
	22967-92-6	Mercury	1.80E-02	6.10E-02	mg/kg	NTC17PCSD42	5 / 10	0.014 - 0.017	6.10E-02	NA	7.80E-01 n	NA	NA	No	BSL
	7440-66-6	Zinc	4.32E+01	1.07E+03	mg/kg	NTC17PCSD48	10 / 10	NA	1.07E+03	NA	2.30E+03 n	NA	NA	No	BSL

(1) Maximum concentration was used for screening.

(2) Background values not available.

(3) Regional Screening Level table, November 2010.

RSL value for pyrene used as surrogate for phenanthrene and benzo(g,h,i)perylene.

Lead screening toxicity value is 400 mg/kg, the EPA residential soil screening level for lead.

RSL for methylmercury was used for mercury.

RSL for endosulfan was used as a surrogate for Endosulfan I and Endosulfan II.

(4) Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Chemicals of Similar Class are also COPCs (CSC)

Deletion Reason: Below Screening Level (BSL)
Not Detected (ND)

COPC = Chemical of Potential Concern

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered

J = Estimated Value

c = Carcinogenic

n = Noncarcinogenic

NA = Not available

Table 2.2

OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Future
Medium: Sediment
Exposure Medium: Fish

Exposure Point	CAS Number	Chemical	Minimum Concentration Qualifier	Maximum Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Fish Tissue Concentration Used for Screening (1)	BSAF Value (2)	Screening Toxicity Value (3)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for Selection or Deletion (4)
Fish from Boat Basin	83-32-9	Acenaphthene	1.90E-03 J	1.10E-02	mg/kg	NTC17PCSD42	5 / 10	0.0038 - 0.004	1.59E-02	0.29	8.11E+00 n	NA	NA	No	BSL
	120-12-7	Anthracene	3.00E-03 J	7.10E-02	mg/kg	NTC17PCSD42	6 / 10	0.0038 - 0.004	1.03E-01	0.29	4.06E+01 n	NA	NA	No	BSL
	56-55-3	Benzo(a)anthracene	3.30E-02	2.60E-01	mg/kg	NTC17PCSD44	5 / 10	0.0038 - 0.004	3.76E-01	0.29	4.32E-03 c	NA	NA	Yes	ASL
	50-32-8	Benzo(a)pyrene	2.40E-02	2.00E-01	mg/kg	NTC17PCSD42	5 / 10	0.0038 - 0.004	2.89E-01	0.29	4.32E-04 c	NA	NA	Yes	ASL
	205-99-2	Benzo(b)fluoranthene	2.00E-02	2.40E-01	mg/kg	NTC17PCSD42	5 / 10	0.0038 - 0.004	3.47E-01	0.29	4.32E-03 c	NA	NA	Yes	ASL
	191-24-2	Benzo(g,h,i)perylene	1.80E-03 J	1.20E-01	mg/kg	NTC17PCSD42	10 / 10	NA	1.73E-01	0.29	4.06E+00 n	NA	NA	No	BSL
	207-08-9	Benzo(k)fluoranthene	6.40E-03	6.40E-02	mg/kg	NTC17PCSD42	5 / 10	0.0038 - 0.004	9.25E-02	0.29	4.32E-02 c	NA	NA	Yes	ASL
	218-01-9	Chrysene	2.90E-02	2.00E-01 J	mg/kg	NTC17PCSD44	5 / 10	0.0038 - 0.004	2.89E-01	0.29	4.32E-01 c	NA	NA	Yes	CSC
	53-70-3	Dibenz(a,h)anthracene	4.20E-03 J	2.70E-02 J	mg/kg	NTC17PCSD42	4 / 10	0.0038 - 0.004	3.90E-02	0.29	4.32E-04 c	NA	NA	Yes	ASL
	206-44-0	Fluoranthene	3.10E-03 J	6.20E-01 J	mg/kg	NTC17PCSD44	9 / 10	0.0038	8.96E-01	0.29	5.41E+00 n	NA	NA	No	BSL
	86-73-7	Fluorene	2.80E-03 J	1.90E-02	mg/kg	NTC17PCSD44	6 / 10	0.0038 - 0.004	2.75E-02	0.29	5.41E+00 n	NA	NA	No	BSL
	193-39-5	Indeno(1,2,3-cd)pyrene	1.70E-02	1.00E-01	mg/kg	NTC17PCSD42	4 / 10	0.0038 - 0.004	1.45E-01	0.29	4.32E-03 c	NA	NA	Yes	ASL
	91-57-6	2-Methylnaphthalene	2.30E-03 J	2.00E-02	mg/kg	NTC17PCSD47	9 / 10	0.004	2.89E-02	0.29	5.41E-01 n	NA	NA	No	BSL
	91-20-3	Naphthalene	4.80E-03	6.50E-03	mg/kg	NTC17PCSD42	3 / 10	0.038 - 0.0044	9.40E-03	0.29	2.70E+00 n	NA	NA	No	BSL
	85-01-8	Phenanthrene	3.90E-03 J	3.20E-01	mg/kg	NTC17PCSD44	10 / 10	NA	4.63E-01	0.29	4.06E+00 n	NA	NA	No	BSL
	129-00-0	Pyrene	4.40E-03 J	4.60E-01 J	mg/kg	NTC17PCSD44	7 / 10	0.0038 - 0.004	6.65E-01	0.29	4.06E+00 n	NA	NA	No	BSL
	72-54-8	4,4'-DDD	2.10E-03 J	1.90E-02	mg/kg	NTC17PCSD49	6 / 10	0.00076 - 0.00083	2.65E-02	0.28	1.31E-02 c	NA	NA	Yes	ASL
	72-55-9	4,4'-DDE	9.20E-04 J	6.80E-02 J	mg/kg	NTC17PCSD49	6 / 10	0.00076 - 0.00083	2.61E+00	7.7	9.28E-03 c	NA	NA	Yes	ASL
	50-29-3	4,4'-DDT	1.40E-03 J	1.90E-02 J	mg/kg	NTC17PCSD49	5 / 10	0.00076 - 0.00083	1.58E-01	1.67	9.28E-03 c	NA	NA	Yes	ASL
	11097-69-1	Aroclor-1254	ND	ND	mg/kg	NA	0 / 10	0.019 - 0.022	ND	1.85	1.58E-03 c	NA	NA	No	ND
	11096-82-5	Aroclor-1260	7.20E-03 J	7.20E-03 J	mg/kg	NTC17PCSD48	1 / 10	0.019 - 0.022	6.64E-02	1.85	1.58E-03 c	NA	NA	Yes	ASL
	72-20-8	Endrin	1.50E-03 J	2.00E-03 J	mg/kg	NTC17PCSD49	2 / 10	0.00076 - 0.00084	1.79E-02	1.8	4.06E-02 n	NA	NA	No	BSL
	58-89-9	Gamma-BHC (Lindane)	2.50E-04 J	2.50E-04 J	mg/kg	NTC17PCSD44	1 / 10	0.00038 - 0.00044	2.24E-03	1.8	2.87E-03 c	NA	NA	No	BSL
	115-29-7	Endosulfan I	ND	ND	mg/kg	NA	0 / 10	0.00038 - 0.00044	ND	1.8	8.11E-01 n	NA	NA	No	ND
	115-29-7	Endosulfan II	ND	ND	mg/kg	NA	0 / 10	0.00027 - 0.00089	ND	1.8	8.11E-01 n	NA	NA	No	ND
	7440-50-8	Copper	1.63E+01	1.67E+02	mg/kg	NTC17PCSD48	10 / 10	NA	8.32E+02	1	5.41E+00 n	NA	NA	Yes	ASL
	7439-92-1	Lead	8.90E+00	1.03E+02	mg/kg	NTC17PCSD48	10 / 10	NA	5.13E+02	1		NA	NA	Yes	ASL
	22967-92-6	Mercury	1.80E-02	6.10E-02	mg/kg	NTC17PCSD42	5 / 10	0.014 - 0.017	3.04E-01	1	1.35E-02 n	NA	NA	Yes	ASL
	7440-66-6	Zinc	4.32E+01	1.07E+03	mg/kg	NTC17PCSD48	10 / 10	NA	5.33E+03	1	4.06E+01 n	NA	NA	Yes	ASL

(1) Fish tissue concentration calculated as ((Max sediment * BSAF * Flipid) / Foc) where Foc = 0.642%, Flipid = 3.2%

(2) BSAF values obtained from RI report (Tetra Tech, 2003).

(3) Calculated using default assumptions using the Regional Screening Level calculator, December 2010.
RSL value for pyrene used as surrogate for phenanthrene and benzo(g,h,i)perylene.
Lead screening toxicity value is 400 mg/kg, the EPA residential soil screening level for lead.
RSL for methylmercury was used for mercury.
RSL for endosulfan was used as a surrogate for Endosulfan I and Endosulfan II.

(4) Rationale Codes

Selection Reason: Above Screening Levels (ASL)
Chemicals of Similar Class are also COPCs (CSC)

Deletion Reason: Below Screening Level (BSL)
Not Detected (ND)

COPC = Chemical of Potential Concern
ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered
J = Estimated Value
c = Carcinogenic
n = Noncarcinogenic
NA = Not available

Table 3.1.RME

MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY

REASONABLE MAXIMUM EXPOSURE

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic	Rationale
North Branch of Pettibone Creek Sediment	Benzo(a)anthracene	mg/kg	1.23E-01	1.31E-01 (NP)	2.60E-01	1.31E-01	mg/kg	95% KM (t) UCL	(1)
	Benzo(a)pyrene	mg/kg	1.01E-01	1.04E-01 (NP)	2.00E-01	1.04E-01	mg/kg	95% KM (t) UCL	(1)
	Benzo(b)fluoranthene	mg/kg	1.14E-01	1.18E-01 (NP)	2.40E-01	1.18E-01	mg/kg	95% KM (t) UCL	(1)
	Benzo(k)fluoranthene	mg/kg	3.17E-02	3.29E-02 (NP)	6.40E-02	3.29E-02	mg/kg	95% KM (t) UCL	(1)
	Chrysene	mg/kg	9.88E-02	1.04E-01 (NP)	2.00E-01 J	1.04E-01	mg/kg	95% KM (t) UCL	(1)
	Dibenz(a,h)anthracene	mg/kg	1.63E-02	1.49E-02 (NP)	2.70E-02 J	1.49E-02	mg/kg	95% KM (t) UCL	(1)
	Indeno(1,2,3-cd)pyrene	mg/kg	5.88E-02	5.41E-02 (NP)	1.00E-01	5.41E-02	mg/kg	95% KM (t) UCL	(1)

ProUCL, Version 4.00.05 used to determine distribution of data and to calculate RME EPC, following recommendations based on distribution and standard deviation in users guide (USEPA, May 2010).

(1) Since the dataset is left-censored with multiple detection limits, use of the Kaplan-Meier method is recommended.

J = Estimated value.

mg/kg = Milligrams per kilogram.

NP = Non-Parametric

95% KM (t) UCL = UCL based on Kaplan-Meier estimates using the Student's t-distribution cutoff value.

Table 3.2.RME

MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY

REASONABLE MAXIMUM EXPOSURE

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Future
Medium: Sediment
Exposure Medium: Fish

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution)		Maximum Concentration (Qualifier)		Exposure Point Concentration			
								Value	Units	Statistic	Rationale
Fish from Boat Basin	Benzo(a)anthracene	mg/kg	1.98E-01	2.11E-01	(NP)	4.18E-01		2.11E-01	mg/kg	95% KM (t) UCL	(1)
	Benzo(a)pyrene	mg/kg	1.62E-01	1.68E-01	(NP)	3.22E-01		1.68E-01	mg/kg	95% KM (t) UCL	(1)
	Benzo(b)fluoranthene	mg/kg	1.83E-01	1.89E-01	(NP)	3.86E-01		1.89E-01	mg/kg	95% KM (t) UCL	(1)
	Benzo(k)fluoranthene	mg/kg	5.10E-02	5.29E-02	(NP)	1.03E-01		5.29E-02	mg/kg	95% KM (t) UCL	(1)
	Chrysene	mg/kg	1.59E-01	1.67E-01	(NP)	3.22E-01	J	1.67E-01	mg/kg	95% KM (t) UCL	(1)
	Dibenz(a,h)anthracene	mg/kg	2.62E-02	2.40E-02	(NP)	4.34E-02	J	2.40E-02	mg/kg	95% KM (t) UCL	(1)
	Indeno(1,2,3-cd)pyrene	mg/kg	9.46E-02	8.70E-02	(NP)	1.61E-01		8.70E-02	mg/kg	95% KM (t) UCL	(1)
	4,4'-DDD	mg/kg	1.20E-02	1.40E-02	(NP)	2.95E-02		1.40E-02	mg/kg	95% KM (t) UCL	(1)
	4,4'-DDE	mg/kg	7.11E-01	1.07E+00	(NP)	2.90E+00	J	1.07E+00	mg/kg	95% KM (BCA) UCL	(2)
	4,4'-DDT	mg/kg	7.83E-02	8.06E-02	(NP)	1.76E-01	J	8.06E-02	mg/kg	95% KM (t) UCL	(1)
	Aroclor-1260	mg/kg	NC	NC	NC	7.39E-02	J	7.39E-02	mg/kg	Max detect	(3)
	Copper	mg/kg	2.25E+02	5.74E+02	(NP)	9.26E+02		5.74E+02	mg/kg	95% Chebyshev (Mean, Sd) UCL	(4)
	Lead	mg/kg	1.49E+02	2.58E+02	(GA)	5.71E+02		2.58E+02	mg/kg	95% Approximate Gamma UCL	(5)
	Mercury	mg/kg	2.03E-01	1.91E-01	(NP)	3.38E-01		1.91E-01	mg/kg	95% KM (t) UCL	(1)
	Zinc	mg/kg	1.00E+03	3.43E+03	(NP)	5.93E+03		3.43E+03	mg/kg	95% Chebyshev (Mean, Sd) UCL	(4)

ProUCL, Version 4.00.05 used to determine distribution of data and to calculate RME EPC, following recommendations based on distribution and standard deviation in users guide (USEPA, May 2010).

(1) Since the dataset is left-censored with multiple detection limits, use of the Kaplan-Meier method is recommended.

(2) UCL based upon Kaplan-Meier bias-corrected accelerated bootstrap method.

(3) Since the constituent was only detected in one sample, the UCL could not be calculated; the detected concentration was used as the EPC.

(4) UCL based on the 95% Chebyshev UCL.

(5) UCL is based on the approximate gamma UCL.

J = Estimated value.

mg/kg = Milligrams per kilogram.

NP = Non-Parametric

GA=Gamma

NC=Not Calculated

95% KM (t) UCL = UCL based on Kaplan-Meier estimates using the Student's t-distribution cutoff value.

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Recreational User	Adult	North Branch of Pettibone Creek	CSed	Chemical Concentration in Sediment	See Table 3.1.RME	mg/kg	See Table 3.1.RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-Sed	Ingestion Rate of Sediment	100	mg/day	(1)	CSed x IR-Sed x EF x ED x CF3 x 1/BW x 1/AT
				EF	Exposure Frequency	52	days/year	(1)	
				ED	Exposure Duration	24	years	(1)	
				CF3	Conversion Factor 3	0.000001	kg/mg	(1)	
				BW	Body Weight	70	kg	(1)	
				AT-C	Averaging Time (Cancer)	25,550	days	(1)	
				AT-N	Averaging Time (Non-Cancer)	8,760	days	(1)	
		Adolescent	North Branch of Pettibone Creek	CSed	Chemical Concentration in Sediment	See Table 3.1.RME	mg/kg	See Table 3.1.RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-Sed	Ingestion Rate of Sediment	100	mg/day	(1)	CSed x IR-Sed x EF x ED x CF3 x 1/BW x 1/AT
				EF	Exposure Frequency	52	days/year	(1)	
				ED	Exposure Duration	10	years	(1)	CDI for chemicals with a mutagenic mode of action =
				CF3	Conversion Factor 3	0.000001	kg/mg	(1)	CSed x IR-Sed x EF x ED x ADAF x CF3 x 1/BW x 1/AT
				BW	Body Weight	42	kg	(1)	
				ADAF	Age-dependent adjustment factor	3	unitless	(3)	
				AT-C	Averaging Time (Cancer)	25,550	days	(1)	
				AT-N	Averaging Time (Non-Cancer)	3,650	days	(1)	
Dermal	Recreational User	Adult	North Branch of Pettibone Creek	CSed	Chemical Concentration in Sediment	See Table 3.1.RME	mg/kg	See Table 3.1.RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				SA	Skin Surface Area Available for Contact	9,190	cm^2	(1)	CSed x SA x SSAF x DABS x CF3 x EF x
				SSAF	Soil to Skin Adherence Factor	0.3	mg/cm^2	(1)	ED x 1/BW x 1/AT
				DABS	Dermal Absorption Factor Solids	0.13	--	(1, 2)	
				CF3	Conversion Factor 3	0.000001	kg/mg	(1)	
				EF	Exposure Frequency	52	days/year	(1)	
				ED	Exposure Duration	24	years	(1)	
				BW	Body Weight	70	kg	(1)	
				AT-C	Averaging Time (Cancer)	25,550	days	(1)	
				AT-N	Averaging Time (Non-Cancer)	8,760	days	(1)	

TABLE 4.1.RME

VALUES USED FOR DAILY INTAKE CALCULATIONS

REASONABLE MAXIMUM EXPOSURE

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Future
Medium: Sediment
Exposure Medium: Sediment

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Recreational User	Adolescent	North Branch of Pettibone Creek	CSed	Chemical Concentration in Sediment	See Table 3.1.RME	mg/kg	See Table 3.1.RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				SA	Skin Surface Area Available for Contact	3,280	cm^2	(1)	CSed x SA x SSAF x DABS x CF3 x EF x
				SSAF	Soil to Skin Adherence Factor	0.3	mg/cm^2	(1)	ED x 1/BW x 1/AT
				DABS	Dermal Absorption Factor Solids	0.13	--	(1, 2)	
				CF3	Conversion Factor 3	0.000001	kg/mg	(1)	CDI for chemicals with a mutagenic mode of action =
				EF	Exposure Frequency	52	days/year	(1)	
				ED	Exposure Duration	10	years	(1)	CSed x SA x SSAF x DABS x CF3 x EF x ADAF
				BW	Body Weight	42	kg	(1)	ED x 1/BW x 1/AT
				ADAF	Age-dependent adjustment factor	3	unitless	(3)	
				AT-C	Averaging Time (Cancer)	25,550	days	(1)	
				AT-N	Averaging Time (Non-Cancer)	3,650	days	(1)	

(1) The exposure factors are the same as those used in the 2001 RI.

(2) This value is chemical-specific. Since the only COPCs for direct contact with sediment were PAHs, the value shown is for PAHs.

(3) USEPA 2005. Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens. Risk Assessment Forum.EPA/630/R-03/003F. ADAF for ages 2 through < 16 years = 3.

TABLE 4.2.RME

VALUES USED FOR DAILY INTAKE CALCULATIONS

REASONABLE MAXIMUM EXPOSURE

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Future
Medium: Fish
Exposure Medium: Fish

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Recreational User	Adult	Boat Basin	Cfish	Chemical Concentration in Sediment	See Table 3.2.RME	mg/kg	See Table 3.2.RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-Fish	Ingestion Rate of Fish	0.02	kg/meal	(1)	CFish x IR-Fish x EF x ED x FI x 1/BW x 1/AT
				FI	Fraction Ingested from Source	0.1	unitless	(1)	
				EF	Exposure Frequency	365	meals/year	(1)	
				ED	Exposure Duration	30	years	(1)	
				BW	Body Weight	70	kg	(1)	
				AT-C	Averaging Time (Cancer)	25,550	days	(1)	
				AT-N	Averaging Time (Non-Cancer)	10,950	days	(1)	

(1) The exposure factors are the same as those used in the 2001 RI.

TABLE 5.1

NON-CANCER TOXICITY DATA -- ORAL/DERMAL

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Chemical of Potential Concern (1)	Chronic/ Subchronic	Oral RfD		Oral Absorption Efficiency for Dermal (2)	Absorbed RfD for Dermal (3)		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfD:Target Organ(s)	
		Value	Units		Value	Units			Source(s)	Date(s) (MM/DD/YYYY)
Benzo(a)anthracene	Chronic	NA	NA	58%-89%	NA	NA	NA	NA	NA	NA
Benzo(a)pyrene	Chronic	NA	NA	58%-89%	NA	NA	NA	NA	NA	NA
Benzo(b)fluoranthene	Chronic	NA	NA	58%-89%	NA	NA	NA	NA	NA	NA
Benzo(k)fluoranthene	Chronic	NA	NA	58%-89%	NA	NA	NA	NA	NA	NA
Chrysene	Chronic	NA	NA	58%-89%	NA	NA	NA	NA	NA	NA
Dibenz(a,h)anthracene	Chronic	NA	NA	58%-89%	NA	NA	NA	NA	NA	NA
Indeno(1,2,3-cd)pyrene	Chronic	NA	NA	58%-89%	NA	NA	NA	NA	NA	NA
4,4'-DDD	Chronic	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDE	Chronic	NA	NA	NA	NA	NA	NA	NA	NA	NA
4,4'-DDT	Chronic	5.00E-04	mg/kg-day	70% - 90%	5.00E-04	mg/kg-day	Liver	100/1	IRIS	12/22/2010
Aroclor-1260	Chronic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	Chronic	4.00E-02	mg/kg-day	NA	4.00E-02	mg/kg-day	Gastrointestinal	NA	HEAST	07/1997
Lead	Chronic	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	Chronic	1.00E-04	mg/kg-day	95%	1.00E-04	mg/kg-day	Nervous system	10/1	IRIS	12/22/2010
Zinc	Chronic	3.00E-01	mg/kg-day	highly variable	3.00E-01	mg/kg-day	Blood	3	IRIS	12/22/2010

Footnote Instructions:

(1) Mercury is evaluted as methylmercury.

(2) Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evalution Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (Final). 2004. Section 4.2 and Exhibit 4-1. USEPA recommends that the oral RfD should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 50%. Constituents that do not have oral absorption efficiencies reported on this table were assumed to have an oral absorption efficiency of 100%.

(3) "Absorbed RfD for Dermal" = Oral RfD * Oral Absorption Efficiency

Definitions: IRIS = Integrated Risk Information System

HEAST = Health Effects Assessment Summary Tables

NA=Not applicable

TABLE 6.1

CANCER TOXICITY DATA -- ORAL/DERMAL

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Chemical of Potential Concern (1)	Oral Cancer Slope Factor		Oral Absorption Efficiency for Dermal (2)	Absorbed Cancer Slope Factor for Dermal (3)		Weight of Evidence/ Cancer Guideline Description	Oral CSF	
	Value	Units		Value	Units		Source(s)	Date(s) (MM/DD/YYYY)
Benzo(a)anthracene	7.30E-01	1/(mg/kg-day)	58%-89%	7.30E-01	1/(mg/kg-day)	B2	IRIS	12/20/2010
Benzo(a)pyrene	7.30E+00	1/(mg/kg-day)	58%-89%	7.30E+01	1/(mg/kg-day)	B2	IRIS	12/20/2010
Benzo(b)fluoranthene	7.30E-01	1/(mg/kg-day)	58%-89%	7.30E-01	1/(mg/kg-day)	B2	IRIS	12/20/2010
Benzo(k)fluoranthene	7.30E-02	1/(mg/kg-day)	58%-89%	7.30E-02	1/(mg/kg-day)	B2	IRIS	12/20/2010
Chrysene	7.30E-03	1/(mg/kg-day)	58%-89%	7.30E-03	1/(mg/kg-day)	B2	IRIS	12/20/2010
Dibenz(a,h)anthracene	7.30E+00	1/(mg/kg-day)	58%-89%	7.30E+00	1/(mg/kg-day)	B2	IRIS	12/20/2010
Indeno(1,2,3-cd)pyrene	7.30E-01	1/(mg/kg-day)	58%-89%	7.30E-01	1/(mg/kg-day)	B2	IRIS	12/20/2010
4,4'-DDD	2.40E-01	1/(mg/kg-day)	NA	2.40E-01	1/(mg/kg-day)	B2	IRIS	12/22/2010
4,4'-DDE	3.40E-01	1/(mg/kg-day)	NA	3.40E-01	1/(mg/kg-day)	B2	IRIS	12/22/2010
4,4'-DDT	3.40E-01	1/(mg/kg-day)	70% - 90%	3.40E-01	1/(mg/kg-day)	B2	IRIS	12/22/2010
Aroclor-1260	2.00E+00	1/(mg/kg-day)	80% - 96%	2.00E+00	1/(mg/kg-day)	NA	RSL (4)	11/2010
Copper	NA	NA	NA	NA	NA	NA	NA	NA
Lead	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	NA	NA	NA	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	NA	NA	NA	NA

Footnotes:

(1) Mercury is evaluted as methylmercury.

(2) Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evalution Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (Final). 2004. Section 4.2 and Exhibit 4-1. USEPA recommends that the oral RfD should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 50%. Constituents that do not have oral absorption efficiencies reported on this table were assumed to have an oral absorption efficiency of 100%.

(3) "Absorbed CSF for Dermal" = Oral Cancer Slope Factor / Oral Absorption Efficiency

(4) See RSL User 's Guide, Section 5 (Special Considerations 5.8 PCBs), November 2010.

Weight of Evidence definitions:

Group B2 chemicals (probable human carcinogens) are agents for which there is sufficient evidence of carcinogenicity in animals but inadequate or a lack of evidence in humans.

Definitions:

IRIS = Integrated Risk Information System

RSL=Regional Screening Levels

NA=Not applicable

TABLE 7.1.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Current/Future
Receptor Population: Recreator
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Sediment	Sediment	Sediment	Ingestion													
				Benzo(a)anthracene	1.3E-01	mg/kg	9.2E-09	mg/kg-day	7.3E-01	1/(mg/kg-day)	6.7E-09	2.7E-08	mg/kg/day	NA	NA	NA
				Benzo(a)pyrene	1.0E-01	mg/kg	7.3E-09	mg/kg-day	7.3E+00	1/(mg/kg-day)	5.3E-08	2.1E-08	mg/kg/day	NA	NA	NA
				Benzo(b)fluoranthene	1.2E-01	mg/kg	8.2E-09	mg/kg-day	7.3E-01	1/(mg/kg-day)	6.0E-09	2.4E-08	mg/kg/day	NA	NA	NA
				Benzo(k)fluoranthene	3.3E-02	mg/kg	2.3E-09	mg/kg-day	7.3E-02	1/(mg/kg-day)	1.7E-10	6.7E-09	mg/kg/day	NA	NA	NA
				Chrysene	1.0E-01	mg/kg	7.2E-09	mg/kg-day	7.3E-03	1/(mg/kg-day)	5.3E-11	2.1E-08	mg/kg/day	NA	NA	NA
				Dibenzo(a,h)anthracene	1.5E-02	mg/kg	1.0E-09	mg/kg-day	7.3E+00	1/(mg/kg-day)	7.6E-09	3.0E-09	mg/kg/day	NA	NA	NA
				Indeno(1,2,3-cd)pyrene	5.4E-02	mg/kg	3.8E-09	mg/kg-day	7.3E-01	1/(mg/kg-day)	2.8E-09	1.1E-08	mg/kg/day	NA	NA	NA
			Exp. Route Total								7.6E-08					0.0E+00
			Dermal													
				Benzo(a)anthracene	1.3E-01	mg/kg	3.3E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	2.4E-08	9.6E-08	mg/kg/day	NA	NA	NA
				Benzo(a)pyrene	1.0E-01	mg/kg	2.6E-08	mg/kg-day	7.3E+00	1/(mg/kg-day)	1.9E-07	7.6E-08	mg/kg/day	NA	NA	NA
				Benzo(b)fluoranthene	1.2E-01	mg/kg	2.9E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	2.2E-08	8.6E-08	mg/kg/day	NA	NA	NA
				Benzo(k)fluoranthene	3.3E-02	mg/kg	8.2E-09	mg/kg-day	7.3E-02	1/(mg/kg-day)	6.0E-10	2.4E-08	mg/kg/day	NA	NA	NA
				Chrysene	1.0E-01	mg/kg	2.6E-08	mg/kg-day	7.3E-03	1/(mg/kg-day)	1.9E-10	7.6E-08	mg/kg/day	NA	NA	NA
				Dibenzo(a,h)anthracene	1.5E-02	mg/kg	3.7E-09	mg/kg-day	7.3E+00	1/(mg/kg-day)	2.7E-08	1.1E-08	mg/kg/day	NA	NA	NA
				Indeno(1,2,3-cd)pyrene	5.4E-02	mg/kg	1.4E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	9.9E-09	3.9E-08	mg/kg/day	NA	NA	NA
			Exp. Route Total								2.7E-07					0.0E+00
		Exposure Point Total									3.5E-07					0.0E+00
	Exposure Medium Total										3.5E-07					0.0E+00

TABLE 7.1.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Current/Future
Receptor Population: Recreator
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Sediment	Fish Tissue	Fish Tissue	Ingestion													
				Benzo(a)anthracene	2.1E-01	mg/kg	2.6E-06	mg/kg-day	7.3E-01	1/(mg/kg-day)	1.9E-06	6.0E-06	mg/kg/day	NA	NA	NA
				Benzo(a)pyrene	1.7E-01	mg/kg	2.1E-06	mg/kg-day	7.3E+00	1/(mg/kg-day)	1.5E-05	4.8E-06	mg/kg/day	NA	NA	NA
				Benzo(b)fluoranthene	1.9E-01	mg/kg	2.3E-06	mg/kg-day	7.3E-01	1/(mg/kg-day)	1.7E-06	5.4E-06	mg/kg/day	NA	NA	NA
				Benzo(k)fluoranthene	5.3E-02	mg/kg	6.5E-07	mg/kg-day	7.3E-02	1/(mg/kg-day)	4.7E-08	1.5E-06	mg/kg/day	NA	NA	NA
				Chrysene	1.7E-01	mg/kg	2.0E-06	mg/kg-day	7.3E-03	1/(mg/kg-day)	1.5E-08	4.8E-06	mg/kg/day	NA	NA	NA
				Dibenzo(a,h)anthracene	2.4E-02	mg/kg	2.9E-07	mg/kg-day	7.3E+00	1/(mg/kg-day)	2.1E-06	6.9E-07	mg/kg/day	NA	NA	NA
				Indeno(1,2,3-cd)pyrene	8.7E-02	mg/kg	1.1E-06	mg/kg-day	7.3E-01	1/(mg/kg-day)	7.8E-07	2.5E-06	mg/kg/day	NA	NA	NA
				4,4'-DDD	1.4E-02	mg/kg	1.7E-07	mg/kg-day	2.4E-01	1/(mg/kg-day)	4.1E-08	4.0E-07	mg/kg/day	NA	NA	NA
				4,4'-DDE	1.1E+00	mg/kg	1.3E-05	mg/kg-day	3.4E-01	1/(mg/kg-day)	4.4E-06	3.0E-05	mg/kg/day	NA	NA	NA
				4,4'-DDT	8.1E-02	mg/kg	9.9E-07	mg/kg-day	3.4E-01	1/(mg/kg-day)	3.4E-07	2.3E-06	mg/kg/day	5.0E-04	mg/kg/day	4.6E-03
				Aroclor-1260	7.4E-02	mg/kg	9.0E-07	mg/kg-day	2.0E+00	1/(mg/kg-day)	1.8E-06	2.1E-06	mg/kg/day	NA	NA	NA
				Copper	5.7E+02	mg/kg	7.0E-03	mg/kg-day	NA	NA	NA	1.6E-02	mg/kg/day	4.0E-02	mg/kg/day	4.1E-01
				Lead	2.6E+02	mg/kg	3.2E-03	mg/kg-day	NA	NA	NA	7.4E-03	mg/kg/day	NA	NA	NA
				Mercury	1.9E-01	mg/kg	2.3E-06	mg/kg-day	NA	NA	NA	5.5E-06	mg/kg/day	1.0E-04	mg/kg/day	5.5E-02
				Zinc	3.4E+03	mg/kg	4.2E-02	mg/kg-day	NA	NA	NA	9.8E-02	mg/kg/day	3.0E-01	mg/kg/day	3.3E-01
			Exp. Route Total								2.8E-05					8.0E-01
		Exposure Point Total									2.8E-05					8.0E-01
	Exposure Medium Total										2.8E-05					8.0E-01
Sediment Total											2.9E-05					8.0E-01
										Total of Receptor Risks Across All Media	2.9E-05				Total of Receptor Hazards Across All Med	8.0E-01

NA = Not applicable.

TABLE 7.2.RME

CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS

REASONABLE MAXIMUM EXPOSURE

Site 17 - NTC Great Lakes HHRA Technical Memorandum

Scenario Timeframe: Current/Future
Receptor Population: Recreator
Receptor Age: Adolescent

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Sediment	Sediment	Sediment	Ingestion													
				Benzo(a)anthracene	1.3E-01	mg/kg	1.9E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	1.4E-08	4.5E-08	mg/kg/day	NA	NA	NA
				Benzo(a)pyrene	1.0E-01	mg/kg	1.5E-08	mg/kg-day	7.3E+00	1/(mg/kg-day)	1.1E-07	3.5E-08	mg/kg/day	NA	NA	NA
				Benzo(b)fluoranthene	1.2E-01	mg/kg	1.7E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	1.3E-08	4.0E-08	mg/kg/day	NA	NA	NA
				Benzo(k)fluoranthene	3.3E-02	mg/kg	4.8E-09	mg/kg-day	7.3E-02	1/(mg/kg-day)	3.5E-10	1.1E-08	mg/kg/day	NA	NA	NA
				Chrysene	1.0E-01	mg/kg	1.5E-08	mg/kg-day	7.3E-03	1/(mg/kg-day)	1.1E-10	3.5E-08	mg/kg/day	NA	NA	NA
				Dibenzo(a,h)anthracene	1.5E-02	mg/kg	2.2E-09	mg/kg-day	7.3E+00	1/(mg/kg-day)	1.6E-08	5.1E-09	mg/kg/day	NA	NA	NA
				Indeno(1,2,3-cd)pyrene	5.4E-02	mg/kg	7.9E-09	mg/kg-day	7.3E-01	1/(mg/kg-day)	5.7E-09	1.8E-08	mg/kg/day	NA	NA	NA
			Exp. Route Total								1.6E-07					0.0E+00
			Dermal													
				Benzo(a)anthracene	1.3E-01	mg/kg	2.4E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	1.8E-08	5.7E-08	mg/kg/day	NA	NA	NA
				Benzo(a)pyrene	1.0E-01	mg/kg	1.9E-08	mg/kg-day	7.3E+00	1/(mg/kg-day)	1.4E-07	4.5E-08	mg/kg/day	NA	NA	NA
				Benzo(b)fluoranthene	1.2E-01	mg/kg	2.2E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	1.6E-08	5.1E-08	mg/kg/day	NA	NA	NA
				Benzo(k)fluoranthene	3.3E-02	mg/kg	6.1E-09	mg/kg-day	7.3E-02	1/(mg/kg-day)	4.5E-10	1.4E-08	mg/kg/day	NA	NA	NA
				Chrysene	1.0E-01	mg/kg	1.9E-08	mg/kg-day	7.3E-03	1/(mg/kg-day)	1.4E-10	4.5E-08	mg/kg/day	NA	NA	NA
				Dibenzo(a,h)anthracene	1.5E-02	mg/kg	2.8E-09	mg/kg-day	7.3E+00	1/(mg/kg-day)	2.0E-08	6.5E-09	mg/kg/day	NA	NA	NA
				Indeno(1,2,3-cd)pyrene	5.4E-02	mg/kg	1.0E-08	mg/kg-day	7.3E-01	1/(mg/kg-day)	7.3E-09	2.3E-08	mg/kg/day	NA	NA	NA
			Exp. Route Total								2.0E-07					0.0E+00
		Exposure Point Total									3.6E-07					0.0E+00
	Exposure Medium Total										3.6E-07					0.0E+00
Sediment Total											3.6E-07					0.0E+00
										Total of Receptor Risks Across All Media	3.6E-07				Total of Receptor Hazards Across All M	0.0E+00

NA = Not applicable.

Risk Evaluation of Remedial Alternatives at Site 17 – Pettibone Creek; Naval Station Great Lakes; Great Lakes, Illinois

Attachment 2

DRAFT

Ecological RERA

Table 1 - Assessment and Measurement Endpoints, Receptors and Chemicals of Concern

Assessment Endpoint	Measurement Endpoint	Receptors	Chemicals of Concern
Protection of the benthic invertebrate community and aquatic receptors	Sediment screening values – Mortality and other adverse effects (i.e., those on growth, feeding rates, and behavior) to fish and benthic macroinvertebrates were evaluated by comparing the measured concentrations of chemicals in the sediment to screening values designed to be protective of ecological receptors	benthic invertebrates and other aquatic organisms	PAHs
			4,4'-DDT
			4-4'-DDE
			4,4'-DDD
			Endosulfan II
			Copper
			Lead
			Mercury
			Zinc
Protection of piscivorous bird community	No observed adverse effects levels (NOAELs) for surrogate wildlife species – Survival, reproductive, and/or developmental effects to piscivorous birds and carnivorous mammals were evaluated by comparing the ingested dose from contaminants in the surface water, sediment, and fish to NOAELs.	belted kingfisher	4,4'-DDT
			4-4'-DDE

Ecological RERA

Table 2 - Summary of risk reduction achieved by proposed action of sediment removal to native sediment for the benthic invertebrate endpoint.

Receptor	Exposure Route	Chemical of Concern	RI-RA maximum sediment concentration	RI-RA EEQ	Native Sediment maximum concentration	Native Sediment EEQ
Benthic Invertebrates	Direct contact, Ingestion of sediment	Organics (ug/kg)				
		anthracene	4000	47	71	0.8
		benzo(a)anthracene	11000	38	260	0.9
		benzo(a)pyrene	11000	151	180	2.5
		benzo(b)fluoranthene	12000	14	240	0.03
		benzo(g,h,i)perylene	7500	44	120	0.7
		chrysene	12000	30	200	0.5
		fluoranthene	33000	11.8	620	0.2
		fluorene	2400	69	19	0.5
		indeno(1,2,3-cd)pyrene	5800	2.3	100	0.04
		phenanthrene	24000	30	320	0.4
		pyrene	27000	77	460	1.3
		4,4'DDT	1800	1800	19	19
		4,4'-DDE	210	105	68	34
		4,4'-DDD	170	85	19	9.5
		endosulfan II	12	80	0.89	NC
		Inorgancis (mg/kg)				
		copper	477	30	167	10.5
		lead	322	10	103	3.2
		mercury	4.7	24	0.061	0.3
		zinc	2120	18	1070	9

NC – Not calculated. This chemical was not detected in 2008

Benthic Invertebrate EEQs calculated using the selected screening values from the RI-RA and maximum sediment concentrations

Benthic Invertebrate EEQs were not calculated for those compounds that did not were not analyzed for in 2008

Ecological RERA
Table 3 - 2008 Native Sediment Data compared to benthic invertebrate PRG.

COCs	PRG[1]	Source[2]	Sample Number Sample Date Sediment description Sample Interval (in ft bgs)	NTC17PCSD49 12/9/2008 Native Soil - Brown CLAY with silt/sand 0.75-1.25		NTC17PCSD48 12/9/2008 Native Soil - Gray CLAY little silt t-sand 2.5-3.0		NTC17PCSD47 12/9/2008 Native Soil - Gray Silty CLAY 2.0-2.5		NTC17PCSD46 12/9/2008 Native Soil - Gray CLAY little silt, sand, gravel 1.0-1.5		NTC17PCSD45 12/9/2008 Native Soil - Gray CLAY little silt 0.25-0.75		NTC17PCSD44 12/9/2008 Native Soil - Brown SAND/SILT/CLAY 0.25-0.75		NTC17PCSD43 12/9/2008 Native Soil - Gray CLAY little silt 1.0-1.5		NTC17PCSD42 12/9/2008 Native Soil - Brown SAND/SILT/CLAY 0.25-0.75		NTC17PCSD41 12/8/2008 Native Soil - Gray SILT little clay/sand 0.5-1.0		NTC17PCSD40 12/8/2008 Native Soil - Gray SILT little clay/sand 1.0-1.5	
Semivolatile Organics (µg/kg)																					
Anthracene	960	Tier 2a		7.8		20		3.8	U	3.8	U	3.9	U	66		12		71		3	J	4	U
Benzo(a)anthracene	1800	SBG		37		33		3.8	U	3.8	U	3.9	U	260		67		220		4	U	4	U
Benzo(a)pyrene	2500	Tier 2a		37		24		3.8	U	3.8	U	3.9	U	180		62		200		4	U	4	U
Benzo(b)fluoranthene	2000	SBG		34		20		3.8	U	3.8	U	3.9	U	200	J	74		240		4	U	4	U
Benzo(g,h,i)perylene	nv			21		12		3.2	J	4.4		3.8	J	100		38		120		5.5		1.8	J
Chrysene	2800	Tier 2a		39		29		3.8	U	3.8	U	3.9	U	200	J	56		170		4	U	4	U
Fluoranthene	9920	Tier 2a		82		69		5.7		3.8	U	7.6		620	J	150		550		9.3		3.1	J
Fluorene	640	Tier 2a		2.8	J	9.7		3.8	U	3.8	U	3.9	U	19		6.3		18		2.9	J	4	U
Indeno(1,2,3-cd)pyrene	1600	Tier 2a		17		4	U	3.8	U	3.8	U	3.9	U	88		30		100		4	U	4	U
Phenanthrene	2880	Tier 2a		52		78		24		16		18		320	J	110		310		18		3.9	J
Pyrene	2200	Tier 2a		68		59		3.8	U	3.8	U	7.7		460	J	130		440		4	U	4.4	
Total PAHs	35000	Tier 2a		417		372.5		59.1		25.5		44.6		2617.8		771.1		2554.7		41		13.2	
Pesticides/PCBs (µg/kg)																					
4,4'-DDD	20	Tier 2b		19	J	3.8	J	0.76	UJ	0.76	UJ	0.78	UJ	2.1	J	0.83	UJ	2.4	J	13	J	6.1	J
4,4'-DDE	15	Tier 2b		68	J	1.2	J	0.76	UJ	0.76	UJ	0.78	UJ	14	J	0.83	UJ	8.4	J	7.4	J	0.92	J
4,4'-DDT	7	Tier 2b		19	J	1.4	J	0.76	UJ	0.76	UJ	0.78	UJ	13	J	0.83	UJ	5	J	3.9	J	0.79	UJ
Total DDT	572	PEC		106		6.4		0.76	U	0.76	U	0.78	U	29.1		0	U	15.8		24.3		7.02	
Endosulfan II	0.5	Tier 2b		0.89	UJ	0.8	UJ	0.76	UJ	0.76	UJ	0.78	UJ	0.27	U	0.83	UJ	0.84	UJ	0.8	UJ	0.79	UJ
Inorganics (mg/kg)																					
Copper	149	PEC		31.4		167		22.6		19.4		53.5		32.1		22		18.1		23.9		16.3	
Lead	128	PEC		36.6		103		11.2		9.6		24		20.6		9.9		33.6		11.4		8.9	
Mercury	1.06	PEC		0.017	U	0.018		0.015	U	0.014	U	0.015	U	0.038		0.023		0.061		0.028		0.016	U
Zinc	459	PEC		97.3		1070		51		43.9		230		81.3	J	44.3	J	99.3	J	45.3		43.2	

J - Estimated concentration
U - Analyte not detected
NC - Value not calculated
nv - No value

= Above the benthic invertebrate PRG

1. PRGs from Table 2-6 of Site 17 FS
2. PEC from MacDonald, D.D., C.G. Ingersoll, and T.A. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxicol. 39: 20-31
Tier 2a - Alternative Sediment Cleanup values for Petroleum Product Releases
Tier 2b - Site spectic Sediment Screening Concentrations, Alternative Objectives
Sediment Cleanup Objectives for Select Contaminants Found at Great Lakes Naval Training Center, Great Lakes, Illinois; 31 January 2002; Alternative Objectives.

Ecological RERA

Table 4 - Food Chain Model for piscivorous bird endpoint (belted kingfisher) and Environmental Effect Quotient (EEQ) using the mean sediment concentration of the 2008 native sediment data.

Chemicals of Concern	2008 Mean Native Sediment Concentration (mg/kg)	Biota-Sediment Accumulation Factor (unitless)	Ingestion Rate-fish (kg-day)	Lipid Content of Fish	Fraction Organic Carbon - North Branch	Fish Tissue Concentration (mg/kg)	Sediment Ingestion Rate (kg/day)	Surface Water Concentration (mg/L)	Water Ingestion Rate (L/day)	Area Use Factor (unitless)	Body Weight (kg)	Chronic Daily Intake (mg/kg-day)	RI-RA NOAEL (mg/kg-day)	RI-RA NOAEL EEQ	RI-RA LOAEL (mg/kg-day)	RI-RA LOAEL EEQ
DDT	4.62E-03	1.67	0.0689	0.0356	0.0039	0.070458242	0.001378	2.57E-05	0.0167	1.00	0.152	3.20E-02	2.80E-03	1.14E+01	2.80E-02	1.14E+00
DDE	1.03E-02	7.7	0.0689	0.0356	0.0039	0.723957949	0.001378	1.81E-05	0.0167	1.00	0.152	3.28E-01	2.80E-03	1.17E+02	2.80E-02	1.17E+01

All exposure assumptions average inputs as identified in RI-RA (2003)

CDI for Piscivorous Bird organics = $\frac{[(Cf * If) + (Cs * Is) + (Cw*Iw)] * AUF}{BW}$

CDI = Chronic Daily Intake
Cf = fish tissue concentration
If = ingestion rate of fish
Cs = sediment concentration
Is = ingestion rate of sediment
Cw = water concentration
Iw = Ingestion rate of water
AUF = Area Use Factor
BW = Body Weight
Fl = Lipid Content of Fish
BSAF = Biota-Sediment Accumulation Factor
Foc = Fraction Organic Carbon

$\frac{Cf = Fl*BSAF*Cs}{Foc}$

Ecological RERA

Table 5 - Summary of risk reduction achieved by proposed action of sediment removal to native sediment for the piscivorous bird endpoint.

Receptor	Exposure Route	Chemical of Concern	RI-RA mean sediment concentration (mg/kg)	RI-RA EEQ		Native Sediment mean concentration (mg/kg)	Native Sediment EEQ
Piscivorous Birds	Direct contact, Ingestion of sediment, Ingestion of prey	4,4'-DDT	1.74E-01	43		4.62E-03	1.14
		4,4'-DDE	8.29E-02	94		1.03E-02	11.7

Piscivorous Bird EEQs are based on mean sediment concentrations, average inputs, and using the LOAEL

Ecological RERA
Table 6 - 2008 Native Sediment Data compared to piscivorous bird based PRG

COCs	PRG[1]	Source[2]	Mean of 2008 Navtive Sediment Data	2008 Native Sediment Sampling Data																			
				NTC17PCSD49	NTC17PCSD48		NTC17PCSD47		NTC17PCSD46		NTC17PCSD45		NTC17PCSD44		NTC17PCSD43		NTC17PCSD42		NTC17PCSD41		NTC17PCSD40	
Pesticides/PCBs (µg/kg)																							
4,4'-DDE	16.3	Tier 2b	10.3	68	1.2	J	0.76	UJ	0.76	UJ	0.78	UJ	14	J	0.83	UJ	8.4	J	7.4	J	0.92	J
4,4'-DDT	75.2	Tier 2b	4.6	19	1.4	J	0.76	UJ	0.76	UJ	0.78	UJ	13	J	0.83	UJ	5	J	3.9	J	0.79	UJ

J - Estimated concentration
U - Analyte not detected

1. PRGs from Table 2-6 of Site 17 FS
2. Tier 2b - Site spectic Sediment Screening Concentrations, Alternative Objectives from
memo "Sediment Cleanup Objectives for Select Contaminants Found at Great Lakes Naval Training Center, Great Lakes, Illinois; 31 January 2002; Alternative Objectives."

APPENDIX D

VOLUME CALCULATIONS

CLIENT:	NAVAL STATION GREAT LAKES	JOB NUMBER:	112G01021
SUBJECT:	SITE 17 - NORTH BRANCH PETTIBONE CREEK		
BASED ON:	Field Measurements/Public Works Drawings	DRAWING NUMBER:	
BY: TWS Date: 5-19-09	CHECKED BY: Date:	APPROVED BY:	DATE:

OBJECTIVE:

The purpose of this calculation is to estimate the volume of sediment within the North Branch of Pettibone Creek between the upstream culverts (where Pettibone Creek surfaces on Naval Station property) and the Boat Basin (through which Pettibone Creek flow prior to discharging into Lake Michigan).

APPROACH:

1. Using average steam widths developed with field observations and field measurements, determine the volume of sediment within the sections of Pettibone Creek from which sediment and material will be removed. In addition calculate the estimated total volume of material to be removed from the stream based on field observation of rock and manmade material.

2. Estimate the volume of material removed from the stream that has a nominal diameter of 3 inches or more. This material will be retained for stream restoration.

3. Estimate the volumes of materials needed to restore the disturbed stream length.

REFERENCES:

Public Works - Storm and Stream Drawing for Area - A, Code IDENT No. 80091.

Tetra Tech field observations and measurements reported in the Site 17 Remedial Investigation Report (TtNUS, 2003) and in the Site 17 Feasibility Study (TtNUS, 2005).

CALCULATIONS:

1) Excavation

As determined during the December 2008 Investigation the average sediment depth in Site 17 - North Branch Pettibone Creek and Tributary is approximately 1 foot. The following calculates the volume of sediment to be removed based on the field observations, length of stream segments and an excavation depth of 1 foot.

Stream Segment	Width (ft)	Length (ft)	Depth (ft)	Volume (cy)
Pettibone Creek North Branch (from Boat Basin to confluence of north and south branch)	25	1,000	1	930
Pettibone Creek North Branch (from north and south branch confluence to north branch tributary)	20	1,580	1	1,170

CLIENT: NAVAL STATION GREAT LAKES		JOB NUMBER: 112G01021	
SUBJECT: SITE 17 - NORTH BRANCH PETTIBONE CREEK			
BASED ON: Field Measurements/Public Works Drawings		DRAWING NUMBER:	
BY: TWS Date: 5-19-09	CHECKED BY: Date:	APPROVED BY:	DATE:

Pettibone Creek North Branch (from north branch tributary to culverts at northern property boundary)	15	960	1	530
North Branch Tributary (north of north and south branch confluence)	15	900	1	500
Total volume of sediment excavation based on stream dimensions =				**3,130**

Note 1 Stream width is an average width as reported in the Site 17 RI and FS. The reported values are based on field observations and measurements.

Note 2 Stream length was measured from figure 1 provided on page 4 of 4 of this calculation.

Note 3 Averaging of depth measurements accounts for areas where sediment thickness is less than 0.5 feet thick and greater than 3 feet thick.

2) Material Processing

Following stream material excavation and dewatering, the excavated material will be screened to segregate the rock material with a nominal diameter of 3 inches or more from the sediment and remaining rock material. Based on field observations and stream photographs the estimated volume of stone with in the excavated material is approximately 20 percent.

Total volume of natural material removed from the stream =	3,130	cy
Assumed percentage of rock greater than 3-inches in size =	20	%
Total volume of rock retained for restoration =	630	cy
Assumed Volume of Rock atop Sediment =	200	cy
Volume of Rock Retained for Restoration =	630	cy
Volume of Rock found in the Excavated Sediment =	430	cy
Assumed Volume of Man-made Material within the Stream =	30	cy
Volume of Material Available for Stream Restoration =	**630**	**cy**
Volume of Material Disposed Off-Site =	**2,500**	**cy**

Volume of material disposed off-site equals the total amount of natural material removed from the stream, minus the volume of natural material retained for stream restoration, plus the volume of man-made material removed from the stream (8,640 - 1,730 + 30 = 6,940).

Non-Hazardous Subtitle D Material =	**2,470**	**cy**
Non-Hazardous Construction Debris =	**30**	**cy**

3) Restoration Materials

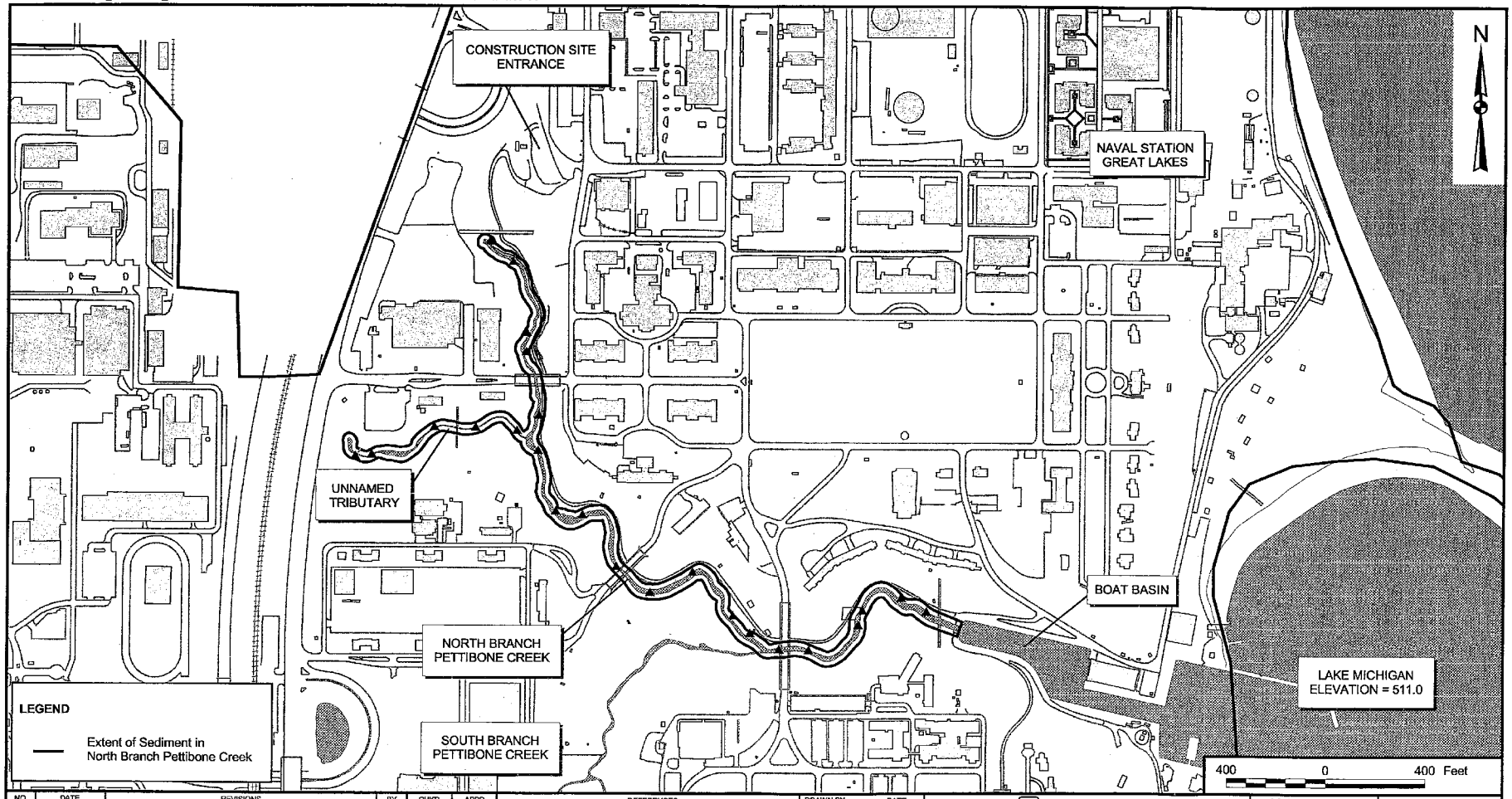
CLIENT: NAVAL STATION GREAT LAKES			JOB NUMBER: 112G01021
SUBJECT: SITE 17 - NORTH BRANCH PETTIBONE CREEK			
BASED ON: Field Measurements/Public Works Drawings			DRAWING NUMBER:
BY: TWS Date: 5-19-09	CHECKED BY: Date:		APPROVED BY: DATE:

Following verification of contaminated sediment removal, the stream will be restored to its pre-construction stream bed profile. The existing stream bed profile is represented by the current top of sediment elevation.

The materials used for stream restoration will be made up of bank-run sands and gravels or similar material, retained stone from material processing, and large rock installed to stabilize stream banks.

Volume of Bank-Run Sands and Gravel Needed for Restoration = 2,500 cy

P:\GIS\GREATLAKES_NTC\SITE7_SITE17 SAMPLE LOCATIONS BAK\SITE17 EXTENT OF EXCAVATION 5/19/09 SS



NO.	DATE	REVISIONS	BY	CHKD	APPD	REFERENCES

DRAWN BY S. STROZ	DATE 2/26/08
CHECKED BY T. SMITH	DATE 5/19/09
COST/SCHEDULE-AREA	
SCALE AS NOTED	

Tetra Tech NUS, Inc.

EXTENT OF EXCAVATION
SITE 17 - PETTIBONE CREEK RAP
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER 01021	OWNER NUMBER 0474
APPROVED BY RFD	5/19/09
APPROVED BY —	DATE
DRAWING NO. FIGURE 3-1	REV 0

APPENDIX E

SUPPLEMENTAL SPECIFICATIONS

SUPPLEMENTAL SPECIFICATIONS
SITE 17 – PETTIBONE CREEK RAC
NAVAL STATION GREAT LAKES
GREAT LAKES, ILLINOIS

EMAC Contractor Requirements

The Environmental Multiple Award Contract (EMAC) contractor will be responsible for performing the following work:

1. Attend pre-RAP implementation conference.
2. Submit documentation in accordance with the EMAC 'Basic Contract' 30 days prior to beginning work to allow the Navy sufficient time to review and comment. The EMAC contractor will then incorporate Navy comments into the documents. These documents include the following:
    - Work Plan
        - Excavation and Handling Plan
        - Hazardous/Waste Management Plan
        - Environmental Protection Plan
        - Erosion and Sediment Control Plan
        - Stormwater Pollution Prevention Plan
        - Transportation and Disposal Plan
    - Site Specific Health and Safety Plan (SSHSP) and Activity Hazard Analysis
    - Project Quality Control Plan (QCP)
3. Acquire permits, including but not limited to the following:
    - Digging Permit (NWSCC 11000/3)
    - IEPA General Stormwater Permit
4. Mobilize required equipment and personnel to excavate the indicated contaminated sediments.
5. Construct and maintain the required erosion and sediment control devices for the duration of the project.
6. Construct required support facilities including, but not limited to, temporary gravel construction entrance, temporary access trails, dewatering pad, decontamination pad(s), and material storage areas.
7. Excavate, transport, and dispose PAH-, Pesticide-, PCB-, and metal-contaminated sediments.
8. Restore stream to pre-construction condition and alignment.
9. Remove all temporary support facilities, leaving perimeter erosion and sediment controls in place until revegetation is complete and as instructed by the Navy.
10. Restore areas used for temporary support facilities (regarde and stabilize to pre-construction conditions.
11. Demobilize equipment and personnel.

In addition to the QC submittals and Safety and Health submittals required by the EMAC Basic Contract, the EMAC contractor shall submit the following to the Navy:

- Field work reports in accordance with Part 6.4 Section C of the Basic Contract.
- Contractor 40 CFR 1910.120 Employee Training Certificates for all Contractor employees scheduled to be on-site.
- Erosion and Sediment Control installation and inspection logs.
- Copies of Naval Station Great Lakes specific permits.
- Certification and sampling results for backfill material and topsoil. A minimum of one sample per borrow source is required.
- Waste transportation subcontractor name, address, contact name, telephone number, and USDOT number.
- Hazardous waste disposal facility name, address, contact name, telephone number, and USEPA and State identification numbers, if required.

- Solid waste disposal facility name, address, contact name, telephone number, USEPA and State identification numbers.
- Copies of Treatment/Disposal Facility Permits.
- Waste profiles, complete waste characterization results, and any waste disposal facility pre-approval or approval documentation.
- Work Site Decontamination Certificates (verification that all vehicles equipment and containers were properly decontaminated prior to leaving the work site).
- Disposal Site Decontamination Certificates (verification that vehicles and containers were decontaminated prior to leaving the disposal facility).
- Shipment Manifests (manifests and other documents required to ship waste).
- Delivery Certificates (verification that waste was received at identified waste disposal facility).
- Treatment and Disposal Certificates (verification that waste was successfully received and disposed).
- Decontamination Log.

The EMAC contractor-provided information will be compiled in the project CTO Closure Report to be prepared by the Navy.

Supplemental Specifications

In addition to the performance specifications presented in the Basic Contract, the EMAC contractor shall perform the activities in accordance with the supplemental specifications provided below.

General Requirements

The EMAC contractor is advised that this project is subject to Federal, State, and local regulatory agency inspections and review for compliance with environmental laws and regulations. The EMAC contractor shall fully cooperate with any representative from any Federal, State, or local regulatory agency who may visit the job site and shall provide immediate notification to the Officer in Charge of Construction (OICC), who shall accompany them on any subsequent site inspections. The EMAC contractor shall complete, maintain, and make available to the OICC, Facility, or regulatory agency personnel all documentation relating to environmental compliance under applicable Federal, State, and local laws and regulations. The EMAC contractor shall immediately notify the OICC if a Notice of Violation, Notice of Deficiency, or similar regulatory notice is issued to the EMAC contractor.

The EMAC contractor shall be responsible for all damages to persons or property resulting from EMAC contractor fault or negligence as well as for the payment of any civil fines or penalties which may be assessed by any Federal, State, or local regulatory agency as a result of the EMAC contractor's or any subcontractor's violation of an applicable Federal, State, or local environmental law or regulation. Should a Notice of Violation, Notice of Noncompliance, Notice of Deficiency, or similar regulatory agency notice be issued to the Government or Facility owner/operator on account of the actions or inactions of the EMAC contractor or one if its subcontractors in the performance of work under this contract, the EMAC contractor shall fully cooperate with the Government in defending against regulatory assessment of any civil fines or penalties arising out of such actions or inactions.

After approval of the EMAC contractor's Work Plan and before commencement of work the EMAC contractor shall submit to the OICC the required certifications. As requested by the OICC, the Navy Representative for this project may review and provide surveillance for the OICC to determine if EMAC contractor's submittals comply with the contract requirements.

The EMAC contractor shall be required to commence work on the approved EMAC contractor's Work Plan within 5 calendar days after receiving the notice to proceed and to prosecute the work diligently after receiving the notice to proceed.

Naval Station Great Lakes will remain in operation during the entire construction period. The EMAC contractor shall schedule the work as to cause the least amount of interference with the Facility. Work schedules shall be subject to the approval of the OICC. Permission to interrupt Facility road services shall be requested in writing a minimum of 15 calendar days prior to the desired date of interruption. The OICC shall be notified 48 hours prior to starting excavation activities.

Regular work hours shall consist of an 8-1/2 hour daily period established by the OICC, Monday through Friday, excluding Government holidays. The EMAC contractor should assume an 8-1/2 hour daily period. Working outside of the 8-1/2 hour daily period will require approval by the OICC. Work hours shall be established during the pre-RAP implementation conference.

On-site storage, laydown, material handling, and decontamination activities shall be limited to areas approved by the OICC.

During the progress of construction activities, the work area and adjacent areas shall be kept clean and free of rubbish, surplus materials, and unneeded construction equipment. No material or debris shall be allowed to flow or wash into watercourses, ditches, gutters, drains, or pipes. Upon completion of the work, the EMAC contractor shall sweep paved areas and rake clean landscaped areas, and remove waste and surplus materials, rubbish, and construction facilities from the site.

Work Restrictions

EMAC contractor personnel employed at the Facility shall become familiar with and obey Facility regulations and keep within the limits of the work and avenues of ingress and egress as directed. Personnel shall not enter any restricted areas unless required to do so and until cleared for such entry. The EMAC contractor's equipment shall be clearly marked for identification.

The EMAC contractor shall indicate on the construction schedule any activity that could potentially interrupt Facility operations. The EMAC contractor shall notify the OICC in writing 15 calendar days prior to the required interruption.

Facilities and Services

Provide utility permits in accordance with the Basic Contract.

Naval Station Great Lakes shall make all reasonably required amounts of utilities available to the EMAC Contractor from existing outlets and supplies, as indicated. The amount of each utility service consumed shall be charged to or paid for by the EMAC Contractor at the prevailing rates charged to Naval Station Great Lakes or shall be furnished at no charge as indicated. The EMAC Contractor shall carefully conserve any utilities furnished without charge.

The point at which Naval Station Great Lakes will deliver such utilities or services and the quantity available will be identified by Naval Station Great Lakes.

The EMAC Contractor, at its expense and in a workmanlike manner satisfactory to the Contracting Officer, shall install and maintain all necessary temporary connections and distribution lines, and all meters required to measure the amount of each utility used for the purpose of determining charges. Before final acceptance of the work by the Government, the EMAC Contractor shall remove all the temporary connections, distribution lines, meters, and associated paraphernalia.

Electric – Electrical power available, primary voltage is [2400 volt 3 phase, 3 wire, 60 cycle AC. Secondary voltages may be 120/208 or 120/240 volts.] Final taps and tie-ins to the Naval Station Great Lakes utility grid will be made by Naval Station Great Lakes electric shop.

Potable Water – Potable water is not available. EMAC Contractor shall provide potable water for use by all personnel.

Water – A reasonable quantity of water is available at [Building [ ] fire station] at no charge. Provide backflow preventor devices on connections to potable water supplies. Under no circumstances will taps to Naval Station Great Lakes fire hydrants be allowed for obtaining water.

Telephone – Telephone service is not available.

Sanitary Facilities - Provide temporary sanitary facilities for use by all personnel in accordance with the Basic Contract.

Municipal Waste – Municipal waste storage and disposal is not available.

Sewer – Water resulting from personnel and equipment decontamination, excavation dewatering, and water from materials handling pad may be discharged to the Naval Station Great Lakes sanitary sewer system, subject to approval by Naval Station Great Lakes based on characterization samples of water to be discharged.

Site Personnel Qualifications

Site Superintendent - The EMAC contractor shall designate a Site Superintendent who shall have responsibility and authority to direct work performed. The Site Superintendent shall be responsible for the management and execution of all site activities in accordance with the RAP, approved EMAC contractor's Work Plan, and all Federal, State, and local laws and regulations. The Site Superintendent may not act in the dual role as the Project Quality Control Manager or Site Health and Safety Specialist (SHSS). The Site Superintendent shall have, as a minimum, the following qualifications:

- A minimum of six years site superintendent experience.
- A minimum of three years experience on hazardous, toxic and radioactive waste (HTRW) projects.
- Familiar with the requirements of the U.S. Army Corps of Engineers Safety - Safety and Health Requirements (EM 385-1-1).
- Experience in the areas of hazard identification and safety compliance.

Project Quality Control Manager - The EMAC contractor shall designate a Project Quality Control (QC) Manager who shall assist and represent the QC Program Manager in continued implementation and enforcement of the approved Project QC Plan. The QC Program Manager or Project QC Manager shall be physically present at the project site whenever work is in progress. The Project QC Manager may be dual hatted with the SHSS if qualified. The Project QC Manager shall have, as a minimum, the following qualifications:

- A minimum two years experience as a Project QC Manager.
- A minimum of ten years combined experience in the following positions: project superintendent, QC manager, project manager, project engineer or construction manager on similar size and type of construction contracts which included the major trades that are part of this RAP.
- Alternatively, the above ten year combined experience requirement may be satisfied by providing a professional engineer registered in the State of Illinois having at least two years experience as a Project QC Manager.
- Familiar with the requirements of the U.S. Army Corps of Engineers Safety - Safety and Health Requirements (EM 385-1-1).
- Experience in the areas of hazard identification and safety compliance.

Site Health and Safety Specialist - The EMAC contractor shall designate a Site Health and Safety Specialist (SHSS) who shall assist and represent the EMAC contractor's Health and Safety (H/S) Manager in continued implementation and enforcement of the approved Site Health and Safety Plan (SSHSP). The SHSS shall have the on-site responsibility and authority to modify and stop work, or remove personnel from the site if working conditions change which may effect on-site and off-site health and safety. The SHSS shall be physically present at the project site at all times. The SHSS may be dual

hatted with the Project QC Manager if qualified. The SHSS shall have, as a minimum, the following qualifications:

- A minimum of five years safety work on similar projects.
- 30-hour OSHA construction safety class or equivalent within the last five years.
- An average of at least 24 hours of formal safety training each year for the last five years.
- Competent person status for at least the following:
    - excavation,
    - health hazard recognition, evaluation and control of chemical, physical and biological agents, and
    - personal protective equipment and clothing to include selection, use and maintenance.
- First aid and cardiopulmonary resuscitation (CPR) qualified.

Quality Control

Approval of the QC Plan is required prior to the start of construction. The OICC reserves the right to require changes in the QC Plan and operations as necessary to ensure the specified quality of work. The Contracting Officer reserves the right to interview the QC Manager at any time in order to verify his/her submitted qualifications.

The OICC shall be notified, in writing, of any proposed changes to the QC Plan, at a minimum of seven calendar days prior to the implementation of the proposed change. Proposed changes must be approved by the OICC.

Combined Contractor Production Report/Contractor Quality Control Report (CPR/CQCR) is required for each day that work is performed. CPR/CQCRs are to be prepared, signed, and dated by the Project QC Manager.

Safety and Occupational Health Requirements

The SHSS and EMAC contractor representatives who have a responsibility or significant role in accident prevention shall attend the pre-RAP implementation conference. The purpose of the conference is for the EMAC contractor and the OICC to become acquainted and explain the functions and operating procedures of their respective organizations and to reach mutual understanding relative to the administration of the overall project before the initiation of work. The EMAC contractor shall discuss the details of the work identified in the approved EMAC contractor's Work Plan and discuss which construction phases will require significant or additional activity hazard analysis. In addition, a schedule for the preparation, submittal, review, and acceptance of additional hazard analysis shall be established to preclude project delays. Lastly, deficiencies in the submitted accident prevention report will be brought to the attention of the EMAC contractor at the conference. The EMAC contractor shall revise the plan to correct deficiencies and resubmit the plan for acceptance.

New employees (prime or subcontractor) will be informed of specific site hazards before they begin work. Documentation of this orientation shall be kept on file at the project site.

If unforeseen materials hazardous to human health are encountered during operations, that portion of the work shall be stopped and the OICC shall be notified immediately. Within 14 days, the Navy will determine if the material is hazardous. If the material is not hazardous or poses no danger, the OICC will direct the EMAC contractor to proceed without change. If the material is determined to be hazardous or to pose danger, and handling of the material is necessary to accomplish the work, the Contracting Officer will issue modifications to the proposed work.

Equipment shall be operated by designated qualified operators. Proof of qualifications shall be kept on the project site for review. Manufacturer's specifications or owner's manual for the equipment shall be on site and reviewed for additional safety precautions or requirements. Such additional safety precautions or requirements shall be incorporated into the activity hazard analysis. Mechanized equipment shall be inspected in accordance with manufacturer's recommendations for safe operations by a competent

person prior to being placed into use. Daily checks or tests shall be conducted and documented on mechanized equipment by designated competent persons.

The competent person for excavations performed as a result of contract work shall be on-site when excavation work is being performed, and shall inspect and document the excavations daily prior to entry by workers. The competent person must evaluate all hazards, including atmospheric, that may be associated with the work, and shall have the resources necessary to correct hazards promptly.

Environmental Controls

An Erosion and Sediment Control Plan is included in the RAP. The Erosion and Sediment Control Plan describes the location and description of all erosion and sediment control measures, a sequence of construction to be followed, graphic details of all erosion and sediment control measures to be used. At a minimum the EMAC contractor should include this Erosion and Sediment Control Plan provided in this RAP, in their required submissions. The Erosion and Sediment Control Plan submitted by the EMAC contractor will be the official Erosion and Sediment Control Plan submission and must include an approval sign-off block/page containing the names of the Facility and EMAC contractor contacts, whose signatures indicate plan acceptance/approval.

The EMAC contractor shall strictly follow the Erosion and Sediment Control Plan and maintain all measures used during construction. Modifications to the approved Erosion and Sediment Control Plan shall be submitted to the OICC and the Illinois Environmental Protection Agency (IEPA) for approval. No modifications to the approved Erosion and Sediment Control Plan will be allowed until these changes have been approved by the OICC and IEPA and three copies of the approved modifications have been submitted to the OICC and one copy of the approved modifications have been submitted to IEPA.

Transportation and Disposal of Contaminated Material

The EMAC contractor shall be solely responsible for complying with all Federal, State, and local requirements for decontamination of vehicles, equipment, and containers and shall bear all responsibility and cost for any noncompliance. In addition to these requirements, the EMAC contractor shall perform the following:

- Visually inspect all vehicles, equipment, and containers leaving the work site for proper decontamination.
- Prepare and maintain a written decontamination log.

The EMAC contractor shall be solely responsible for complying with all Federal, State, and local requirements for transporting contaminated materials through the applicable jurisdictions and shall bear all responsibility and cost for any noncompliance. In addition to these requirements, the EMAC contractor shall perform the following:

- Inspect and document all vehicles and containers for proper operation and covering.
- Inspect all vehicles and containers for proper markings, manifest documents, and other requirements for waste shipment.

All contaminated materials removed from the site shall be disposed in a treatment/disposal facility permitted to accept such material.

The EMAC contractor shall properly dispose of investigation derived waste, personnel protective equipment, and miscellaneous wastes associated with implementation of the RAP, including sampling and analysis that are generated by the Navy representatives.

APPENDIX F

EROSION AND SEDIMENT CONTROL STANDARDS

1. INTRODUCTION

Design procedures and standards are presented in this chapter for implementing sediment, runoff and soil stabilization control measures. Each group of control measures presented in the planning matrix (Fig. 4-1) has design guidelines, steps in design, sample design, and requirements for plans, specifications and maintenance. In addition, sections on rainfall runoff and flood routing are included in Chapter 7 because many control measures are selected and designed based on the volume and velocity of runoff through the measure.

Sample problems in this chapter use basic engineering equations instead of tables, charts or nomographs, which all users might not have. It is assumed that users have a basic understanding of the equations, and have appropriate engineering handbooks required to use the equations. References to shortcut methods of problem solutions and additional sample problems are given.

For the purpose of this handbook it was determined that use of the word "should" be used throughout to indicate that there is sound engineering reason for use of the method or procedure described. Use of the would "shall" has been avoided to eliminate the likelihood of interpretation of the word as mandatory in the legislative sense.

The selection of the appropriate control measure will depend upon an analysis of the existing site conditions, the intended use of the site, and the duration of the control measures.

Site Analysis

A thorough site evaluation is necessary to determine what control measures would be appropriate. Included in the evaluation should be an analysis of the existing vegetation, surface topography, and subsurface conditions. The potential retention of existing vegetation, particularly plants with root systems capable of soil stabilization, may reduce the intensity of the required control measure. The site's surface stability is determined by slope, length and gradient, soil permeability and structural characteristics, and local climate conditions, particularly rainfall amount.

Site Use

The intended use of the site requiring sediment, runoff and soil stabilization should be identified so that a measure(s) may be selected that is compatible with the intended use from the standpoint of expected maintenance, adaptability, and aesthetics. Certain intended uses would preclude certain kinds of control measures. These must be identified before control measures are selected. Also, the surface protection measures must provide the durability and function called for by varying uses that include athletic fields, passive parks, detention basins, and wildlife areas.

Duration of Control

The length of time for which the control measure will be needed should also be determined. A site needing control measures for 12 months or less could rely upon a temporary control measure while a site needing control measures for more than 12 months would need permanent control measures. Also, certain design quantities, such as sediment volume, are determined from length of exposure of soils to erosion.

2. SOIL STABILIZATION METHODS

Vegetative Stabilization

The degree of success obtained in establishing vegetative control of an area can be increased by adhering to the following basic procedures:

Subgrade Preparation

Following all site construction, but immediately prior to topsoil placement, the subgrade should be scarified to a depth of four inches (4") by disking or harrowing to permit the bonding of the topsoil

and the subsoil. All final subgrades should have adequate surface drainage prior to the addition of topsoil.

Topsoil Spreading

Topsoil is the surface layer of the soil profile, generally characterized as being darker than the subsoil due to the presence of organic matter. It is the zone of major root development, holding much of the nutrients and water available to plants.

Although topsoil provides an excellent growth medium, there are disadvantages to its use. Stripping, stockpiling, and reapplying topsoil, or importing topsoil, may not always be cost-effective. Topsoiling can delay seeding or sodding operations, increasing the exposure time of denuded areas. Most topsoil contains weed seeds, and weeds may compete with desirable species. Advantages of topsoil include its high organic matter content and friable consistence, water-holding capacity, and nutrient content.

In site planning, the option of topsoiling should be compared with that of preparing a seedbed in subsoil. The clay content of subsoils does provide high moisture availability and deter leaching of nutrients, and when properly limed and fertilized, subsoils may provide a good growth medium which is generally free of weed seeds.

Topsoiling is strongly recommended where ornamental plants or high-maintenance turf will be grown. Topsoiling is a required procedure when establishing vegetation on shallow soils, soils containing potentially toxic materials, and soils of critically low pH (high acid) levels.

If topsoiling is to be done, the following items should be considered:

- Check if an adequate volume of topsoil exists on the site. Topsoil should be spread at a compacted minimum depth of four inches.
- Location of the topsoil stockpile so that it meets specifications and does not interfere with work on the site.
- Allow sufficient time in scheduling for topsoil to be spread and bonded prior to seeding, sodding, or planting.
- Care must be taken not to apply topsoil to subsoil if the two soils have contrasting textures. Sandy topsoil over clayey subsoil is a particularly poor combination, as water creeps along the junction between the soil layers and causes the topsoil to slough.

Soil Amendments

Whenever possible, a soil test should be performed to determine exact soil deficiencies. If the soil test indicates a pH of 6.0 or below, then ground limestone should be spread uniformly over the soil surface at a rate of one ton per acre (50 pounds per 1,000 square feet) to raise the pH 0.50 of a point. A soil pH of 6.0 to 7.5 is recommended.

Nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) should be applied according to the needs identified by the soil test. If a soil test is not available, the following commercial fertilizers should be applied prior to seeding or sodding:

GRASS MIXTURES

130 pounds each of N, P_2O_5 and K_2O per acre.

(3.0 pounds per 1000 sq. ft.)

GRASS AND LEGUME MIXTURES

65 pounds of nitrogen per acre (1.5 pounds per 1000 sq. ft.) and 130 pounds each of phosphorus and potassium per acre (3.0 pounds per 1000 sq. ft.)

SOD

Same combination as for grass mixtures.

For soils low to very low in phosphorus, double the phosphorus application for all types of seeding and sodding to promote vigorous root development.

The soil amendments should be uniformly spread over the surface. They should then be mixed into the soil to a depth of three inches by disking or harrowing. This tilling operation should also break up any remaining large chunks or clods of topsoil.

Clean Up and Preparation

All remaining sticks, roots, stones and oth foreign material larger than one and one-ha

inches as well as any stakes, trash or other debris which may interfere with seeding or sodding operations, growth, or maintenance should be removed.

A final raking of the topsoil should be performed either by hand or mechanical means to create a smooth, uniform seedbed. This operation should result in a firm seedbed comprised of soil aggregates ranging from fine to coarse, with none larger than one and one-half inches in diameter.

Seeding and Sodding

SEEDING

After subgrade preparation, topsoil spreading, fertilizing and final seedbed preparation are completed, the site is ready for seeding. Whether the seeding is to be permanent or temporary, the time of year significantly influences site conditions, required maintenance, and ultimate degree of success. Figure 6-2 suggests optimum dates for temporary or permanent seeding operations. The shaded portions indicate periods when soil moisture and temperature are more likely to be favorable for rapid seed germination and growth. They are based on average annual weather conditions.

Seeding operations scheduled during the optimum dates encourage vigorous germination and growth. Frequently, however, it is difficult to control construction timing, and it may be desirable to consider a dormant or winter seeding.

Dormant seeding is the application of seed at a time when soil temperature is too low for seed germination. See Figure 6-2 for optimum seeding dates.

If construction is completed after November 1 in Zone I and November 15 in Zones II and III and soil conditions are satisfactory and soil temperature is below 50 degrees F, then the procedure for seeding is the same as during seasonal operations: (1) incorporate fertilizer, (2) prepare seedbed, (3) distribute seed, (4) apply mulch.

An alternate application method, overseeding, is used if construction is completed between September 1 and November 1 in Zone I, September 10 to November 15 in Zone II and September 20 to November 15 in Zone III (Figure 6-2) when the soil temperature is above 50 degrees F. The same process is followed except the seed is not applied until after the soil temperature drops below 50 degrees F. The seed is then broadcast over the top of the mulch using increased rates. In Zone I the overseeding can usually be done from November 1 until March 15. In Zones II and III the overseeding can usually be done from November 15 until March 1. The ideal time is the end of February, however, seed should not be distributed on top of snow.

	Use		Sunny (Less than 50% shade)			Shady (More than 50% shade)		
			Wet	Norm	Dry	Wet	Norm	Dry
Permanent Seeding	Cuts, fills, borrow areas, stormwater detention ponds, gully banks, sediment basins, road sides, diversion ridges, filter strips.		2 9	2 4 5 6 9	5 6	1 9	1 4 5 9	1 5
Permanent Seeding	Heavily used areas (athletic fields, playgrounds, etc.)		1	1 4 10	1 4 10	1 7	7	7
Permanent Seeding	Moderately used areas (parks, lawns, etc.)		1	1 4 10	1 10	1 7	1 4 7	7
Permanent Seeding	Areas pending development (longer than one year)	Straw	1 2	2 3 5 8	2 3 5 8	9	9	9
Permanent Seeding	Areas pending development (longer than one year)	Non-straw	10	10	10	7	7	7
Permanent Seeding	Wildlife and natural areas		2 9	3 5 8	6	9	9	9
Permanent Seeding	Vegetative diversion channels		2 5	4 5	5	7	3 7	3
*	Temporary Seedings (less than one year)		11 12 13					

Figure 6-1: Seed Mixture Adaptability Chart

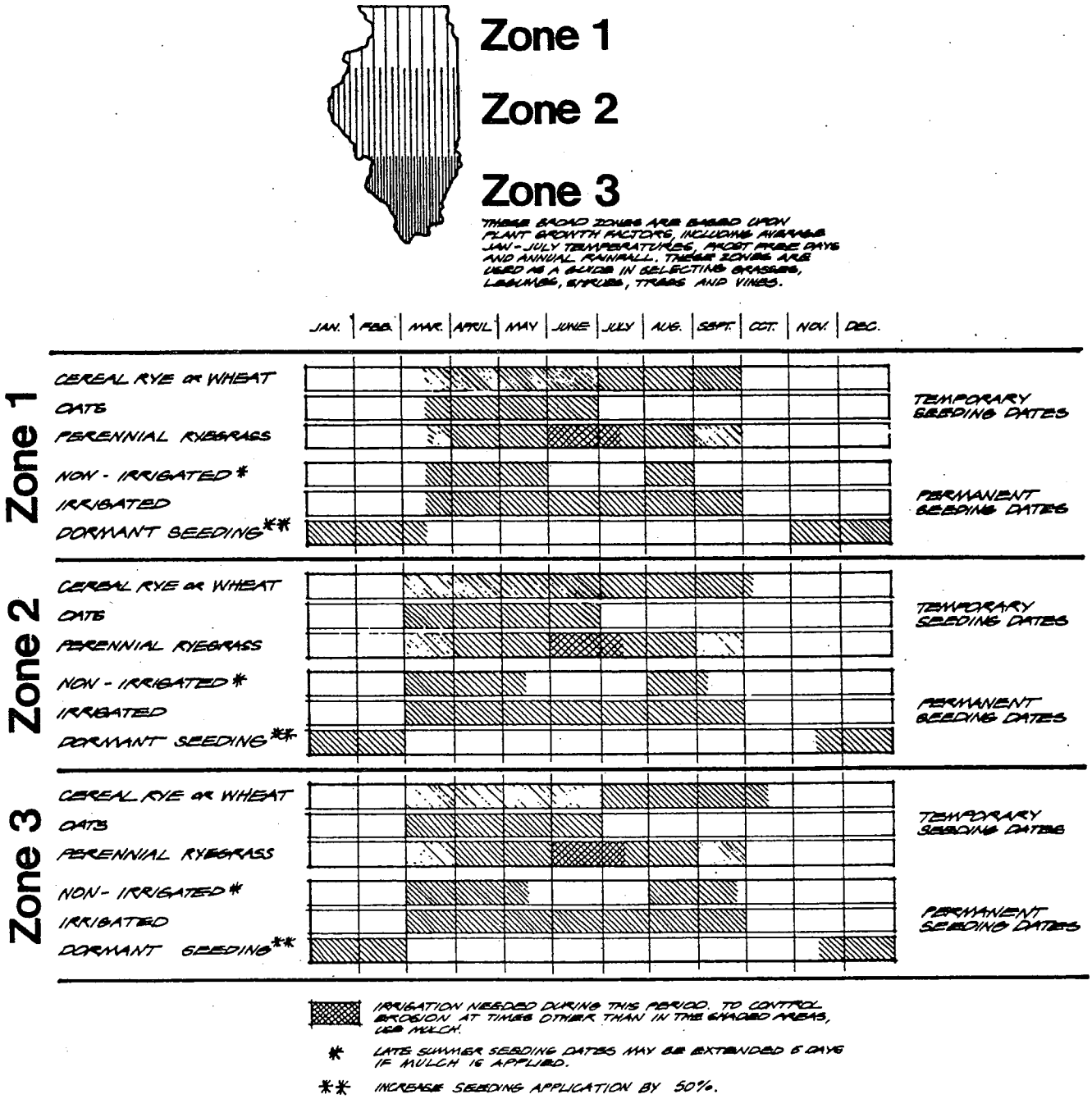


Figure 6-2: Approximate Seeding Dates for Illinois

SPECIES	SOIL CONDITION			Shade Tolerance	Close Mowing to 2-3½ inches	Tromping Tolerance	Fertility Needs	Winter Hardiness	Flooding Tolerance (days)	Mature Height (inches)	Emergence Time (days)	Salt Tolerance		
	Wet	Norm	Dry									Gen.	Soil	Spray
Creeping Red Fescue Festuca rubra	2	1	2	1	1	1	Med.	1	20-25	12-18	7-21			S
Kentucky Bluegrass Poa pratensis	2	1	2	1	1	1	Med.	1	25-35	12-18	10-20			MT
Reed Canarygrass Phalaris arundinacea	1	1	2	2	–	1	High	1	45-50	48	5-21		MT	
Smooth Brome Bromus inermis	1	1	2	2	–	2	Med.	1	24-28	18-24	5-14		MT	
Tall Fescue Festuca L. arundinacea	2	1	1	1	1	1	Low	1	24-35	24-36	5-14		T	
Timothy Phleum pratense	2	1	1	–	2	2	Med.	1	45-50	36	5-14			
Perennial ryegrass Lolium perenne	2	1	2	–	1	2	Med-High	2	15-20	12-18	5-10		MT	
Alfalfa Medicago sativa	–	1	1	–	–	–	High	1	10-14	18	7-12		MT	
Crownvetch Coronilla varia	–	1	1	2	–	–	Low	1	5-10	24	14-21	T		
White Clover Trifolium repens	2	1	–	2	1	2	Med.	2	10-20	18	7-12	S	S	
Red Clover Trifolium pratense	–	1	–	2	–	–	Med.	1	7-10	18	5-10	S	S	
Birdsfoot Trefoil Lotus corniculatus	1	1	1	–	2	2	Med.	1	20-30	18-30	10-15	T	T	

Ranking:
1 Good
2 Medium
– Not tolerant

Salt Tolerance (to both soil salts & spray):
T Tolerance
MT Medium Tolerance
S Slight Tolerance

Figure 6-3: Plant Adaptability

GRASS OR LEGUME SPECIES *Rates are given in pounds per acre	Seeding mix number (t)-(t)												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Creeping Red Fescue							55			16			
Kentucky Bluegrass[1]				90			44			55			
Reed Canarygrass[1]		15											
Smooth Bromegrass			30		30	44		8					
Tall Fescue	240	15			30				44				30
Timothy								2					
Perennial Ryegrass[3]				30							30	30	20
Alfalfa[5] (i)					10			4					
Crownvetch[2] (i)						22							
White Clover (Ladino) (i)			¼							4			
Red Clover (i)								2					
Birdsfoot Trefoil (optional)[4] (i)		4											
Cereal Rye or Wheat											300		30
Oats											300		

1. May be sprigged on 2-3 inch centers instead of seeding.
2. May be sprigged on 2 foot centers instead of seeding.
3. Only use improved varieties of perennial ryegrass (i.e. Manhattan, Pennfine, NK 200, etc.)
4. Susceptible to root rot throughout Southern Illinois.
   Dawn variety may have adequate resistance to persist throughout the state of Illinois.
5. Exclude alfalfa when mixture is used for waterways.

(i) Inoculate all legume seed with the correct bacterial innoculant using label recommendations.

(t) these rates are for temporary use (less than one year) only.

Figure 6-4: Recommended Seed Mixtures

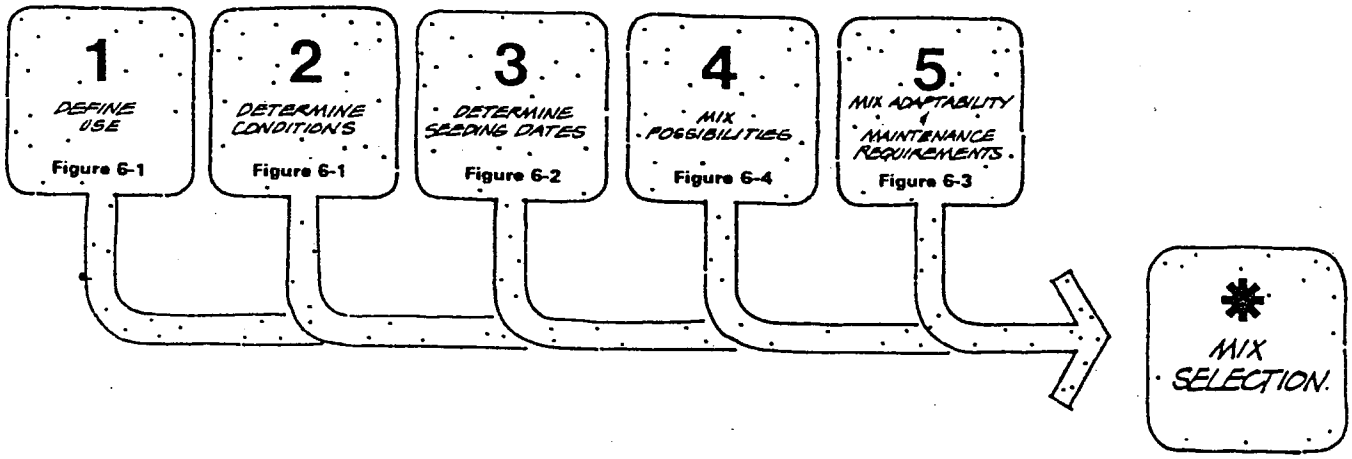


Figure 6-5: Seed Mix Selection Process

Seed mixtures should be selected according to site conditions, planned use, and duration of use as well as the date of seeding. Figure 6-1 lists several site and climatic conditions along with a variety of land uses, including a temporary use. Coded seed mixture suggestions are determined by cross referencing the land use with the site conditions.

The numbered codes refer to specific seed mixtures found in Figure 6-4.

Seeding areas such as expressway rights-of-way may warrant use of salt tolerant species, while a naturalized area may be a setting where use of a native grass mixture providing an unmanicured appearance would be desirable.

If the selected seed mixture contains legumes (alfalfa, crownvetch, clover, birdsfoot trefoil), all legume seeds must be inoculated with a suitable bacterial inoculant. In many cases, the inoculant is specific to the species of legume being used.

When sowing the selected seed mixture, the mixture should be evenly distributed using a commercial turf seeder, broadcast seeder, grain drill, or hydro-seeder. The seed should be planted at a depth of one-quarter to one-half inch. In order to obtain the proper seed depth following broadcasting or hydro-seeding, secondary raking, harrowing or rolling with a corrugated roller is necessary.

Mulching immediately after seeding operations is recommended for temporary surface stabilization and moisture retention. The materials typically used for this purpose are straw or wood cellulose fiber.

Straw should be wheat, barley, oat or rye straw, threshed, air dried and free from noxious weeds and other foreign matter. It should be spread at a rate of two bales per 1,000 square feet.

Wood cellulose fiber should not contain growth or germination inhibiting factors and should be dyed green for metering. It should be applied in a uniform manner at a rate of 1,200 pounds per acre using a hydro-seeding machine. The mixing and application of this material should be performed in accordance with the manufacturers' specifications. This method is best suited to sites having slopes less than 3% in grade and 150 feet in length.

Newly seeded sites should be kept moist, but not wet until the seed has germinated. The quantity of water applied should be increased, and frequency of waterings decreased as the turf becomes established. Inadequate watering greatly increases the chance of seed failure.

SODDING OPERATIONS

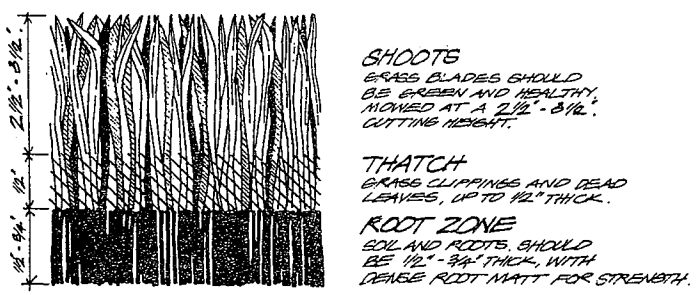
The principal advantages of sod in vegetative surface stabilization are instant erosion protection and flexibility in timing of installation. Sod can be laid any time that it can be cut and kept moist until establishment, although it is best not to lay sod after October 1.

All sod used should be nursery grown Kentucky Bluegrass Mixture free from bent, quack, and merion bluegrass or noxious weeds. The sod strips (18" x 72") should be firm with a compact growth of grass and good root development. The roots should be free from stones and other debris and should contain sufficient moisture to maintain viability during transportation. Sod should be installed immediately after cutting. However, it can be stored at the site for up to 48 hours providing it is kept covered and moist.

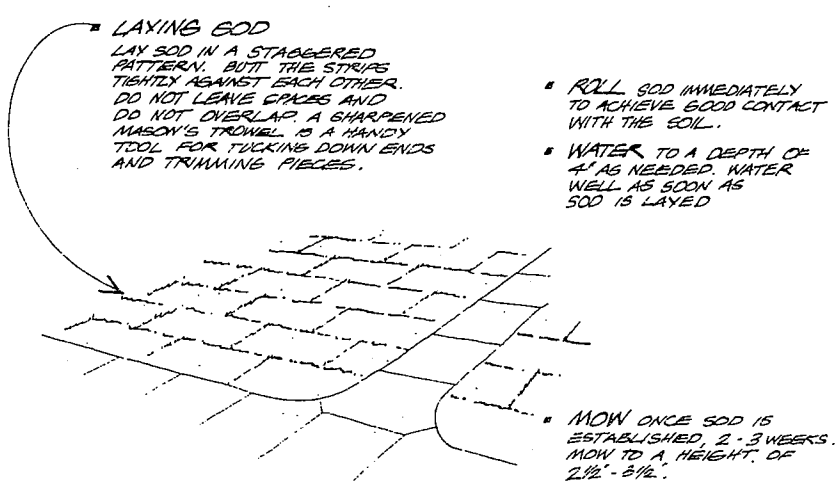
After completion of subgrade preparation, topsoil spreading, fertilizing and final raking as was done for seeding, an additional step involving the compaction of the sod bed by rolling should be performed. In addition, during hot periods the sod bed should be slightly moistened immediately prior to sod laying.

The sod should be unrolled and placed so that all joints are tight fitting and staggered like joints in a brick wall. On slopes, sod is placed perpendicular to the slope. Rolling following placement provides good contact between root zone and soil surface.

On slopes of 3:1 (33 1/3%) or greater, sod should be fastened to the surface using wooden pegs or thin metal hooks that lock into the plastic webbing used in some commercial sod. This prevents slippage while the roots become established.



Appearance of Good Sod



Laying Sod

Maintenance

Vegetative control measures require follow-up maintenance at regular periods. Follow-up maintenance includes the repair of seeded, sodded, or other vegetatively stabilized areas where the desired degree of stabilization has not been achieved. Spring plantings should be inspected during the summer months so that any corrective measures that may be needed can be implemented during the fall planting season. Fall plantings should be inspected during the early spring so that any corrective measures can be performed during the spring planting season.

Where groundcover, whether vegetative or mulch material, has not developed as expected, the area should be redone as soon as possible. The cause for failure should be ascertained and corrected as soon as possible. Such physical conditions such as soil conditions may be unfavorable, resulting in the failure, thereby requiring an alternative approach and/or type of soil cover.

Areas requiring reseeding or resodding should be prepared in the same manner as the original installation. In naturalized areas, reseeding where failures occur will maintain desired surface protection and prevent infiltration of undesirable weeds. Where permanent vegetative cover has been successfully established, a regular maintenance program for fertilization and mowing of grasses should be performed.

FERTILIZING

Turf should be fertilized to produce a healthy dense stand of grass that will crowd weeds and recover quickly from disease and insect injury. Amount and formulation of the fertilizer depends on the grass mixture and level of turf management. Turf management professionals should be consulted for specific recommendations. If no information is available, a total annual rate of 130 pounds of N per acre (3 pounds per 1000 sq. ft.) and 40 pounds each of P_2O_5 and K_2O per acre (1 pound per 1000 sq. ft.) should be applied as split applications, once in the spring and once in the fall. The Nitrogen (N) should be omitted in stands containing legumes.

MOWING

In areas subjected to intense activity, turf should be mowed approximately two and one-half to three and one-half inches long. Generally, no more than one third of the total foliage should be removed during mowing. In naturalized areas, mowing should be restricted to once or twice a year, if the preferred alternative of burning is not allowed or possible. Mowing every third year is sufficient to control woody growth. Such mowing should take place after August 1, when most ground nesting birds have hatched.

Proper mowing height, adequate fertilization, and watering will produce a vigorous turf that will usually not allow weeds to compete. When weeds do occur, timely application of specific herbicides will reduce or eliminate them. Herbicide use must be restricted where legumes are used in the seed mixture.

In both manicured and naturalized settings, salt damage is possible when streets, driveways, and sidewalks are adjacent to the turf. The widespread use of salt to dispel ice in northeastern Illinois during the winter must be accounted for during the planning process. Figure 6-3 indicates relative salt tolerance of several species. Findings are not based on specific levels of salt in the soil or foliage, but rather on injury symptoms.

WATERING

Sod must be watered adequately to prevent desication during the first few weeks after installation. All water should be applied as a spray or dispersion to prevent runoff or damage to the sod and to allow the soaking of the sod and sod bed. The watering should be applied in the absence of adequate rainfall according to the following generally accepted schedule:

WEEK NUMBERS 1 & 2

First watering immediately after laying sod. Three subsequent waterings at 4 day intervals or as needed to prevent desication.

WEEK NUMBER 3

One watering.

Subsequent waterings, if needed, should be applied at weekly intervals. The sod and sod bed should be soaked to a depth of four inches. During the period of intensive watering, new sod should be protected from heavy traffic to avoid disturbing the established finished grade.

Prairie Restoration

A natural prairie setting may be used instead of the seeding mixtures given under permanent vegetative cover. A natural prairie planting has several advantages. The natural prairie is aesthetically pleasing to some people and provides an opportunity for people to see what a natural prairie looks like. The natural prairie requires less maintenance since mowing and fertilizer application is not required to maintain stands. The natural prairie also provides an excellent cover for wildlife. Prairie plantings should be burned once a year to kill off deciduous growth.

Because the climatic and soil conditions of Illinois are different in southern, central, and northern Illinois, the local Soil and Water Conservation District or the Cooperative Extension Service should be consulted for species adaptation and maintenance within a specific area.

Non Vegetative Stabilization

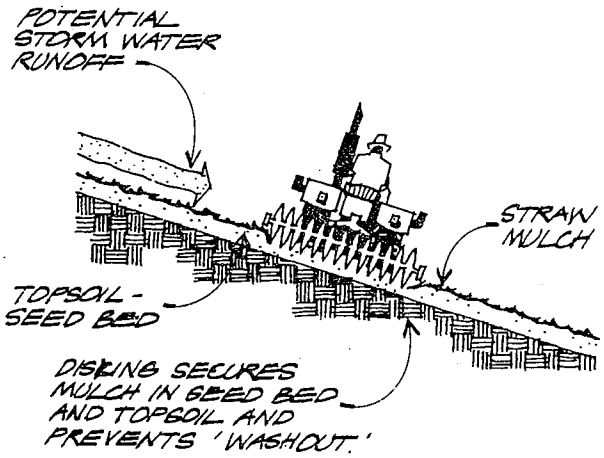
As described earlier, mulching newly seeded surfaces helps to control surface erosion and moisture loss. Additionally, mulch is recommended for sites where turf establishment is difficult because of steep slopes or poor soil.

Temporary Mulching

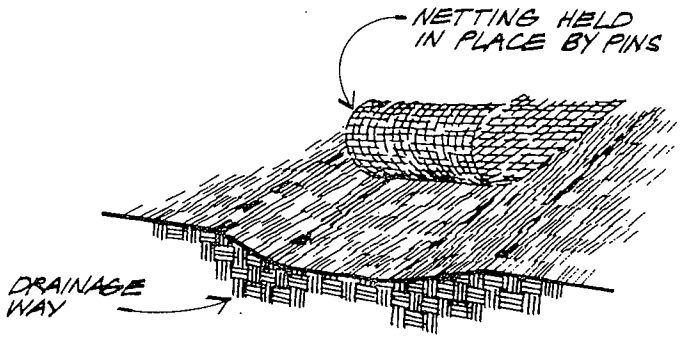
For temporary erosion control, mulch may be applied any time conditions are suitable for spreading and anchoring regardless of vegetative cover. Some examples of suitable mulch include: 1) air dried straw spread uniformly so 80 percent of the surface is covered five or six straws thick at approximately two tons per acre; 2) excelsior blanket, jute netting, paper fabric, or a similar system applied according to manufacturers' specifications, and 3) wood cellulose fiber mixed with water and applied with a hydro-seeder to form a dense mat after drying.

When using straw mulch, it should be anchored using one of the following suggestions:

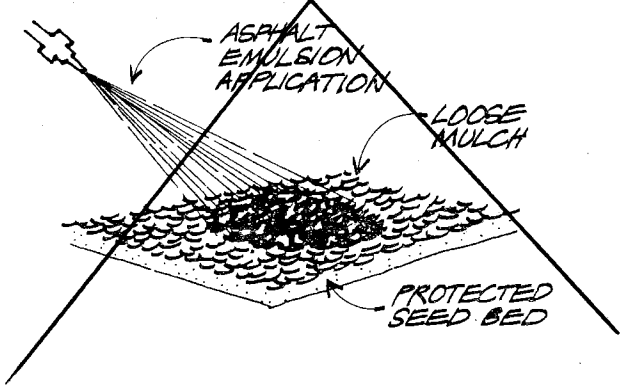
- Press straw into the soil to a two-inch depth by use of a serrated straight disc or a dull farm disc set straight.



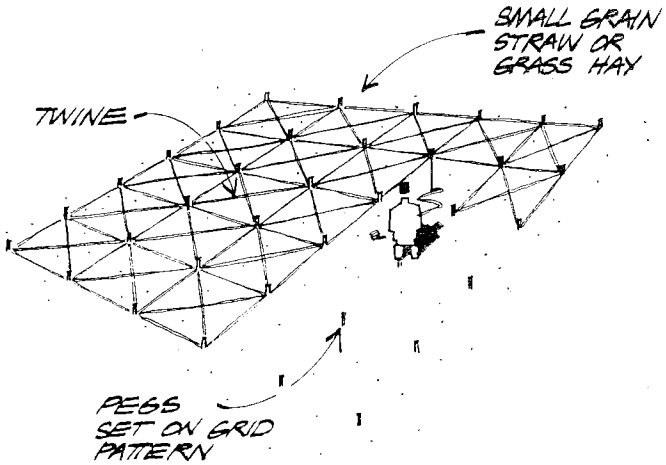
- Apply a netting on top of mulch and secure with staples. Netting should be one inch by two inch mesh. Closer spacing may deter plants from emerging through mulch. Install according to manufacturers' specifications.



- Apply a spray coating of emulsified asphalt. The emulsified asphalt shall conform to the requirements of ASTM specification #977, Type - medium setting, grade MS-2, or Type - slow setting, grade SS-1. The rate of application of emulsified asphalt shall be .05 gallons per square yard (242 gal. per acre). Emulsified asphalt should not be used when air temperatures are below 32 degrees F. Follow manufacturers' specifications on mixing and temperature control.



- Pegs or staples and twine or heavy string may be used to tie down small grain straw or grass hay. Drive eight-to ten-inch stakes into the soil every four feet in a square pattern leaving two to three inches above the surface. Stretch twine between stakes in a square and criss-cross pattern. Secure twine around each stake with two or more turns. Twine may be applied in the same pattern as above and secured with six-inch long wire staples.

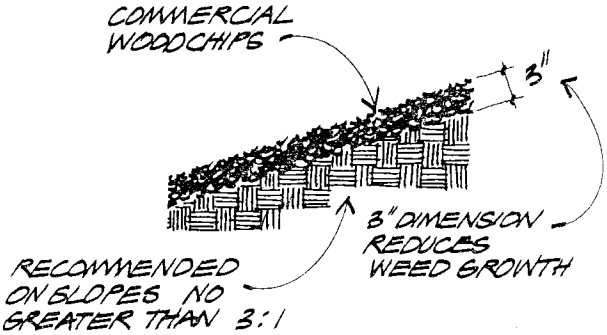


Permanent Mulching

In situations where the establishment of vegetative stabilization is either not practical or desirable, but where erosion control is needed, permanent type mulches such as wood chips or aggregates may be used.

WOOD CHIPS

Chipped wood or chunk bark are typically combined with landscaping of trees and shrubs. If raw wood chips (obtained from chipping site clearings) are used, they may leach nitrogen from the soil during their decomposition process. To alleviate this, an application of a chemical supplement (i.e. ammonium nitrate or ammonium sulfate applied at the rate of ½ to 1 pound per bushel of mulch or a commercial 5N-10P-5K fertilizer applied at the rate of two pounds per 100 square feet) should be added to the mulch.



AGGREGATE COVER

Gravel and crushed stone provide long-term protection against erosion, particularly on short slopes (see Figure 6-6). Before they are applied they should be washed and a black polyethylene sheeting first placed on the ground to prevent seed germination and growth through the aggregate cover. Aggregate should be placed three inches deep at a rate of nine cubic yards per 1,000 square feet (approximately 2,000 lb./cubic yard). Aggregate cover used as a subbase to roads and parking lots should be placed as soon as final grade is reached. Applicable local or IDOT specifications should govern the requirements of this placement.

Maintenance

Permanent mulches will require maintenance from time to time. This primarily involves the replacement of materials to their original level when the level has been substantially reduced due to decomposition for the organic mulches and displacement or disappearance for both the organic and inorganic mulches. Occasional weed removal may be necessary in situations where a polyethylene underlayment was not used. In cases where weed growth becomes a problem, the timely use of the proper herbicide will reduce or eliminate this problem.

MULCH TYPE	Effectiveness in immediate erosion protection	Effectiveness in establishing vegetation (ground cover, trees & shrubs)	COMMENT
Straw alone [1-2]	Medium	Medium	For flat slopes and non-windy areas.
Punched straw [1-2]	Medium	High	Ideal for vegetating fill.
Net-anchored straw [1-2]	High	High	Retains straw on slope.
Tackifiers w/straw [1-2]	High	Medium-High	Straw glued with tackifiers prevents its blowing away.
Woodchips [3]	Medium	Medium	For flat areas and stepped slopes.
Gravel - crushed stone [2-3]	High	Medium	Provides for mechanical protection and vegetative growth.
Mulch blanket [1-2]	Medium	Medium	Binder dissolves leaving fiber mat with net.
Shredded bark [2-3]	High	Medium	Not suitable for groundcover use.
Wood fiber [1-2]	Medium	High	Applied with seed by hydroseeder.
Wood fiber and chemical mulch [1-2]	High	High	Improved retention of fiber on slope and improved germination.
Wood excelsior mat [1-2] (excelsior mat)	High	High	Covered by net and stapled in steep or windy areas.
Fiberglass [1-2]	Medium	Medium	Available in loose or matted form.
Fiberglass & asphalt [1-2]	High	High	May be difficult to mow.
Jute [1-2]	Medium-High	Medium-High	Slope must be smooth.
Straw coconut mat [1-2]	High	High	Covered by net and stapled in steep or windy areas.

(1) Mulching with seeding.
(2) Mulching alone for erosion control.
(3) Ornamental mulching.

Figure 6-6: List of Mulches and Other Protective Coverings

3. RUNOFF CONTROL MEASURES

The following information provides guidance for designing drainageways to carry runoff nonerosively and to direct sediment-laden water to sediment trapping facilities. Guidelines for diversions, waterways, enclosed drainage structures, structural spillways, and outlets are contained in this section. Selection of the appropriate runoff control measure will be dependent on analysis of the existing site conditions, the intended use of the site, and the duration of use of the measure as described in the introduction to this Chapter.

Filter Barriers

For filter barrier considerations the drainage area should be limited to half an acre. For individual lots, the drainage area may be increased to one acre.

When barriers are used along property lines or at the base of slopes, they should be installed parallel to the contours. When used at storm sewer inlets, as much filter area as possible should be provided. Reference 6-27 contains various barriers that may be used around storm sewer inlets.

Filter barriers may be made of straw bales or other filter material. All of the filter materials demonstrate very high filtering efficiencies for sandy sediments, while there is less efficiency and considerable variation in filtering clay and fine silt particles. The table below demonstrates relative efficiencies of materials.

Material	Flow Rate (gal./sq.ft./min.)	Filter Efficiency (%)
Straw	5.6	67
Burlap (10 oz. fabric)	2.4	84
Synthetic Fabric	0.3 (avg.)	97 (avg.)

Source: Va Highway and Transportation Research Council

Figure 6-23: Flow Rates and Filtering Efficiencies of Sediment Filter Materials

Design Guidelines for Straw Bale Barriers

SHEET FLOW APPLICATIONS

1. Bales shall be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.

2. All bales shall be either wire-bound or string-tied. Straw bales shall be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales (in order to prevent deterioration of the bindings.)

3. The barrier shall be entrenched and backfilled. A trench shall be excavated the width of a bale and the length of the proposed barrier to a minimum depth of four inches. After the bales are staked and chinked (filled by wedging), the excavated soil shall be backfilled against the barrier. Backfill soil shall conform to the ground level on the downhill side and shall be built up to four inches against the uphill side of the barrier.

4. Each bale shall be securely anchored by at least two stakes or rebars driven through the bale. The first stake in each bale shall be driven toward the previously laid bale to force the bales together. Stakes or re-bars shall be driven deep enough into the ground to securely anchor the bales.

5. The gaps between bales shall be chinked with straw to prevent water from escaping between the bales. (Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency.)

6. Inspection shall be frequent and repair or replacement shall be made promptly as needed.

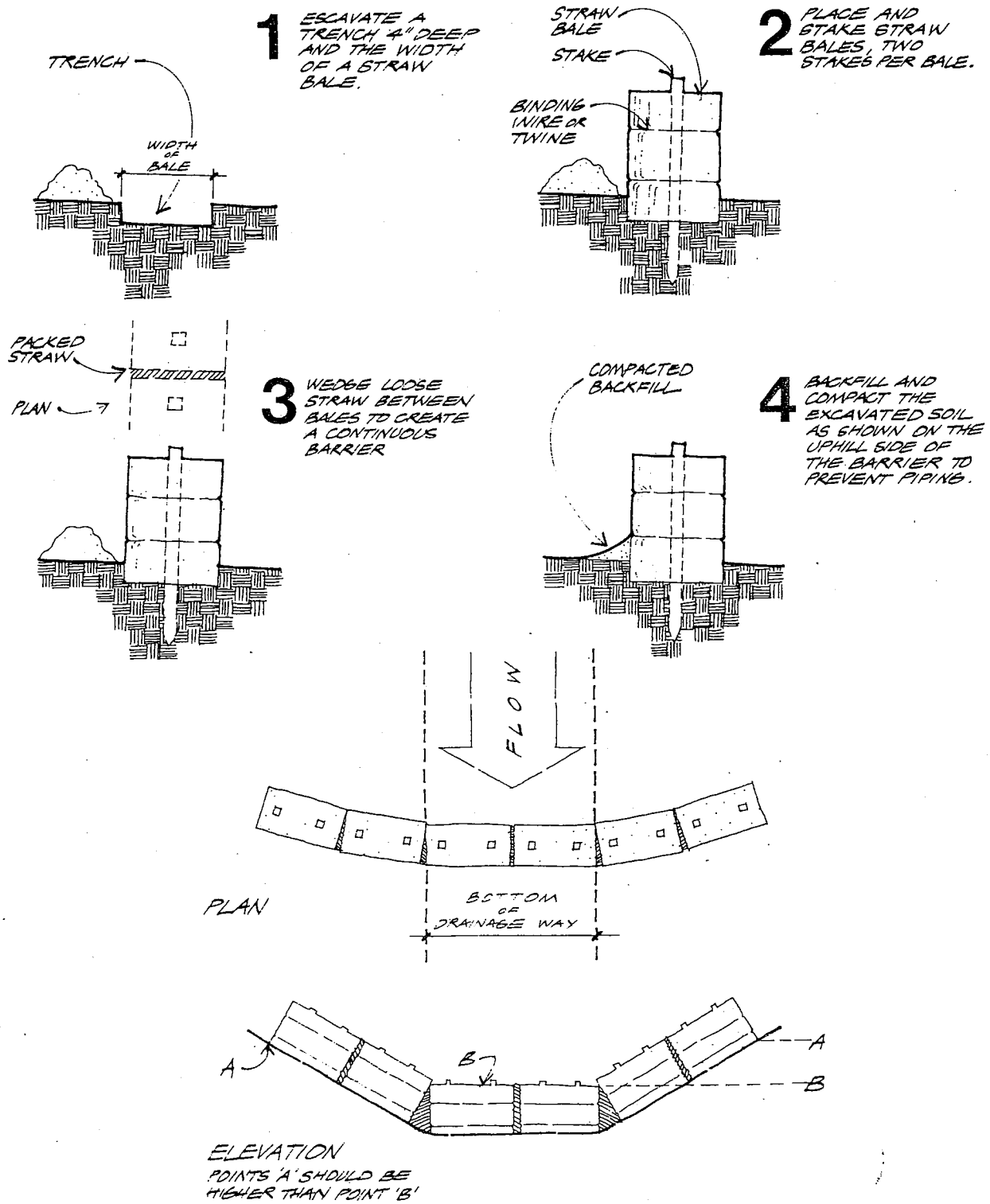
7. Straw bale barriers shall be removed when they have served their usefulness, but not before the upslope areas have been permanently stabilized.

CHANNEL FLOW APPLICATIONS

1. Bales shall be placed in a single row, lengthwise, oriented perpendicular to the contour, with ends of adjacent bales tightly abutting one another.

2. The remaining steps for installing a straw bale barrier for sheet flow applications apply here, with the following addition.

3. The barrier shall be extended to such a length that the bottoms of the end bales are higher in elevation than the top of the lowest middle bale to assure that sediment-laden runoff will flow either through or over the barrier but not around it.



Placement and Construction of a Straw Bale Barrier

Design Guidelines for Synthetic Filter Fences

MATERIALS

1. Synthetic filter fabric shall be a pervious sheet of propylene, nylon, polyester or ethylene yarn and shall be certified by the manufacturer or supplier as conforming to the following requirements:

PHYSICAL PROPERTY	REQUIREMENTS
Filtering Efficiency	75% (min.)
Tensile Strength at 20% (max.) Elongation	Extra Strength - 50 lbs./lin. in. (min.) Standard Strength - 30 lbs./lin. in. (min.)
Flow Rate	0.3 gal./sq. ft./min. (min.)

Figure 6-24: Synthetic Filter Fabric Requirements

2. Burlap shall be 10 ounce per square yard fabric.

3. Posts for filter fences shall be either 4-inch diameter wood or 1.33 pounds per linear foot steel with a minimum length of five feet. Steel posts shall have projections for fastening wire to them.

4. Stakes for filter fences shall be 1" x 2" wood (preferred) or equivalent metal with a minimum length of three feet.

5. Wire fence reinforcement for silt fences using standard strength filter cloth shall be a minimum of 42 inches in height, a minimum of 14 gauge and shall have a maximum mesh spacing of six inches.

CONSTRUCTION

This sediment barrier utilizes burlap, standard strength or extra strength synthetic filter fabrics. It is designed for situations in which only sheet or overland flows are expected. In special cases burlap may be used in drainageways.

1. The height of the barrier shall not exceed 36 inches (higher barriers may impound volumes of water sufficient to cause failure of the structure).

2. The fabric shall be purchased in a continuous roll cut to the length of the barrier to avoid the use of joints. When joints are necessary, filter cloth shall be spliced together only at a support post, with a minimum 6-inch overlap, and securely sealed.

3. Posts shall be spaced a maximum of 10 feet apart at the barrier location and driven securely into the ground (minimum of 12 inches). When extra strength fabric is used without the wire support fence, post spacing shall not exceed six feet.

4. A trench shall be excavated approximately four inches wide and four inches deep along the line of posts and upslope from the barrier.

5. When standard strength filter fabric is used, a wire mesh support fence shall be fastened securely to the upslope side of the posts using heavy duty wire staples at least one inch long, tie wires or hog rings. The wire shall extend into the trench a minimum of two inches and shall not extend more than 36 inches above the original ground surface.

6. The standard strength filter fabric shall be stapled or wired to the fence, and eight inches of the fabric shall be extended into the trench. The fabric shall not extend more than 36 inches above the original ground surface. Filter fabric shall not be stapled to existing trees.

7. When extra strength filter fabric or burlap and closer post spacing are used, the wire mesh support fence may be eliminated. In such a case, the filter fabric is stapled or wired directly to the posts with all other provisions of item No. 6 applying.

8. The trench shall be backfilled and the soil compacted over the filter fabric.

9. Filter barriers shall be removed when they have served their useful purpose, but not before the upslope area has been permanently stabilized.

Plans and Specifications

Plans should show the location and all dimensions of filter barrriers. Sufficient detail must be shown that control measures are installed as designed. Material requirements must be specified.

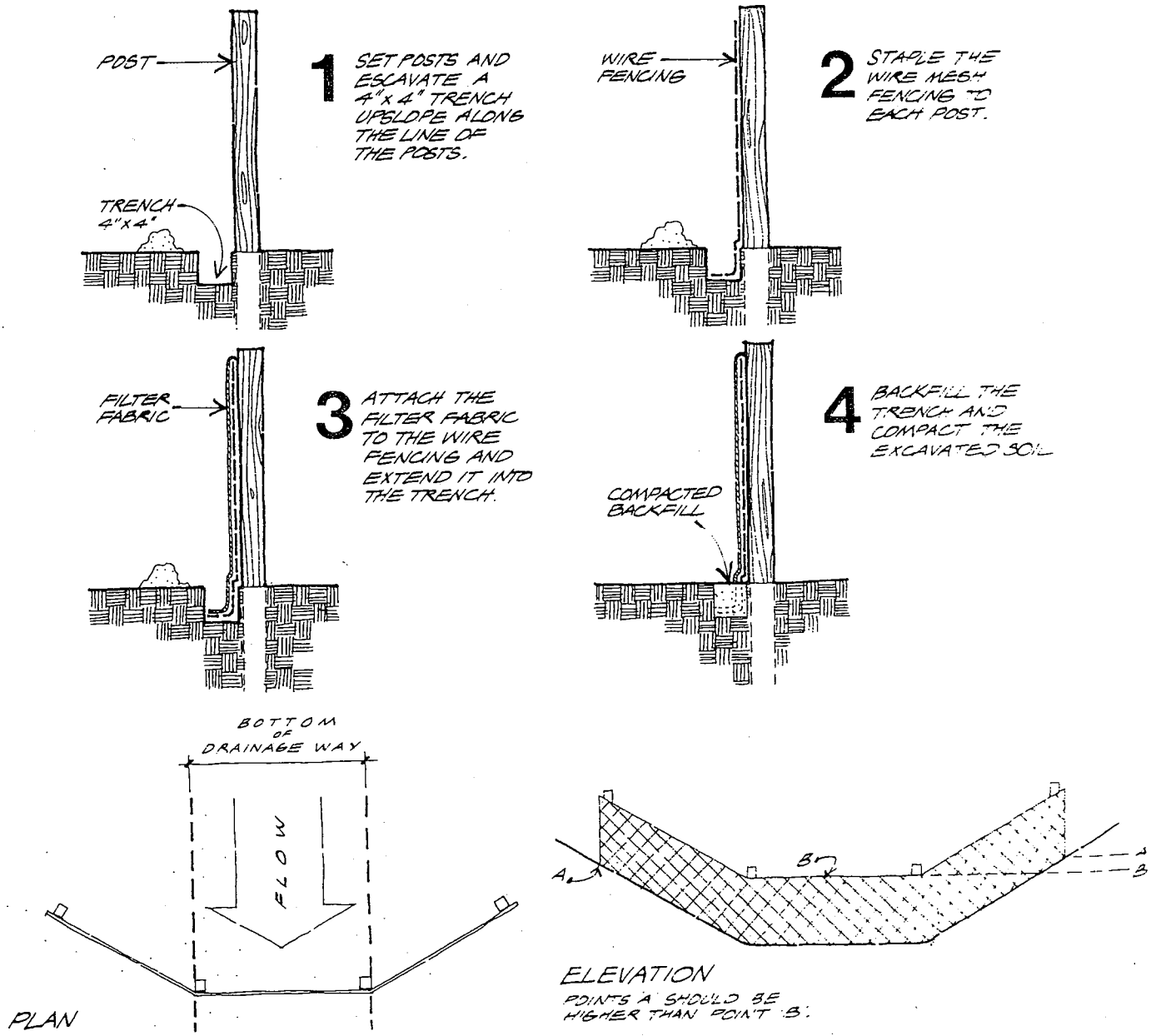
Maintenance

1. Filter barriers shall be inspected immediately after each rainfall and at least daily during prolonged rainfall. Any required repairs shall be made immediately.

2. Should the fabric decompose or become ineffective prior to the end of the expected usable life and the barrier still be necessary, the fabric shall be replaced promptly.

3. Sediment deposits should be removed after each storm event. They must be removed when deposits reach approximately half the height of the barrier.

4. Any sediment deposits remaining in place after the silt fence or filter barrier is no longer required shall be dressed to conform with the existing grade, prepared and seeded.



Placement and Construction of a Synthetic Filter Barrier

Vegetative Filter

Design Guidelines for Vegetative Filters

Vegetative filters should only be used to filter sediment from overland flow, since this control practice is intended to be used only where concentrations of sediment and rates of runoff are low.

Vegetation, either existing or established, should have a deep root system, dense, well-ramified top growth, resistant to flooding and drought, plus the ability to recover growth subsequent to inundation with sediment. Establishing vegetation by seeding or sodding should be done in accordance with the vegetative section of this chapter and such vegetation should be established prior to land disturbance if it is intended to be used to protect adjacent properties.

When used to protect adjacent property or streams, the minimum width of the filter strip should be at least 15 feet.

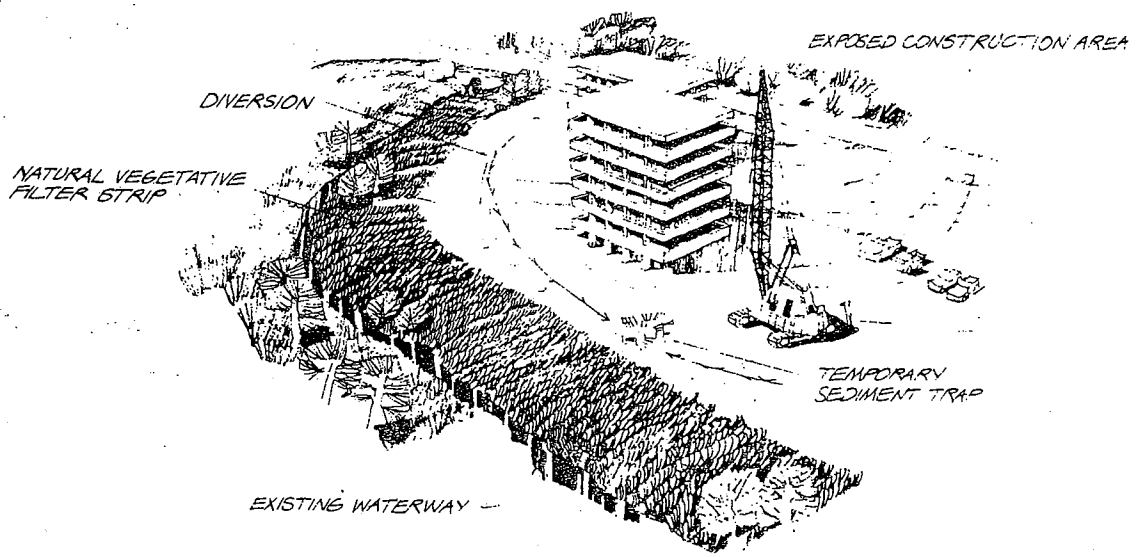
The width of the filter strip should be increased proportionately for longer slopes or for higher sediment concentrations. When using filter strips at inlets to storm sewers, as large an area as possible should be provided to insure it will function as intended. Filters should be placed along the contours whenever possible. No construction should be allowed within filter strip areas.

Plans and Specifications

Plans should show the location, width and length of filter strips. The type of vegetation and specifications for soil preparation and seeding should be included. If existing vegetation is to be used, directions should be provided as to how it will be protected or improved.

Maintenance

Maintenance for vegetative filter strips is the same as that recommended for any vegetation as given in vegetative section of this chapter. A healthy growth of vegetation can best be maintained by fertilizing, removing sediment when the filter becomes clogged, and by preventing construction traffic from driving upon or across filter strips.



Use of a Vegetative Filter to Protect a Waterway

Stabilized Construction Entrance

Design Guidelines

This measure consists of stabilizing points of ingress and egress from the construction site by using stone, asphalt, or other durable surfacing materials.

Minimum stone size shall be two inches in diameter.

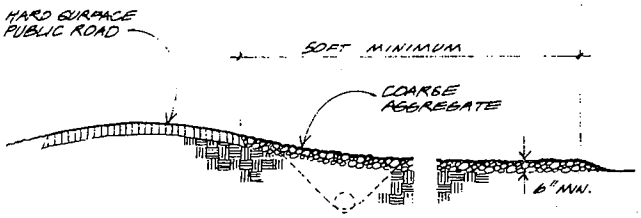
Minimum stone thickness shall be six inches.

Asphalt quality and subgrade should be in keeping with industry standards for temporary construction.

Entrance width should be not less than the width required for two-way ingress and egress.

Entrance length should be no less than 50 feet.

When mud or other debris carried from the site on wheels or tracks of construction equipment may be offensive, present a safety hazard or cause damage to other property, the wheels or tracks should be cleaned to remove mud or debris prior to vehicles leaving the construction site.



Gravel Construction Entrance

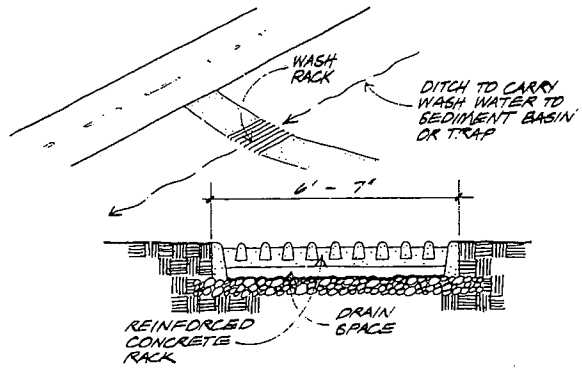
When washing is required, it should be done on a stabilized area and runoff from this area should not be allowed to leave the construction site.

Plans and Specifications

Plans, at a minimum, should show the location, length, width, thickness and type of materials to be used. Specifications should describe materials, thicknesses and methods of application.

Maintenance

The entrance should be maintained in a condition which will prevent tracking or flowing of sediment onto public rights-of-way. This could require periodic top dressing with additional surface materials as conditions demand. Repair and/or cleanout of any features used to trap sediment is essential and all sediment spilled, dropped, washed or tracked onto public rights-of-way should be removed immediately.



Construction Entrance with Wash Rack

Dust and Traffic Control

Design Guidelines

When dust blowing from construction sites or roads may become a traffic hazard, or a danger to the health, comfort or well-being of persons downwind, it should be controlled either permanently or temporarily depending upon the stage of development of the site.

Some of the methods and materials for dust control are given below:

TEMPORARY METHODS

1. Mulches - See standards for critical area stabilization with mulches only. Chemical mulch binders may be used instead of asphalt to bind mulch materials. Binders such as Curasol or Terratack should be used according to manufacturer's recomendations.

2. Vegetative Cover - See standards for temporary vegetative cover.

3. Spray-on Adhesives - For use on mineral particle soils (not effective on muck soils). Traffic must be kept off these areas after spraying.

	Water Dilution	Nozzle Type	Gallons/Acre
Anionic asphalt emulsion	7:1	Coarse spray	1,200
Latex emulsion	12½:1	Pine spray	235
Resin-in-water emulsion	4:1	Pine spray	300

4. Tillage - This roughens surface and brings clods to the surface. This is an emergency measure which should be used before soil blowing starts. Begin plowing on windward side of site. Chisel-type plows spaced about 12 inches apart, spring-toothed harrows, and similar plows are examples of equipment which may produce the desired effect.

5. Irrigation - This is an emergency treatment. Site is sprinkled with water until the surface is moist. Constant repetition is required for effective control.

6. Barriers - Solid board fences, snow fences, burlap fences, crate walls, bales of hay and similar material can be used to control air currents and soil.

7. Calcium Chloride - Apply at rate that will keep surface moist. This material is best used on road surfaces.

PERMANENT METHODS

1. Permanent Vegetation - See standards for permanent vegetative cover, and permanent stabilization with sod. Existing trees or large shrubs may afford valuable protection if left in place.

2. Non-vegetative soil cover measures such as rock, asphalt, or concrete.

Plans and Specifications

Specifications should indicate when dust control is needed and the method of control to be used. Appropriate industry standards should be used. Vegetative and mulching specifications should be according to those given in this chapter.

Maintenance

When temporary dust control measures are used, repetitive treatment should be applied as needed to accomplish control.

APPENDIX G

NAVAL STATION GREAT LAKES SPILL PROCEDURES

CONTRACTOR SPILL OR CHEMICAL RELEASE REQUIREMENTS
NAVAL STATION GREAT LAKES (NSGL)

1. **Spills or chemical releases occurring on Navy property.** All spills or chemical releases of petroleum products (including cooking oil and animal grease), hazardous substances, regulated waste, regulated gases or sewage occurring on Navy property shall be immediately reported to:

   a. Great Lakes Emergency Dispatch Center (HAZMAT, Fire, Police, Ambulance) — 911 (847) 688-3333

   b. PWD 24-Hour Service Desk — (847) 688-4820

   c. Public Works Department (PWD) Environmental Division — (847) 688-6934 x11 or x20

2. The Navy will take prompt response action as deemed necessary to contain and otherwise resolve spills or releases with potential impact to environmentally sensitive areas occurring on NSGL including storm sewers; tributary waters of Lake Michigan; creeks/streams; wetlands; critical habitats; and protected or susceptible habitats.

3. **Off-site spills or releases.** All spills or releases occurring off-site involving government property is responsibility of the Contactor for reporting to federal, State and local agencies, and will be reported to:

   a. Navy Project Manager or Contractor Officer (as identified in the initial project meeting)

   b. PWD Environmental Division Director — (847) 688-6934 x11 or x20

   c. PWD 24-Hour Service Desk (after normal business hours) — (847) 688-4820

4. **Reporting of spills or releases.** The Navy's designated PWD Environmental Representative is responsible for reporting spill or release incidents occurring on Navy property to Federal, State, and local agencies. Contractor is responsible for reporting all incidents occurring off Navy property.

5. **Liability.** Spills and/or chemical release cleanup, remediation, damage to the environment and other related costs incurred resulting from Contractor actions shall be the responsibility of the Contractor. Such actions taken by the Navy or its designated responder(s) as deemed appropriate, shall be at the expense of the responsible Contractor.

APPENDIX H

SOIL SAMPLING SOP

TETRA TECH	STANDARD OPERATING PROCEDURES	Number SA-1.3	Page 1 of 31
		Effective Date 04/072008	Revision 9
		Applicability Tetra Tech NUS, Inc.	
		Prepared Earth Sciences Department	
Subject SOIL SAMPLING		Approved Tom Johnston	

TABLE OF CONTENTS

SECTION **PAGE**

1.0 PURPOSE 2

2.0 SCOPE 2

3.0 GLOSSARY 2

4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS 3

5.0 HEALTH AND SAFETY 4

6.0 PROCEDURES 5

6.1 Overview 6
6.2 Soil Sample Collection 6
6.2.1 Procedure for Preserving and Collecting Soil Samples for Volatile Organic Compound Analysis 6
6.2.2 Procedure for Collecting Soil Samples for Non-Volatile Analyses 9
6.2.3 Procedure for Collecting Undisturbed Soil Samples 10
6.3 Surface Soil Sampling 13
6.4 Near-Surface Soil Sampling 14
6.5 Subsurface Soil Sampling With a Hand Auger 15
6.6 Subsurface Soil Sampling with a Split-Barrel Sampler 17
6.7 Subsurface Soil Sampling Using Direct-Push Technology 18
6.8 Excavation and Sampling of Test Pits and Trenches 18
6.8.1 Applicability 18
6.8.2 Test Pit and Trench Excavation 19
6.8.3 Sampling in Test Pits and Trenches 21
6.8.4 Backfilling of Trenches and Test Pits 25
6.9 Records 25

7.0 REFERENCES 26

ATTACHMENTS

A SOIL & SEDIMENT SAMPLE LOG SHEET 28
B SPLIT-SPOON SAMPLER 29
C TEST PIT LOG 30
D REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING 31

1.0 PURPOSE

This Standard Operating Procedure (SOP) describes the procedures to be used to collect surface, near-surface, and subsurface soil samples. Additionally, it describes the methods for sampling of test pits and trenches to determine subsurface soil and rock conditions and for recovery of small-volume or bulk samples from pits.

2.0 SCOPE

This document applies to the collection of surface, near-surface, and subsurface soil samples exposed through hand digging, hand augering, drilling, or machine excavating at hazardous substance sites for laboratory testing, onsite visual examination, and onsite testing.

3.0 GLOSSARY

Composite Sample - A composite sample is a combination of more than one grab sample from various locations and/or depths and times that is homogenized and treated as one sample. This type of sample is usually collected when determination of an average waste concentration for a specific area is required. Composite samples shall not be collected for volatile organics analysis.

Confined Space - As stipulated in 29 Code of Federal Regulations (CFR) 1910.146, a confined space means a space that: (1) is large enough and so configured that an employee can bodily enter and perform assigned work; (2) has limited or restricted means for entry or exit (e.g., tanks, vessels, silos, storage bins, hoppers, vaults, pits, and excavations); and (3) is not designed for continuous employee occupancy. TtNUS considers all confined space as permit-required confined spaces.

Grab Sample - One sample collected at one location and at one specific time.

Hand Auger - A sampling device used to extract soil from the ground.

Representativeness – A qualitative description of the degree to which an individual sample accurately reflects population characteristics or parameter variations at a sampling point. It is therefore an important characteristic not only of assessment and quantification of environmental threats posed by the site, but also for providing information for engineering design and construction. Proper sample location selection and proper sample collection methods are important to ensure that a truly representative sample has been collected.

Sample for Non-Volatile Analyses - Includes all chemical parameters other than volatile organics (e.g., semivolatiles, pesticides/PCBs, metals, etc.) and those engineering parameters that do not require undisturbed soil for their analysis.

Split-Barrel Sampler - A steel tube, split in half lengthwise, with the halves held together by threaded collars at either end of the tube. Also called a split-spoon sampler, this device can be driven into resistant materials using a drive weight mounted in the drilling string. A standard split-barrel sampler is typically available in two common lengths, providing either 20-inch or 26-inch longitudinal clearance for obtaining 18-inch or 24-inch-long samples, respectively. These split-barrel samplers commonly range in size from 2 to 3.5 inches OD. The larger sizes are commonly used when a larger volume of sample material is required (see Attachment B).

Test Pit and Trench - Open, shallow excavations, typically rectangular (if a test pit) or longitudinal (if a trench), excavated to determine shallow subsurface conditions for engineering, geological, and soil chemistry exploration and/or sampling purposes. These pits are excavated manually or by machine (e.g., backhoe, clamshell, trencher, excavator, or bulldozer).

Thin-Walled Tube Sampler - A thin-walled metal tube (also called a Shelby tube) used to recover relatively undisturbed soil samples. These tubes are available in various sizes, ranging from 2 to 5 inches outside diameter (OD) and from 18 to 54 inches in length.

4.0 RESPONSIBILITIES AND PERSONNEL QUALIFICATIONS

Project Manager - The Project Manager is responsible for determining the sampling objectives, selecting proposed sampling locations, and selecting field procedures used in the collection of soil samples. Additionally, in consultation with other project personnel (geologist, hydrogeologist, etc.), the Project Manager establishes the need for test pits or trenches and determines their approximate locations and dimensions.

Site Safety Officer (SSO) - The SSO (or a qualified designee) is responsible for providing the technical support necessary to implement the project Health and Safety Plan. This will include (but not be limited to) performing air quality monitoring during sampling, boring, and excavation activities and to ensure that workers and offsite (downwind) individuals are not exposed to hazardous levels of airborne contaminants. The SSO/designee may also be required to advise the FOL on other safety-related matters regarding boring, excavation, and sampling, such as mitigative measures to address potential hazards from unstable trench walls, puncturing of drums or other hazardous objects, etc.

Field Operations Leader (FOL) - This individual is primarily responsible for the execution of the planning document containing the Sampling and Analysis Plan (SAP). This is accomplished through management of a field sampling team for the proper acquisition of samples. He or she is responsible for the supervision of onsite analyses; ensuring proper instrument calibration, care, and maintenance; sample collection and handling; the completion and accuracy of all field documentation; and making sure that custody of all samples obtained is maintained according to proper procedures. When appropriate and as directed by the FOL, such responsibilities may be performed by other qualified personnel (e.g., field technicians) where credentials and time permit. The FOL is responsible for finalizing the locations for collection of surface, near-surface, and subsurface (hand and machine borings, test pits/trenches) soil samples. He/she is ultimately responsible for the sampling and backfilling of boreholes, test pits, and trenches and for adherence to Occupational Safety and Health Administration (OSHA) regulations during these operations through self acquisition or through the management of a field team of samplers.

Project Geologist/Sampler - The project geologist/sampler is responsible for the proper acquisition of samples in accordance with this SOP and/or other project-specific documents. In addition, this individual is responsible for the completion of all required paperwork (e.g., sample log sheets, field notebook, boring logs, test pit logs, container labels, custody seals, and chain-of-custody forms) associated with the collection of those samples.

Competent Person - A Competent Person, as defined in 29 CFR 1929.650 of Subpart P - Excavations, means one who is capable of identifying existing and predictable hazards in the surroundings, or working conditions that are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

General personnel qualifications for groundwater sample collection and onsite water quality testing include the following:

- Occupational Safety and Health Administration (OSHA) 40-hour and applicable refresher training.
- Capability of performing field work under the expected physical and environmental (i.e., weather) conditions.

- Familiarity with appropriate procedures for sample documentation, handling, packaging, and shipping.

5.0 HEALTH AND SAFETY

Health and safety precautions are identified for individual sample collection procedures throughout this SOP. In addition to those precautions, the following general hazards may be incurred during sampling activities:

- Knee injuries from kneeling on hard or uneven surfaces
- Slips, trips, and falls
- Cuts and lacerations
- Traffic hazards associated with sampling in parking areas, along roadways and highways.

Methods of avoiding these hazards are provided below.

Knee injuries – If kneeling is required during soil sampling, this could result in knee injuries from stones/foreign objects and general damage due to stress on the joints. To minimize this hazard:

- Clear any foreign objects from the work area.
- Wear hard-sided knee pads.
- Stretch ligaments, tendons and muscles before, during and after. Take breaks as frequently as necessary.
- Report pre-existing conditions to the SSO if you feel this activity will aggravate an existing condition.

Slips, Trips, and Falls – These hazards exist while traversing varying terrains carrying equipment to sample locations. To minimize these hazards:

- Pre-survey sampling locations. Eliminate, barricade, or otherwise mark physical hazards leading to the locations.
- Carry small loads that do not restrict the field of vision.
- Travel the safest and clearest route (not necessarily the shortest).

Cuts and Lacerations - To prevent cuts and lacerations associated with soil sampling, the following provisions are required:

- Always cut away from yourself and others when cutting tubing or rope. This will prevent injury to yourself and others if the knife slips.
- Do not place items to be cut in your hand or on your knee.
- Change blades as necessary to maintain a sharp cutting edge. Many accidents result from struggling with dull cutting attachments.

- Whenever practical, wear cut-resistant gloves (e.g., leather or heavy cotton work gloves) at least on the hand not using the knife.
- Keep cutting surfaces clean and smooth.
- Secure items to be cut – do not hold them against the opposing hand, a leg, or other body part.
- When transporting glassware, keep it in a hard-sided container such as a cooler so that if there is a fall, you will be less likely to get cut by broken glass.
- DO NOT throw broken sample jars or glass ampoules into garbage bags. Place broken glass and glass ampoules in hard-sided containers such as a cardboard box or directly into a dumpster. DO NOT reach into garbage bags to retrieve any item accidentally thrown away. Empty the contents onto a flat surface to avoid punctures and lacerations from reaching where you cannot see.

Vehicular and Foot Traffic Hazards – When sampling along the roadway or near traffic patterns, follow the following precautions:

- Motorists may be distracted by onsite activities – ASSUME THEY DO NOT SEE YOU OR MEMBERS OF YOUR FIELD CREW.
- DO NOT place obstructions (such as vehicles) along the sides of the road that may cause site personnel to move into the flow of traffic to avoid your activities or equipment or that will create a blind spot.
- **Provide a required free space of travel**. Maintain at least 6 feet of space between you and moving traffic. Where this is not possible, use flaggers and/or signs to warn oncoming traffic of activities near or within the travel lanes.
- Face Traffic. Whenever feasible, if you must move within the 6 feet of the required free space or into traffic, attempt to face moving traffic at all times. Always leave yourself an escape route.
- Wear high-visibility vests to increase visual recognition by motorists.
- Do not rely on the vehicle operator's visibility, judgment, or ability. Make eye contact with the driver. Carefully and deliberately use hand signals so they will not startle or confuse motorists or be mistaken for a flagger's direction before moving into traffic.
- Your movements may startle a motorist and cause an accident, so move deliberately. Do not make sudden movements that might confuse a motorist.

6.0 PROCEDURES

The following procedures address surface and subsurface sampling.

CAUTION

Each situation must be evaluated individually to determine the applicability and necessity for obtaining a utility clearance ticket/dig permit. Common sense dictates, prior to digging or boring with power equipment, no matter what the depth, or digging by hand in a manner that could damage unprotected underground utilities, that a dig permit is required. See SOP HS-1.0, Utility Locating and Excavation Clearance, for additional clarification. If you do not know or are unsure as to whether a ticket is necessary – **Get the Ticket**.

6.1 Overview

Soil sampling is an important adjunct to groundwater monitoring. Sampling of the soil horizons above the groundwater table can detect contaminants before they migrate to the water table, and can establish the amount of contamination absorbed or adsorbed on aquifer solids that have the potential of contributing to groundwater contamination.

Soil types can vary considerably on a hazardous waste site. These variations, along with vegetation, can affect the rate of contaminant migration through the soil. It is important, therefore, that a detailed record be maintained during sampling operations, particularly noting sampling locations, depths, and such characteristics as grain size, color, and odor. Subsurface conditions are often stable on a daily basis and may demonstrate only slight seasonal variation especially with respect to temperature, available oxygen and light penetration. Changes in any of these conditions can radically alter the rate of chemical reactions or the associated microbiological community, thus further altering specific site conditions. Certain vegetation species can create degradation products that can alter contaminant concentrations in soil. This is why vegetation types and extent of degradation of this foliage must be recorded. To prevent degradation, samples must be kept at their at-depth temperature or lower, protected from direct light, sealed tightly in approved glass containers, and be analyzed as soon as possible after collection. In addition, to the extent possible, vegetation should be removed from the sample.

The physical properties of the soil, its grain size, cohesiveness, associated moisture, and such factors as depth to bedrock and water table, will limit the depth from which samples can be collected and the method required to collect them. It is the intent of this document to present the most commonly employed soil sampling methods used at hazardous waste sites.

6.2 Soil Sample Collection

6.2.1 Procedure for Preserving and Collecting Soil Samples for Volatile Organic Compound Analysis

Samples collected using traditional methods such as collection in a jar with no preservation have been known to yield non-representative samples due to loss of volatile organic compounds (VOCs). To prevent such losses, preservation of samples with methanol or sodium bisulfate may be used to minimize volatilization and biodegradation. This preservation may be performed either in the field or laboratory, depending on the sampling methodology employed. Because of the large number of sampling methods and associated equipment required, careful coordination between field and laboratory personnel is needed.

Soil samples to be preserved by the laboratory are currently being collected using Method SW-846, 5035. For samples preserved in the field, laboratories are currently performing low-level analyses (sodium bisulfate preservation) and high- to medium-level analyses (methanol preservation) depending on the needs of the end user.

The following procedures outline the necessary steps for collecting soil samples to be preserved at the laboratory, and for collecting soil samples to be preserved in the field with methanol or sodium bisulfate.

6.2.1.1 Soil Samples to be Preserved at the Laboratory

Soil samples collected for volatile organic analysis that are to be preserved at the laboratory shall be obtained using a hermetically sealed sample vial such as an EnCore™ sampler. Each sample shall be

obtained using a reusable sampling handle (T-handle) that can be provided with the EnCore™ sampler when requested and purchased. Collect the sample in the following manner for each EnCore™ sampler:

1. Scene Safety - Evaluate the area where sampling will occur. Ensure that the area is safe from physical, chemical, and natural hazards. Clear or barricade those hazards that have been identified.

2. Wear the appropriate personal protective equipment (PPE). This will include, at a minimum, safety glasses and nitrile surgeon's gloves. If you must kneel on the ground or place equipment on the surface being sampled, cover the ground surface with plastic to minimize surface contamination of your equipment and clothing. Wear knee pads to protect your knees from kneeling on hard or uneven surfaces.

3. Load the Encore™ sampler into the T-handle with the plunger fully depressed.

4. Expose the area to be sampled using a hand trowel or similar device to remove surface debris.

5. Press the T-handle against the freshly exposed soil surface, forcing soil into the sampler. The plunger will be forced upward as the cavity fills with soil.

6. When the sampler is full, rotate the plunger and lock it into place. If the plunger does not lock, the sampler is not full. This method ensures there is no headspace. Soft soil may require several plunges or forcing soil against a hard surface such as a sample trowel to ensure that headspace is eliminated.

7. Use a paper towel to remove soil from the side of the sampler so a tight seal can be made between the sample cap and the rubber O-ring.

8. With soil slightly piled above the rim of the sampler, force the cap on until the catches hook the side of the sampler.

9. Remove any surface soil from the outside of the sampler and place in the foil bag provided with the sampler. Good work hygiene practices and diligent decontamination procedures prevents the spread of contamination even on the outside of the containers.

10. Label the bag with appropriate information in accordance with SOP SA-6.3.

11. Place the full sampler inside a lined cooler with ice and cool to 4˚C ± 2 ˚C. Make sure any required trip blanks and temperature blanks are also in the cooler. Secure custody of the cooler in accordance with SOP SA-6.3.

12. Typically, collect three Encore™ samplers at each location. Consult the SAP or laboratory to determine the required number of Encore™ samplers to be collected.

13. The T-handle shall be decontaminated before moving to the next interval or location using a soap and water wash and rinse, and where applicable, the selected solvent as defined in the project planning documents.

Using this type of sampling device eliminates the need for field preservation and the shipping restrictions associated with preservatives. A complete set of instructions is included with each Encore™ sampler.

After the Encore™samples are collected, they should be placed on ice immediately and delivered to the laboratory within 48 hours (following the chain-of-custody and documentation procedures outlined in SOP SA-6.1). Samples must be preserved by the laboratory within 48 hours of sample collection.

6.2.1.2 Soil Samples to be Preserved in the Field

Soil samples preserved in the field may be prepared for analyses using both the low-level (sodium bisulfate preservation) and high- to medium-level (methanol preservation) methods.

Safety Reminder

When using chemicals in the field to preserve samples, the FOL and/or SSO must ensure that Materials Safety Data Sheets (MSDSs) have been provided with the chemicals to be used. They also must ensure that these chemicals have been added to the Chemical Inventory List contained within Section 5.0, Hazard Communication, of your Health and Safety Guidance Manual (HSGM). Lastly, but most importantly, the FOL and/or SSO must review the hazards with personnel using these chemicals and ensure that provisions are available for recommended PPE and emergency measures (e.g., eyewash, etc.).

Methanol Preservation (High to Medium Level):

Bottles may be pre-spiked with methanol in the laboratory or prepared in the field. Soil samples to be preserved in the field with methanol shall utilize 40 to 60 mL glass vials with septum-lined lids. Each sample bottle shall be filled with 25 mL of demonstrated analyte-free purge-and-trap grade methanol. The preferred method for adding methanol to the sample bottle is by removing the lid and using a pipette or scaled syringe to add the methanol directly to the bottle.

CAUTION

NEVER attempt to pipette by mouth

In situations where personnel are required to spike the septum using a hypodermic needle, the following provisions for handling sharps must be in place:

- Training of personnel regarding methods for handling of sharps
- Hard-sided containers for the disposal of sharps
- Provisions for treatment in cases where persons have received a puncture wound

Soil shall be collected with the use of a decontaminated (or disposable), small-diameter coring device such as a disposable tube/plunger-type syringe with the tip cut off. The outside diameter of the coring device must be smaller than the inside diameter of the sample bottle neck.

A small electronic balance or manual scale will be necessary for measuring the volume of soil to be added to the methanol-preserved sample bottle. Calibration of the scale shall be performed prior to use and intermittently throughout the day according to the manufacturer's requirements.

The sample should be collected as follows:

1. Weigh the unused syringe and plunger to the nearest 0.01 gram.

2. Pull the plunger back and insert the syringe into the soil to be sampled.

3. Collect 8 to 12 grams of soil by pushing the syringe barrel into the soil.

4. Weigh the sample and adjust until obtaining the required amount of sample.

5. Record the sample weight to the nearest 0.01 gram in the field logbook and/or on the sample log sheet.

6. Extrude the weighed soil sample into the methanol-preserved sample bottle taking care not to contact the sample container with the syringe.

7. If dirty, wipe soil particles from the threads of the bottle and cap. Cap the bottle tightly.

8. After capping the bottle, swirl the sample (do not shake) in the methanol and break up the soil such that all of the soil is covered with methanol.

9. Place the sample on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

Sodium Bisulfate Preservation (Low Level):

> ***CAUTION***
> Care should be taken when adding the soil to the sodium bisulfate solution. A chemical reaction of soil containing carbonates (limestone) may cause the sample to effervesce or the vial to possibly explode. To avoid this hazard or hazards of this type, a small sample aliquot should be subjected to the sample preservative. If it effervesces in an open air environment, utilize an alternative method such as Encore™ or 2-ounce jar.

Bottles may be prepared in the laboratory or in the field with sodium bisulfate solution. Samples to be preserved in the field using the sodium bisulfate method are to be prepared and collected as follows:

1. Add 1 gram of sodium bisulfate to 5 mL of laboratory-grade deionized water in a 40 to 60 mL glass vial with septum-lined lid.

2. Collect the soil sample and record the sample weight to the nearest 0.01 gram in the field logbook or on the sample log sheet as described for methanol preservation

3. Add the weighed sample to the sample vial.

4. Collect duplicate samples using the methanol preservation method on a one-for-one sample basis because it is necessary for the laboratory to perform both low-level and medium-level analyses.

5. Place the samples on ice immediately and prepare for shipment to the laboratory as described in SOP SA-6.1.

> ***NOTE***
> If lower detection limits are necessary, an option to field preserving with sodium bisulfate may be to collect EnCore™ samplers at a given sample location. Consult the planning documents to determine whether this is required. If it is, collect samples in accordance with the Encore™ sampling procedure above and then send all samplers to the laboratory to perform the required preservation and analyses.

6.2.2 Procedure for Collecting Soil Samples for Non-Volatile Analyses

Samples collected for non-volatile analyses may be collected as either grab or composite samples as follows:

1. With a stainless steel trowel or other approved tool, transfer a portion of soil to be sampled to a stainless steel bowl or disposable inert plastic tray.

2. Remove roots, vegetation, sticks, and stones larger than the size of a green pea.

3. Thoroughly mix the soil in the bowl or tray to obtain as uniform a texture and color as practicable. The soil type, moisture content, amount of vegetation, and other factors may affect the amount of time required to obtain a properly mixed sample. In some cases, it may be impossible to obtain a uniform sample appearance. Use the field logbook to describe any significant difficulties encountered in obtaining a uniform mixture.

4. Transfer the mixed soil to the appropriate sample containers and close the containers.

5. Label the sample containers in accordance with SOP SA-6.3.

6. Place the containers in a cooler of ice as soon after collection as possible.

7. Prepare the sample shipment and ship the samples in accordance with SOP SA-6.1.

> ***NOTE***
> Cooling may not be required for some samples depending on the scheduled analyses. Consult the planning documents if in doubt regarding correct sample preservation conditions. When in doubt – Cool to 4˚C.

> ***NOTE***
> Head space is permitted in soil sample containers for non-volatile analyses to allow for sample expansion.

6.2.3 Procedure for Collecting Undisturbed Soil Samples

> ***NOTE***
> Use of thin-walled undisturbed tube samplers is restricted by the consistency of the soil to be sampled. Often, very loose and/or wet samples cannot be retrieved by the samplers, and soil with a consistency in excess of very stiff cannot be penetrated by the sampler. Devices such as Dennison or Pitcher core samplers can be used to obtain undisturbed samples of stiff soil. Using these devices normally increases sampling costs, and therefore their use should be weighed against the need for acquiring an undisturbed sample. These devices are not discussed in this SOP because they are not commonly used.

When it is necessary to acquire undisturbed samples of soil for purposes of engineering parameter analysis (e.g., permeability), a thin-walled, seamless tube sampler (Shelby tube) shall be employed using the following collection procedure:

1. In preparation for sampling utilizing a drill rig, field personnel must complete the following activities:

   - Ensure that all subsurface drilling activities are preceded by a utility clearance for the area to be investigated. This includes activities described in SOP HS-1.0, Utility Location and Excavation Clearance, as well as any location-specific procedures that may apply.

REMEMBER
If you are digging near a marked utility (within the diameter of an underground utility that has been marked plus 18 inches), you must first locate the utility through vacuum extraction or hand digging to ensure that your activities will not damage the utility.

- Complete an Equipment Inspection Checklist for the drill rig or direct-push technology (DPT) rig. This checklist will be provided in the HASP.
- Review the Safe Work Permit prior to conducting the activity.
- Review the activity to be conducted.

2. Remove all surface debris (e.g., vegetation, roots, twigs, etc.) from the specific sampling location and drill and/or clean out the borehole to the desired sampling depth. Be careful to minimize potential disturbance of the material to be sampled. In saturated material, withdraw the drill bit slowly to prevent loosening of the soil around the borehole and to maintain the water level in the hole at or above groundwater level.

CAUTION
The use of bottom-discharge bits or jetting through an open-tube sampler to clean out the borehole shall not be allowed. Only the use of side-discharge bits is permitted.

3. Determine whether a stationary piston-type sampler is required to limit sample disturbance and aid in retaining the sample. Either the hydraulically operated or control rod activated-type of stationary piston sampler may be used.

4. Prior to inserting the tube sampler into the borehole, check to ensure that the sampler head contains a check valve. The check valve is necessary to keep water in the rods from pushing the sample out the tube sampler during sample withdrawal. In addition, the check valve maintains a positive suction within the tube to help retain the sample.

5. A stainless steel tube sampler is typically used to minimize chemical reaction between the sample and the sampling tube.

6. With the sampling tube resting on the bottom of the hole and the water level in the boring at groundwater level or above, push the tube into the soil with a continuous and rapid motion, without impacting or twisting. If the soil is too hard to penetrate by pushing alone, careful hammering may be used by minimizing drop distance (tapping) of the hammer. Before pulling the tube, turn it at least one revolution to shear the sample off at the bottom. In no case shall the tube be pushed farther than the length provided for the soil sample. Allow about 3 inches in the tube for cuttings and sludge.

7. Upon removal of the sampling tube from the hole, measure the length of sample in the tube and also the length penetrated.

8. Remove disturbed material in the upper end of the tube and measure the length of sample again.

9. After removing at least 1 inch of soil from the lower end, place enough packing material (clean inert material such as paper or cloth) tightly in each end of the Shelby tube and then pour melted wax into each end to make at least a ½-inch wax plug and then add more packing material to fill the voids at both ends.

10. Place plastic caps on the ends, tape the caps in place, and dip the ends in wax to prevent loss of soil.

11. Affix label(s) to the tube as required and record sample number, depth, penetration, and recovery length on the label.

12. Mark the "up" direction on the side and upper end of the tube with indelible ink.

13. Complete a chain-of-custody form (see SOP SA-6.3) and other required forms (including Attachment A of this SOP).

14. Ship samples protected with suitable resilient packing material to reduce shock, vibration, and disturbance.

CAUTION

To preserve sample integrity do not allow tubes to freeze, and store the samples vertically with the same orientation they had in the ground, (i.e., top of sample is up) in a cool place out of the sun at all times.

CAUTION

A primary concern in the preparation of the wax plugs is the potential for the heat source and melted wax to cause a fire and/or burns. Follow the directions below to prevent injury or fire.

Electrical Heating

Using hot plates to melt the wax is acceptable. In an outdoor setting, make sure a Ground Fault Circuit Interrupter (GFCI) is employed within the electrical circuit. If a portable generator is used, ensure that the generator is an adequate distance from the sampling operation (at least 50 feet). Ensure that the extension cord is rated for the intended load and for outdoor use and is free from recognizable damage. Ensure flammable preservatives are not employed or stored near the hot plate. Although a Hot Work Permit is not required, scene safety evaluation by site personnel of the above elements is. As always, if a fire potential exists, the provisions for extinguishing must be immediately accessible as well as any provisions for first aid measures.

Open Flame

If an open flame is used, the following provisions are necessary:

- Complete a Hot Work Permit and any local permit required for elevated temperature applications. The Hot Work Permit, provided in your HASP, will aid the FOL and/or the SSO in ensuring that fire protection provisions (extinguishers, fire watches, etc.) are in place as well as ensuring that local requirements have been addressed.

- Ensure that water is available to address any wax splashes or contact. If possible, immerse the contacted area. Where this is not possible, run water over the area and apply cold compresses. The need for medical attention or first aid shall be determined on site under the direction of the SSO.

6.3 Surface Soil Sampling

The simplest, most direct method of collecting surface soil samples for subsequent analysis is by use of a stainless steel shovel, hand auger, soil corer, or stainless steel or disposable plastic trowel.

> ***NOTE***
> Multiple depth intervals are used to describe surface soil. Sometimes surface soil is defined as soil from 0 to 2 inches below ground surface (bgs), and sometimes it is defined as soil from other depths such as 0 to 2 feet bgs. Ensure that the definition of surface soil depth is clear before collecting surface soil samples.
>
> For the purposes of instruction, the terms "surface soil" and "near-surface soil" are used in this SOP as follows:
>
> - Surface soil - 0 to 6 inches bgs
> - Near-surface soil - 6 to 18 inches bgs
>
> If these intervals are defined differently in the planning documents, substitute the appropriate depth ranges.

In general, the following equipment is necessary for obtaining surface soil samples:

- Stainless steel or pre-cleaned disposable trowel.
- Stainless steel hand auger, soil corer, or shovel.
- Real-time air monitoring instrument (e.g., PID, FID) as directed in project planning document.
- Required PPE.
  - Nitrile surgeon's or latex gloves may be used, layered as necessary.
  - Safety glasses
  - Other – Items identified on the Safe Work Permit may be required based on location-specific requirements such as hearing protection, steel-toed work boots, and a hard hat when working near a drill rig. These provisions will be listed in the HASP or directed by the FOL and/or SSO.

> ***Safety Reminder***
> The use of latex products may elicit an allergic reaction in some people. Should this occur, remove the latex gloves, treat for an allergic reaction, and seek medical attention as necessary.

- Required paperwork (see SOP SA-6.3 and Attachment A of this SOP)
- Required decontamination equipment
- Required sample container(s)
- Wooden stakes or pin flags

- Sealable polyethylene bags (e.g., Ziploc® baggies)
- Heavy duty cooler
- Ice
- Chain-of-custody records and custody seals

When acquiring surface soil samples, use the following procedure:

1. Place padding or use knee pads when kneeling near the sample location. If necessary, place plastic sheeting to provide a clean surface for sample equipment to avoid possible cross- contamination.
2. Carefully remove vegetation, roots, twigs, litter, etc. to expose an adequate soil surface area to accommodate sample volume requirements.
3. Using a precleaned syringe or EnCore™ samplers, follow the procedure in Section 6.2.1 for collecting surface soil samples for volatile analysis. Surface soil samples for volatile organic analysis should be collected deeper than 6 inches bgs because shallower material has usually lost most of the volatiles through evaporation. Ensure that the appropriate surface soil depth is being analyzed in accordance with the planning document.
4. Using decontaminated sampling tools, thoroughly mix in place a sufficient amount of soil to fill the remaining sample containers. See Section 6.5 of this procedure for hand auger instruction, as needed.
5. Transfer the sample into those containers utilizing a stainless steel trowel.
6. Cap and securely tighten all sample containers.
7. Affix a sample label to each container. Be sure to fill out each label carefully and clearly, addressing all the categories described in SOP SA-6.3.
8. Proceed with the handling and processing of each sample container as described in SOP SA-6.2.
9. Site restoration – Whenever removing sample materials, always restore the surface. It is our intent to leave the area better than we found it. Do NOT create trip hazards in areas when pedestrian traffic may exist.

6.4 Near-Surface Soil Sampling

Collection of samples from near the surface (depth of 6 to 18 inches) can be accomplished with tools such as shovels, hand auger, soil corers, and stainless steel or pre-cleaned disposable trowels and the equipment listed under Section 6.5 of this procedure.

To obtain near-surface soil samples, the following protocol shall be used:

1. With a clean shovel, make a series of vertical cuts in the soil to the depth required to form a square approximately 1 foot by 1 foot.
2. Lever out the formed plug and scrape the bottom of the freshly dug hole with a decontaminated stainless steel or pre-cleaned disposable trowel to remove any loose soil.

3. Follow steps 1 through 9 of Section 6.3.

6.5 Subsurface Soil Sampling With a Hand Auger

A hand augering system generally consists of a variety of stainless steel bucket bits (approximately 6.5 inches long and 2, 2.75, 3.25, and 4 inches in diameter), series of extension rods (available in 2-, 3-, 4- and 5-inch lengths), and a T-handle connected to extension rods and to the auger bucket. A larger-diameter bucket bit is commonly used to bore a hole to the desired sampling depth and then it is withdrawn. The larger-diameter bit is then replaced with a smaller-diameter bit, lowered down the hole, and slowly turned into the soil to the completion depth (approximately 6 inches). The apparatus is then withdrawn and the soil sample collected.

The hand auger can be used in a wide variety of soil conditions. It can be used to sample soil either from the surface, or to depths in excess of 12 feet. However, the presence of subsurface rocks and landfill material and collapse of the borehole normally limit sampling depth.

To accomplish soil sampling using a hand augering system, the following equipment is required:

- Complete hand auger assembly (variety of bucket bit sizes)
- Stainless steel mixing bowls
- The equipment listed in Section 6.3
- Miscellaneous hand tools as required to assemble and disassemble the hand auger units

CAUTION

Potential hazards associated with hand augering include:

- Muscle strain and sprain due to over twisting and/or over compromising yourself.
- Equipment failure due to excessive stress on the T-handle or rods through twisting. Failure of any of these components will result in a sudden release and potential injury due to that failure.

As in all situations, any intrusive activities that could damage underground utilities shall be proceeded by a Dig/Excavation permit/ticket. Call the Utility Locating service in the area or your Project Health and Safety Officer for more information. When in doubt – **Get the Ticket!**

To obtain soil samples using a hand auger, use the following procedure:

1. Wearing designated PPE, attach a properly decontaminated bucket bit to a clean extension rod and attach the T-handle to the extension rod.
2. Clear the area to be sampled of any surface debris (vegetation, twigs, rocks, litter, etc.).
3. Twist the bucket into the ground while pushing vertically downward on the auger. The cutting shoes fill the bucket as it is advanced into the ground.
4. As the auger bucket fills with soil, periodically remove any unneeded soil.

5. Add rod extensions as necessary to extend the reach of the auger. Also, note (in a field notebook, boring log, and/or on a standardized data sheet) any changes in the color, texture or odor of the soil as a function of depth. The project-specific planning document (SAP, HASP, etc.) describe requirements for scanning the soil with a real-time air monitoring instrument (e.g., PID, FID, etc.) and recording the measurements.

6. After reaching the desired depth (e.g., the top of the interval to be sampled), slowly and carefully withdraw the apparatus from the borehole to prevent or minimize movement of soil from shallower intervals to the bottom of the hole.

7. Remove the soiled bucket bit from the rod extension and replace it with another properly decontaminated bucket bit. The bucket bit used for sampling is to be smaller in diameter than the bucket bit employed to initiate the borehole.

8. Carefully lower the apparatus down the borehole. Care must be taken to avoid scraping the borehole sides.

9. Slowly turn the apparatus until the bucket bit is advanced approximately 6 inches.

10. Discard the top of the core (approximately 1 inch), which represents any loose material collected by the bucket bit before penetrating the sample material.

11. Using a precleaned syringe or EnCore™ samplers, follow the procedure in Section 6.2.1 for collecting a soil sample for volatile compound analysis directly from the bucket bit.
12. Utilizing a properly decontaminated stainless steel trowel or dedicated disposable trowel, remove the remaining sample material from the bucket bit and place into a properly decontaminated stainless steel mixing bowl.

13. Homogenize the sample material as thoroughly as practicable then fill the remaining sample containers. Refer to Section 6.2.2.

14. Follow steps 4 through 7 listed in Section 6.3.

6.5.1 Sampling Using Stainless Steel Soil Corers

A soil corer is a stainless steel tube equipped with a cutting shoe and sample window in the side. The soil corer is advanced into the soil by applying downward pressure (body weight). The soil is unloaded by then forcing a ram towards the cutting shoe, which results in the discharge of the soil core through a window in the sleeve.

Use, application, and sample protocol is the same as for hand augering provided above, but without necessarily rotating the corer while advancing it.

SAFETY REMINDER

Hand augering and soil corer sampling can be physically demanding based on the type of geology and subsurface encumbrances encountered. Soil coring has some added hazards such the corer collapsing under your weight. To reduce the potential for muscle strain and damage, the following measures will be incorporated:

- Stretch and limber your muscles before heavy exertion. This hazard becomes more predominant in the early morning hours (prior to muscles becoming limber) and later in the day (as a result of fatigue).

- Job rotation – Share the duties so that repetitive actions do not result in fatigue and injury.

- Increase break frequencies as needed, especially as ambient conditions of heat and/or cold stress may dictate.

- Do not force the hand tools or use cheater pipes or similar devices to bypass an obstruction. Move to another location near the sampling point. Exerting additional forces on the sampling devices can result in damage and/or failure that could potentially injure someone in the immediate vicinity.

- Do not over compromise yourself when applying force to the soil corer or hand auger. If there is a sudden release, it could result in a fall or muscle injury due to strain.

6.6 Subsurface Soil Sampling with a Split-Barrel Sampler

A split-barrel (split-spoon) sampler consists of a heavy carbon steel or stainless steel sampling tube that can be split into two equal halves to reveal the soil sample (see Attachment B). A drive head is attached to the upper end of the tube and serves as a point of attachment for the drill rod. A removable tapered nosepiece/drive shoe attaches to the lower end of the tube and facilitates cutting. A basket-like sample retainer can be fitted to the lower end of the split tube to hold loose, dry soil samples in the tube when the sampler is removed from the drill hole. This split-barrel sampler is made to be attached to a drill rod and forced into the ground by means of a 140-pound or larger casing driver.

Safety Reminder

It is intended through the Equipment Inspection for Drill Rigs form provided in the HASP that the hammer and hemp rope, where applicable, associated with this activity will be inspected (no physical damage is obvious), properly attached to the hammer (suitable knots or sufficient mechanical devices), and is in overall good condition.

Split-barrel samplers are used to collect soil samples from a wide variety of soil types and from depths greater than those attainable with other soil sampling equipment.

The following equipment is used for obtaining split-barrel samples:

- Drilling equipment (provided by subcontractor).
- Split-barrel samplers (2-inch OD, 1-3/8-inch ID, either 20 inches or 26 inches long); Larger OD samplers are available if a larger volume of sample is needed.
- Drive weight assembly, 140-pound weight, driving head, and guide permitting free fall of 30 inches.
- Stainless steel mixing bowls.
- Equipment listed in Section 6.3.

The following steps shall be followed to obtain split-barrel samples (Steps 1 through 4 are typically performed by the drilling subcontractor):

1. Attach the split-barrel sampler to the sampling rods.

2. Lower the sampler into the borehole inside the hollow stem auger bits.

3. Advance the split-barrel sampler by hammering the length (typically 18 or 24 inches) of the split-barrel sampler into the soil using 140-pound or larger hammer.

4. When the desired depth is achieved, extract the drill rods and sampler from the augers and/or borehole.

5. Detach the sampler from the drill rods.

6. Place the sampler securely in a vise so it can be opened using pipe wrenches.

> ***CAUTION***
> Pipe wrenches are used to separate the split spoon into several components. The driller's helper should not apply excessive force through the use of cheater pipes or push or pull in the direction where, if the wrench slips, hands or fingers will be trapped against an immovable object.

7. Remove the drive head and nosepiece with the wrenches, and open the sampler to reveal the soil sample.

8. Immediately scan the sample core with a real-time air monitoring instrument (e.g., FID, PID, etc.) (as project-specific planning documents dictate). Carefully separate (or cut) the soil core, with a decontaminated stainless steel knife or trowel, at about 6-inch intervals while scanning the center of the core for elevated readings. Also scan stained soil, soil lenses, and anomalies (if present), and record readings.

9. If elevated vapor readings were observed, collect the sample scheduled for volatile analysis from the center of the core where elevated readings occurred. If no elevated readings where encountered, the sample material should be collected from the core's center (this area represents the least disturbed area with minimal atmospheric contact) (refer to Section 6.2.1).

10. Using the same trowel, remove remaining sample material from the split-barrel sampler (except for the small portion of disturbed soil usually found at the top of the core sample) and place the soil into a decontaminated stainless steel mixing bowl.

11. Homogenize the sample material as thoroughly as practicable then fill the remaining sample containers (refer to Section 6.2.2).

12. Follow steps 4 through 7 in Section 6.3.

6.7 Subsurface Soil Sampling Using Direct-Push Technology

Subsurface soil samples can be collected to depths of 40+ feet using DPT. DPT equipment, responsibilities, and procedures are described in SOP SA-2.5.

6.8 Excavation and Sampling of Test Pits and Trenches

6.8.1 Applicability

This subsection presents routine test pit or trench excavation techniques and specialized techniques that are applicable under certain conditions.

CAUTION

During the excavation of trenches or pits at hazardous waste sites, several health and safety concerns arise from the method of excavation. No personnel shall enter any test pit or excavation over 4 feet deep except as a last resort, and then only under direct supervision of a Competent Person (as defined in 29 CFR 1929.650 of Subpart P - Excavations). Whenever possible, all required chemical and lithological samples should be collected using the excavator bucket or other remote sampling apparatus. If entrance is required, all test pits or excavations must be stabilized by bracing the pit sides using specifically designed wooden, steel, or aluminum support structures or through sloping and benching. Personnel entering the excavation may be exposed to toxic or explosive gases and oxygen-deficient environments; therefore, monitoring will be conducted by the Competent Person to determine if it is safe to enter. Any entry into a trench greater than 4 feet deep will constitute a Confined Space Entry and must be conducted in conformance with OSHA standard 29 CFR 1910.146. In all cases involving entry, substantial air monitoring, before entry, appropriate respiratory gear and protective clothing determination, and rescue provisions are mandatory. There must be at least three people present at the immediate site before entry by one of the field team members. This minimum number of people will increase based on the potential hazards or complexity of the work to be performed. The reader shall refer to OSHA regulations 29 CFR 1926.650, 29 CFR 1910.120, 29 CFR 1910.134, and 29 CFR 1910.146. High-hazard entries such as this will be supported by members of the Health Sciences Group professionally trained in these activities.

Excavations are generally not practical where a depth of more than about 15 to 20-feet is desired, and they are usually limited to a few feet below the water table. In some cases, a pumping system may be required to control water levels within the pit, providing that pumped water can be adequately stored or disposed. If soil data at depths greater than 15-feet are required, the data are usually obtained through test borings instead of test pits.

In addition, hazardous wastes may be brought to the surface by excavation equipment. This material, whether removed from the site or returned to the subsurface, must be properly handled according to any and all applicable federal, state, and local regulations.

6.8.2 Test Pit and Trench Excavation

Test pits or trench excavations are constructed with the intent that they will provide an open view of subsurface lithology and/or disposal conditions that a boring will not provide. These procedures describe the methods for excavating and logging test pits and trenches installed to determine subsurface soil and rock conditions. Test pit operations shall be logged and documented (see Attachment C).

Test pits and trenches may be excavated by hand or power equipment to permit detailed descriptions of the nature and contamination of the in-situ materials. The size of the excavation will depend primarily on the following:

- The purpose and extent of the exploration

- The space required for efficient excavation
- The chemicals of concern
- The economics and efficiency of available equipment

Test pits normally have a cross section that is 4 to 10 feet square; test trenches are usually 3 to 6 feet wide and may be extended for any length required to reveal conditions along a specific line. The following table provides guidelines for design consideration based on equipment efficiencies.

Equipment	Typical Widths, in Feet
Trenching machine	0.25 to 1.0
Backhoe/Track Hoe	2 to 6

The lateral limits of excavation of trenches and the position of test pits shall be carefully marked on area base maps. If precise positioning is required to indicate the location of highly hazardous materials, nearby utilities, or dangerous conditions, the limits of the excavation shall be surveyed. Also, if precise determination of the depth of buried materials is needed for design or environmental assessment purposes, the elevation of the ground surface at the test pit or trench location shall also be determined by survey. If the test pit/trench will not be surveyed immediately, it shall be backfilled and its position identified with stakes placed in the ground at the margin of the excavation for later surveying.

The construction of test pits and trenches shall be planned and designed in advance as much as possible. However, the following field conditions may necessitate revisions to the initial plans:

- Subsurface utilities
- Surface and subsurface encumbrances
- Vehicle and pedestrian traffic patterns
- Purpose for excavation (e.g., the excavation of potential ordnance items)

The final depth and construction method shall be collectively determined by the FOL and designated Competent Person. The actual layout of each test pit, temporary staging area, and spoils pile may further be predicated based on site conditions and wind direction at the time the test pit is excavated. Prior to excavation, the area may be surveyed by magnetometer or metal detector or other passive methods specified in SOP HS1.0, Utility Location and Excavation Clearance, to identify the presence of underground utilities or drums. Where possible, the excavator should be positioned upwind and preferably within an enclosed cab.

No personnel shall enter any test pit or excavation except as a last resort, and then only under direct supervision of a Competent Person. If entrance is required, OSHA requirements must be met (e.g., walls must be braced with wooden or steel braces, ladders must be placed for every 25 feet of lateral travel and extended 3 feet above ground surface). A temporary guard rail or vehicle stop must be placed along the surface of the hole before entry in situations where the excavation may be approached by traffic. Spoils will be stockpiled no closer than 2 feet from the sidewall of the excavation. The excavation equipment operator shall be careful not to undercut sidewalls and will, where necessary, bench back to increase stability. The top cover, when considered clean, will be placed separately from the subsurface materials to permit clean cover. It is emphasized that the project data needs should be structured such that required samples can be collected without requiring entrance into the excavation. For example,

samples of leachate, groundwater, or sidewall soil can be collected with telescoping poles or similar equipment.

Dewatering and watering may be required to ensure the stability of the side walls, to prevent the bottom of the pit from heaving, and to keep the excavation stable. This is an important consideration for excavations in cohesionless material below the groundwater table and for excavations left open greater than a day. Liquids removed as a result of dewatering operations must be handled as potentially contaminated materials. Procedures for the collection and disposal of such materials should be discussed in the site-specific project plans.

Where possible excavations and test pits shall be opened and closed within the same working day. Where this is not possible, the following engineering controls shall be put in place to control access:

- Trench covers/street plates
- Fences encompassing the entire excavation intended to control access
- Warning signs warning personnel of the hazards
- Amber flashing lights to demarcate boundaries of the excavation at night

Excavations left open will have emergency means to exit should someone accidentally enter.

6.8.3 Sampling in Test Pits and Trenches

6.8.3.1 General

Log test pits and trenches as they are excavated in accordance with the Test Pit Log presented in Attachment C. These records include plan and profile sketches of the test pit/trench showing materials encountered, their depth and distribution in the pit/trench, and sample locations. These records also include safety and sample screening information.

Entry of test pits by personnel is extremely dangerous, shall be avoided unless absolutely necessary, and can occur only after all applicable health and safety and OSHA requirements have been met as stated above. These provisions will be reiterated as appropriate in the project-specific HASP.

The final depth and type of samples obtained from each test pit will be determined at the time the test pit is excavated. Sufficient samples are usually obtained and analyzed to quantify contaminant distribution as a function of depth for each test pit. Additional samples of each waste phase and any fluids encountered in each test pit may also be collected.

In some cases, samples of soil may be extracted from the test pit for reasons other than waste sampling and chemical analysis, for instance, to obtain geotechnical information. Such information includes soil types, stratigraphy, strength, etc., and could therefore entail the collection of disturbed (grab or bulk) or relatively undisturbed (hand-carved or pushed/driven) samples that can be tested for geotechnical properties. The purposes of such explorations are very similar to those of shallow exploratory or test borings, but often test pits offer a faster, more cost-effective method of sampling than installing borings.

6.8.3.2 Sampling Equipment

The following equipment is needed for obtaining samples for chemical or geotechnical analysis from test pits and trenches:

- Backhoe or other excavating machinery.
- Shovels, picks, hand augers, and stainless steel trowels/disposable trowels.
- Sample container - bucket with locking lid for large samples; appropriate bottle ware for chemical or geotechnical analysis samples.
- Polyethylene bags for enclosing sample containers; buckets.
- Remote sampler consisting of 10-foot sections of steel conduit (1-inch-diameter), hose clamps, and right angle adapter for conduit (see Attachment D).

6.8.3.3 Sampling Methods

The methods discussed in this section refer to test pit sampling from grade level. If test pit entry is required, see Section 6.8.3.4.

- Excavate the trench or pit in several 0.5- to 1.0-foot depth increments. Where soil types support the use of a sand bar cutting plate, use of this device is recommended to avoid potentially snagging utilities with the excavator teeth. It is recommended that soil probes or similar devices be employed where buried items or utilities may be encountered. This permits the trench floor to be probed prior to the next cut.
- After each increment:
  - the operator shall wait while the sampler inspects the test pit from grade level
  - the sampler shall probe the next interval where this is considered necessary. Practical depth increments for lithological evaluations may range from 2 to 4 feet i or where lithological changes are noted.
- The backhoe operator, who will have the best view of the test pit, shall immediately cease digging if:
  - Any fluid phase, including groundwater seepage, is encountered in the test pit
  - Any drums, other potential waste containers, obstructions, or utility lines are encountered
  - Distinct changes of material being excavated are encountered

This action is necessary to permit proper sampling of the test pit and to prevent a breach of safety protocol. Depending on the conditions encountered, it may be required to excavate more slowly and carefully with the backhoe.

For obtaining test pit samples from grade level, the following procedure shall be followed:

- Use the backhoe to remove loose material from the excavation walls and floor to the greatest extent possible.
- Secure the walls of the pit, if necessary. (There is seldom any need to enter a pit or trench that would justify the expense of shoring the walls. All observations and samples should be taken from the ground surface.)

- Samples of the test pit material are to be obtained either directly from the backhoe bucket or from the material after it has been deposited on the ground, as follows:

  a. The sampler or FOL shall direct the backhoe operator to remove material from the selected depth or location within the test pit/trench.

  b. The backhoe operator shall bring the bucket over to a designated location on the sidewall a sufficient distance from the pit (at least 5 feet) to allow the sampler to work around the bucket.

  c. After the bucket has been set on the ground, the backhoe operator shall either disengage the controls or shut the machine down.

  d. When signaled by the operator that it is safe to do, the sampler will approach the bucket.

  e. The soil shall be monitored with a photoionization or flame ionization detector (PID or FID) as directed in the project -specific planning documents.

  f. The sampler shall collect the sample from the center of the bucket or pile in accordance with surface soil sampling procedures of Section 6.3 or 6.4, as applicable. Collecting samples from the center of a pile or bucket eliminates cross-contamination from the bucket or other depth intervals.

- If a composite sample is desired, several depths or locations within the pit/trench will be selected, and the bucket will be filled from each area. It is preferable to send individual sample bottles filled from each bucket to the laboratory for compositing under the more controlled laboratory conditions. However, if compositing in the field is required, each sample container shall be filled from materials that have been transferred into a mixing bucket and homogenized. Note that homogenization/compositing is not applicable for samples to be subjected to volatile organic analysis.

> ***CAUTION***
> Care must be exercised when using the remote sampler described in the next step because of potential instability of trench walls. In situations where someone must move closer than 2 feet to the excavation edge, a board or platform should be used to displace the sampler's weight to minimize the chance of collapse of the excavation edge. Fall protection should also be employed when working near the edges or trenches greater than 6 feet deep. An immediate means to extract people who have fallen into the trench will be immediately available. These means may include ladders or rope anchor points.

- Using the remote sampler shown in Attachment D, samples can be taken at the desired depth from the sidewall or bottom of the pit as follows:

  a. Scrape the face of the pit/trench using a long-handled shovel or hoe to remove the smeared zone that has contacted the backhoe bucket.

  b. Collect the sample directly into the sample jar, by scraping with the jar edge, eliminating the need for sample handling equipment and minimizing the likelihood of cross-contamination.

  c. Cap the sample jar, remove it from the remote sampler assembly, and package the sample for shipment in accordance with SOP SA-6.3.

- Complete documentation as described in SOP SA-6.3 and Attachment C of this SOP.

6.8.3.4 In-Pit Sampling

Under rare conditions, personnel may be required to enter the test pit/trench. This is necessary only when soil conditions preclude obtaining suitable samples from the backhoe bucket (e.g., excessive mixing of soil or wastes within the test pit/trench) or when samples from relatively small discrete zones within the test pit are required. This approach may also be necessary to sample any seepage occurring at discrete levels or zones in the test pit that are not accessible with remote samplers.

In general, personnel shall sample and log pits and trenches from the ground surface, except as provided for by the following criteria:

- There are no practical alternative means of obtaining such data.
- The SSO and Competent Person determine that such action can be accomplished without breaching site safety protocol. This determination will be based on actual monitoring of the pit/trench after it is dug (including, at a minimum, measurements of oxygen concentration, flammable gases, and toxic compounds, in that order). Action levels will be provided in project-specific planning documents.
- A company-designated Competent Person determines that the pit/trench is stable trough soil classification evaluation/inspections or is made stable (by cutting/grading the sidewalls or using shoring) prior to entrance of any personnel. OSHA requirements shall be strictly observed.

If these conditions are satisfied, only one person may enter the pit/trench. On potentially hazardous waste sites, this individual shall be dressed in selected PPE as required by the conditions in the pit. He/she shall be affixed to a harness and lifeline and continuously monitored while in the pit.

A second and possible third individual shall be fully dressed in protective clothing including a self-contained breathing device and on standby during all pit entry operations to support self rescue or assisted self rescue. The individual entering the pit shall remain therein for as brief a period as practical, commensurate with performance of his/her work. After removing the smeared zone, samples shall be obtained with a decontaminated trowel or spoon.

6.8.3.5 Geotechnical Sampling

In addition to the equipment described in Section 6.8.3.2, the following equipment is needed for geotechnical sampling:

- Soil sampling equipment, similar to that used in shallow drilled boring (i.e., thin-walled tube samplers), that can be pushed or driven into the floor of the test pit.
- Suitable driving (e,g., sledge hammer) or pushing (e.g., backhoe bucket) equipment used to advance the sampler into the soil.
- Knives, spatulas, and other suitable devices for trimming hand-carved samples.
- Suitable containers (bags, jars, tubes, boxes, etc.), labels, wax, etc. for holding and safely transporting collected soil samples.
- Geotechnical equipment (pocket penetrometer, torvane, etc.) for field testing collected soil samples for classification and strength properties.

Disturbed grab or bulk geotechnical soil samples may be collected for most soil in the same manner as comparable soil samples for chemical analysis. These collected samples may be stored in jars or plastic-lined sacks (larger samples), which will preserve their moisture content. Smaller samples of this type are usually tested for their index properties to aid in soil identification and classification: larger bulk samples are usually required to perform compaction tests.

Relatively undisturbed samples are usually extracted in cohesive soil using thin-walled tube samplers, and such samples are then tested in a geotechnical laboratory for their strength, permeability, and/or compressibility. The techniques for extracting and preserving such samples are similar to those used in performing Shelby tube sampling in borings, except that the sampler is advanced by hand or backhoe, rather than by a drill rig. Also, the sampler may be extracted from the test pit by excavation around the tube when it is difficult to pull it out of the ground. If this excavation requires entry of the test pit, the requirements described in Section 6.8.3.4 shall be followed. The thin-walled tube sampler shall be pushed or driven vertically into the floor or steps excavated in the test pit at the desired sampling elevations. Extracting tube samples horizontally from the walls of the test pit is not appropriate because the sample will not have the correct orientation.

A sledge hammer or backhoe may be used to drive or push the tube into the ground. Place a piece of wood over the top of the sampler or sampling tube to prevent damage during driving/pushing of the sample. Pushing the sampler with a constant thrust is always preferable to driving it with repeated blows, thus minimizing disturbance to the sample. When using a sledge hammer, it is recommended that the sampler be stabilized using a rope/strap wrench or pipe wrench to remove the person's hands holding the sampler from the strike zone. If the sample cannot be extracted by rotating it at least two revolutions (to shear off the sample at the bottom), hook the sampler to the excavator or backhoe and extract. This means an alternative head will be used as a connection point or that multiple choke hitches will be applied to extract the sampler. If this fails and the excavator can dig deeper without potentially impacting subsurface utilities, excavate the sampler. If this fails or if the excavator cannot be used due to subsurface utilities, hand-excavate to remove the soil from around the sides of the sampler. If hand-excavation requires entry into the test pit, the requirements in Section 6.8.3.4 must be followed. Prepare the sample as described in Steps 9 through 13 in Section 6.2.3, and label, pack and transport the sample in the required manner, as described in SOPs SA-6.3 and SA-6.1.

6.8.4 Backfilling of Trenches and Test Pits

All test pits and excavations must be either backfilled, covered, or otherwise protected at the end of each day. No excavations shall remain open during non-working hours unless adequately covered or otherwise protected.

Before backfilling, the onsite crew may photograph, if required by the project-specific work plan, all significant features exposed by the test pit and trench and shall include in the photograph a scale to show dimensions. Photographs of test pits shall be marked to include site number, test pit number, depth, description of feature, and date of photograph. In addition, a geologic description of each photograph shall be entered in the site logbook. All photographs shall be indexed and maintained as part of the project file for future reference.

After inspection, backfill material shall be returned to the pit under the direction of the FOL. Backfill should be returned to the trench or test pit in 6-inch to 1-foot lifts and compacted with the bucket. Remote controlled tampers or rollers may be lowered into the trench and operated from top side. This procedure will continue to the grade surface. It is recommended that the trench be tracked or rolled in. During excavation, clean soil from the top 2 feet may have been separated to be used to cover the last segments. Where these materials are not clean, it is recommended that clean fill be used for the top cover.

If a low-permeability layer is penetrated (resulting in groundwater flow from an upper contaminated flow zone into a lower uncontaminated flow zone), backfill material must represent original conditions or be impermeable. Backfill could consist of a soil-bentonite mix prepared in a proportion specified by the FOL (representing a permeability equal to or less than original conditions). Backfill can be covered by "clean" soil and graded to the original land contour. Revegetation of the disturbed area may also be required.

6.9 Records

The appropriate sample log sheet (see Attachment A of this SOP) must be completed by the site geologist/sampler for all samples collected. All soil sampling locations should be documented by tying in the location of two or more nearby permanent landmarks (building, telephone pole, fence, etc.) or obtaining GPS coordinates; and shall be noted on the appropriate sample log sheet, site map, or field notebook. Surveying may also be necessary, depending on the project requirements.

Test pit logs (see Attachment C of this SOP) shall contain a sketch of pit conditions. If the project-specific work plan requires photographs, at least one photograph with a scale for comparison shall be taken of each pit. Included in the photograph shall be a card showing the test pit number. Boreholes, test pits, and trenches shall be logged by the field geologist in accordance with SOP GH-1.5.

Other data to be recorded in the field logbook include the following:

- Name and location of job
- Date of boring and excavation
- Approximate surface elevation
- Total depth of boring and excavation
- Dimensions of pit
- Method of sample acquisition
- Type and size of samples
- Soil and rock descriptions
- Photographs if required
- Groundwater levels
- PID/FID/LEL/O_2 meter readings
- Other pertinent information, such as waste material encountered

In addition, site-specific documentation to be maintained by the SSO and/or Competent Person will be required including:

- Calibration logs
- Excavation inspection checklists

- Soil type classification

7.0 REFERENCES

American Society for Testing and Materials, 1987. ASTM Standards D1587-83 and D1586-84. ASTM Annual Book of Standards. ASTM. Philadelphia, Pennsylvania. Volume 4.08.

NUS Corporation, 1986. Hazardous Material Handling Training Manual.

NUS Corporation and CH2M Hill, August, 1987. Compendium of Field Operation Methods. Prepared for the U.S. EPA.

OSHA, Excavation, Trenching and Shoring 29 CFR 1926.650-653.

OSHA, Confined Space Entry 29 CFR 1910.146.

USEPA, November 2001. Environmental Investigations Standard Operating Procedures and Quality Assurance Manual.

ATTACHMENT A
SOIL & SEDIMENT SAMPLE LOG SHEET

Tetra Tech NUS, Inc.

SOIL & SEDIMENT SAMPLE LOG SHEET

Page___ of ___

Project Site Name: _____
Project No.: _____

[] Surface Soil
[] Subsurface Soil
[] Sediment
[] Other: _____
[] QA Sample Type: _____

Sample ID No.: _____
Sample Location: _____
Sampled By: _____
C.O.C. No.: _____

Type of Sample:
[] Low Concentration
[] High Concentration

GRAB SAMPLE DATA:

Date:	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Time:			
Method:			
Monitor Reading (ppm):			

COMPOSITE SAMPLE DATA:

Date:	Time	Depth	Color	Description (Sand, Silt, Clay, Moisture, etc.)
Method:				
Monitor Readings (Range in ppm):				

SAMPLE COLLECTION INFORMATION:

Analysis	Container Requirements	Collected	Other

OBSERVATIONS / NOTES:

MAP:

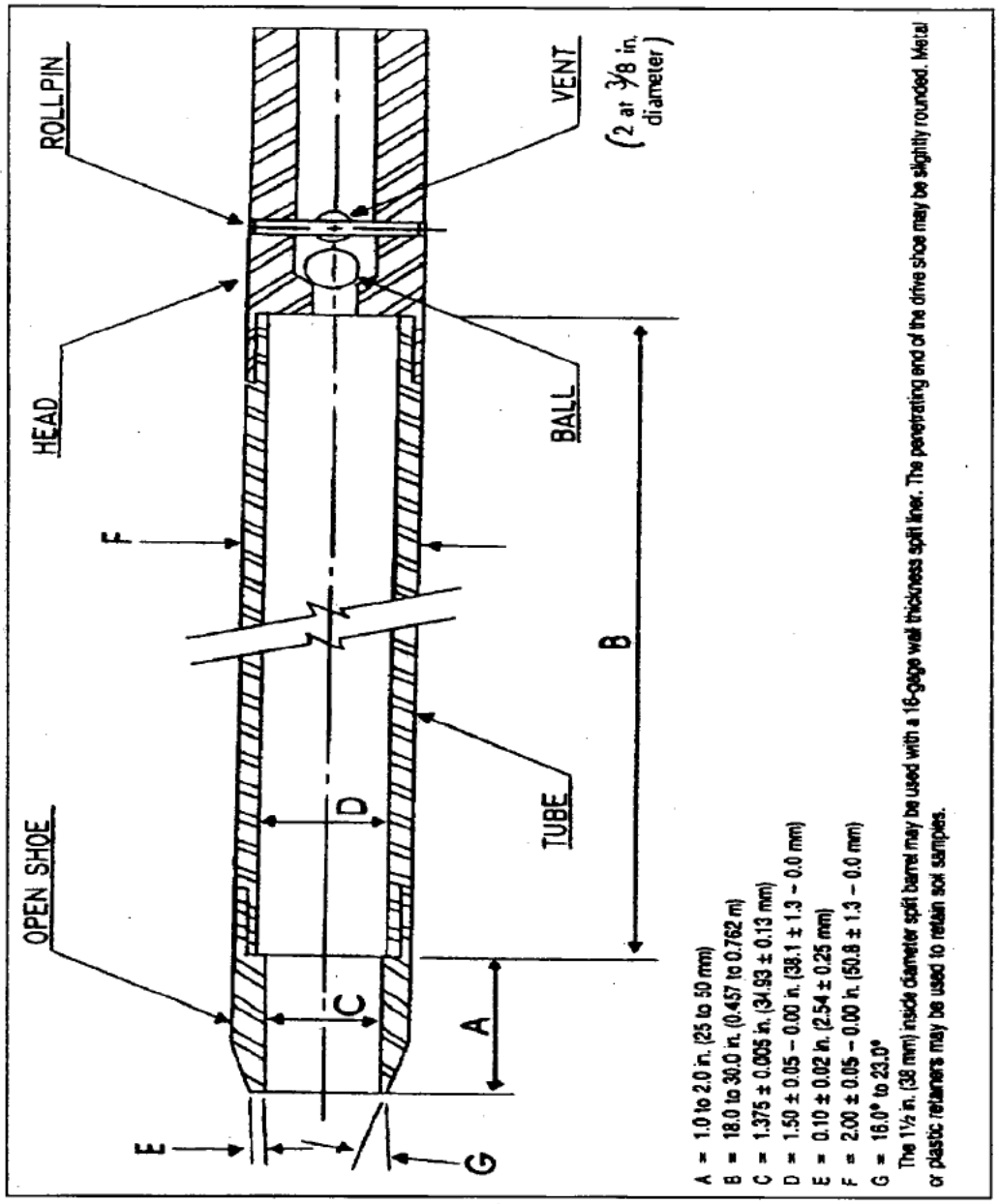
Circle if Applicable:

MS/MSD

Duplicate ID No.:

Signature(s):

ATTACHMENT B
SPLIT-SPOON SAMPLER



A = 1.0 to 2.0 in. (25 to 50 mm)
B = 18.0 to 30.0 in. (0.457 to 0.762 m)
C = 1.375 ± 0.005 in. (34.93 ± 0.13 mm)
D = 1.50 ± 0.05 – 0.00 in. (38.1 ± 1.3 – 0.0 mm)
E = 0.10 ± 0.02 in. (2.54 ± 0.25 mm)
F = 2.00 ± 0.05 – 0.00 in. (50.8 ± 1.3 – 0.0 mm)
G = 16.0° to 23.0°

The 1½ in. (38 mm) inside diameter split barrel may be used with a 16-gage wall thickness split liner. The penetrating end of the drive shoe may be slightly rounded. Metal or plastic retainers may be used to retain soil samples.

ATTACHMENT C
TEST PIT LOG

Tetra Tech NUS, Inc.

TEST PIT LOG

Page ___ of ___

PROJECT NAME: _____ TEST PIT No.: _____
PROJECT NUMBER: _____ DATE: _____
LOCATION: _____ GEOLOGIST: _____

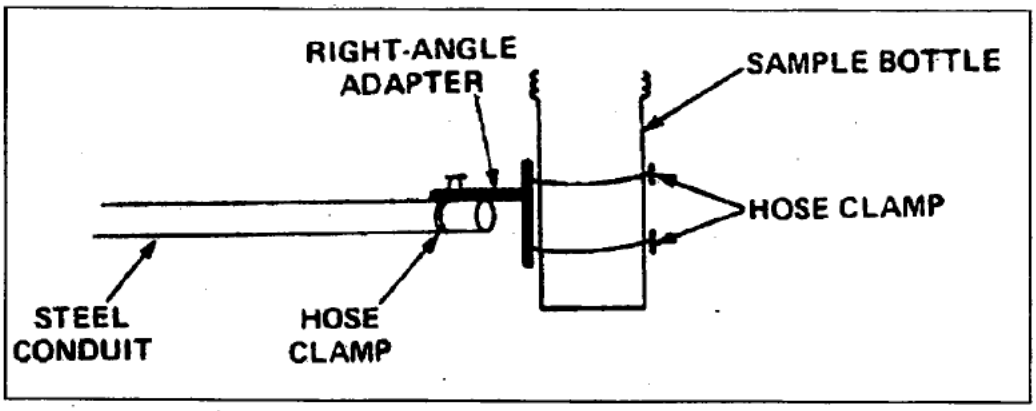
Depth (Ft.)	Lithology Change (Depth/Ft.)	MATERIAL DESCRIPTION Soil/Waste Characteristics (lithology, density, color, etc.)	USCS	Remarks	PID/FID READING Source (ppm)	BZ (ppm)

TEST PIT CROSS SECTION AND / OR PLAN VIEW

REMARKS: _____

PHOTO LOG: _____

ATTACHMENT D
REMOTE SAMPLE HOLDER FOR TEST PIT/TRENCH SAMPLING



APPENDIX I

PETTIBONE NORTH BRANCH PHOTOGRAPHS, MARCH 2011

Photo 1 – Boat Basin, Main Channel of Pettibone Creek, Looking East

Photo 2 – Weir near Boat Basin, Main Channel of Pettibone Creek, Looking West

Photo 3 – Weir near Boat Basin, Main Channel of Pettibone Creek, Looking East

Photo 4 – Damaged Wall in Need of Replacement, Main Channel of Pettibone Creek, Looking East

Photo 5 – Point Bar, Main Channel of Pettibone Creek, Looking West

Photo 6 – Stream Bank Scour near Steam Pipe Support, Main Channel of Pettibone Creek, Looking Southeast

Photo 7 – Point Bar, Main Channel of Pettibone Creek, Looking East-Southeast

Photo 8 – Point Bar, Main Channel of Pettibone Creek, Looking Southwest

Photo 9 – Point Bars, Main Channel of Pettibone Creek, Looking East

Photo 10 – Point Bars, Previously Placed Bank Stabilization Measures, Main Channel of Pettibone Creek, Looking Northeast

Photo 11 – Main Channel of Pettibone Creek near Steam Pipe Support, Looking Southeast

Photo 12 – Main Channel of Pettibone Creek near Steam Pipe Support, Looking North

Photo 13 – Point Bar near Steam Pipe Support, Main Channel of Pettibone Creek, Looking North

Photo 14 –Main Channel of Pettibone Creek, Looking North

Photo 15 –Main Channel of Pettibone Creek, Looking North

Photo 16 – Point Bar near Samson Street, Main Channel of Pettibone Creek, Looking West, Northwest

Photo 17 – Point Bar near Samson Street, Main Channel of Pettibone Creek, Looking Northeast

Photo 18 – Point Bar near Samson Street, Main Channel of Pettibone Creek, Looking Northeast

Photo 19 – Point Bar near Samson Street, Main Channel of Pettibone Creek, Looking Northeast

Photo 20 – Junction of Western North and South Branches of Pettibone Creek, Looking South

Photo 21 – Junction of North and South Branches of Pettibone Creek, Looking South-Southeast

Photo 22 – Point Bar West of Samson Street, North Channel of Pettibone Creek, Looking North

Photo 23 – Point Bars, North Channel of Pettibone Creek, Looking East

Photo 24 – Large Point Bar, North Channel of Pettibone Creek, Looking West

Photo 25 – Large Point Bar, North Channel of Pettibone Creek, Looking Southeast

Photo 26 – North Channel of Pettibone Creek, Looking Northeast

Photo 27 – North Channel of Pettibone Creek, Looking Northeast

Photo 28 – Debris Accumulation, North Channel of Pettibone Creek, Looking Southeast

Photo 29 – Access Road Adjacent to North Channel of Pettibone Creek, Looking West-Southwest

Photo 30 – Access Road Adjacent to North Channel of Pettibone Creek, Looking East

Photo 31 – Gabion Basket Stream Bank Protection, North Channel of Pettibone Creek, Looking West-Southwest

Photo 32 – Debris Accumulation, North Channel of Pettibone Creek, Looking North-Northeast

Photo 33 – Gabion Basket Stream Bank Protection, North Channel of Pettibone Creek, Looking Northwest

Photo 34 – North Channel of Pettibone Creek at Barry Road, Looking South-Southeast

Photo 35 – North Channel of Pettibone Creek at Barry Road, Looking Northeast

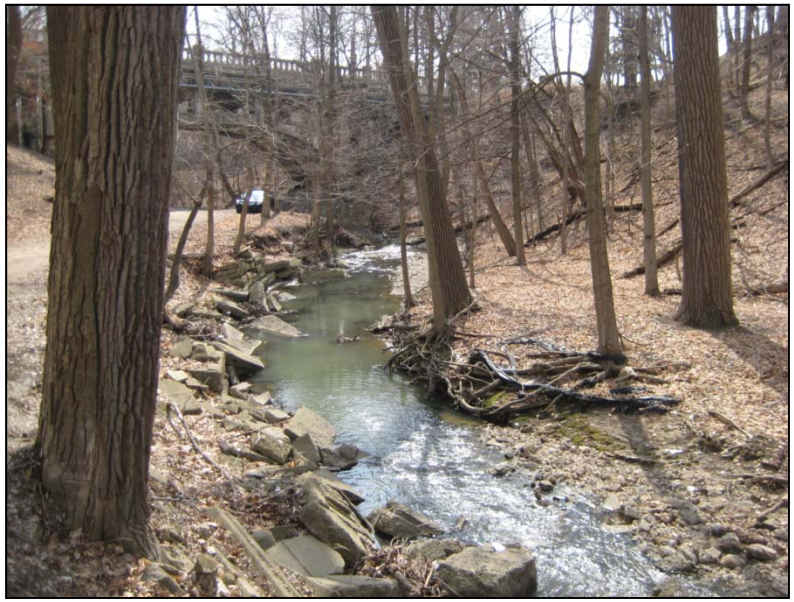


Photo 36 – North Channel of Pettibone Creek, Looking Southeast

Photo 37 – North Channel of Pettibone Creek, Collapsed Roadway Bridge, Looking West

Photo 38 – North Channel of Pettibone Creek, Collapsed Roadway Bridge, Looking South

Photo 39 – North Channel of Pettibone Creek, Collapsed Roadway Bridge, Looking Southeast

Photo 40 – Scour Pool Formed at Unprotected Outlet of Existing Storm Water Piping. North Channel of Pettibone Creek, Looking West

Photo 41 – Sedimentation, Point Bars, North Channel of Pettibone Creek, Looking Northwest

Photo 42 – Large Gravel Point Bar, North Channel of Pettibone Creek, Looking Southwest

Photo 43 – North Channel of Pettibone Creek, Looking East

Photo 44 – Junction of Western Tributary and North Branch of Pettibone Creek, Looking Northeast

Photo 45 – North Branch of Pettibone Creek, Farragut Avenue Bridge in Background, Looking North

Photo 46 – Junction of Western Tributary and North Branch of Pettibone Creek, Looking West-Northwest

Photo 47 – Junction of Western Tributary and North Branch of Pettibone Creek, Looking West-Northwest

Photo 48 – North Branch of Pettibone Creek, Farragut Avenue Bridge in Background, Looking North

Photo 49 – Large Gravel Point Bar, North Channel of Pettibone Creek, Looking East

Photo 50 – North Branch of Pettibone Creek, Farragut Avenue Bridge in Background, Looking East

Photo 51 – North Branch of Pettibone Creek, Beneath Farragut Avenue Bridge, Looking South

Photo 52 – Point Bar, Gabion Baskets, North Branch of Pettibone Creek, Beneath Farragut Avenue Bridge, Looking Northeast

Photo 53 – Point Bar, Gabion Baskets, North Branch of Pettibone Creek, Looking Northeast

Photo 54 – Bank Erosion, concrete Debris, North Branch of Pettibone Creek, Looking South

Photo 55 – Fallen Tree, Storm Water Outlet Pipe, North Branch of Pettibone Creek, Looking South

Photo 56 – Fallen Tree, Storm Water Outlet Pipe, North Branch of Pettibone Creek, Looking South

Photo 57 – North Branch of Pettibone Creek, Wooden Pedestrian Walk Bridge in Background, Looking North

Photo 58 – North Branch of Pettibone Creek, Looking South

Photo 59 – Culverts at Headwaters of North Branch of Pettibone Creek, Looking North

APPENDIX J

HEC-RAS ANALYSIS – PRE-CONSTRUCTION FLOWS

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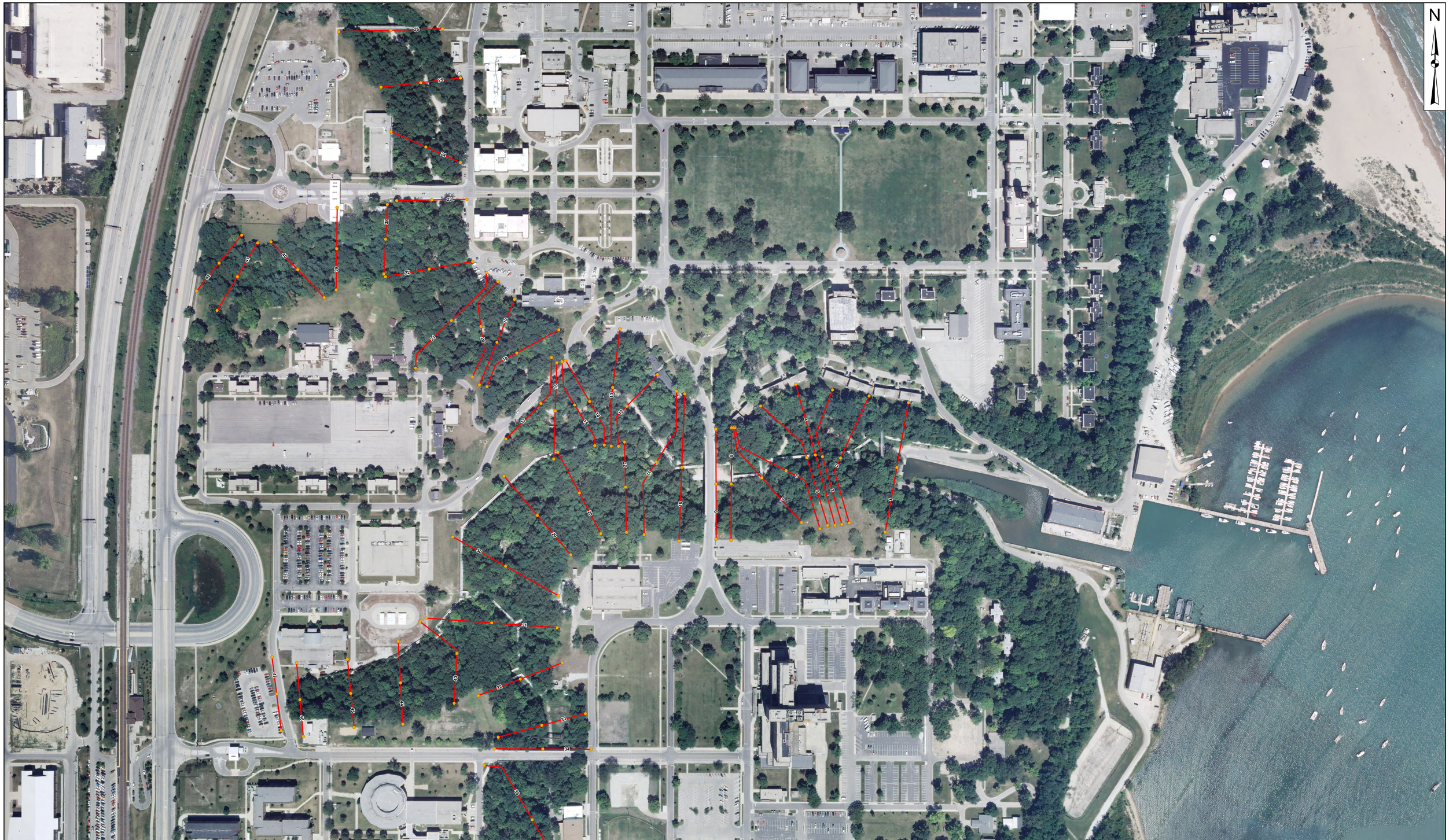

DRAWN BY	DATE
T. WHEATON	03/31/11
CHECKED BY	DATE
B. SMITH	03/31/11
REVISED BY	DATE

SCALE
AS NOTED

NAVFAC

CROSS SECTION LOCATIONS
NS GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. FIGURE 1	REV 0

PGH P:\GIS\GREATLAKES_NS\MAPDOCS\MXD\CROSS_SECTION_LOCATIONS_SOUTH.MXD 03/31/11 TW

DRAWN BY	DATE
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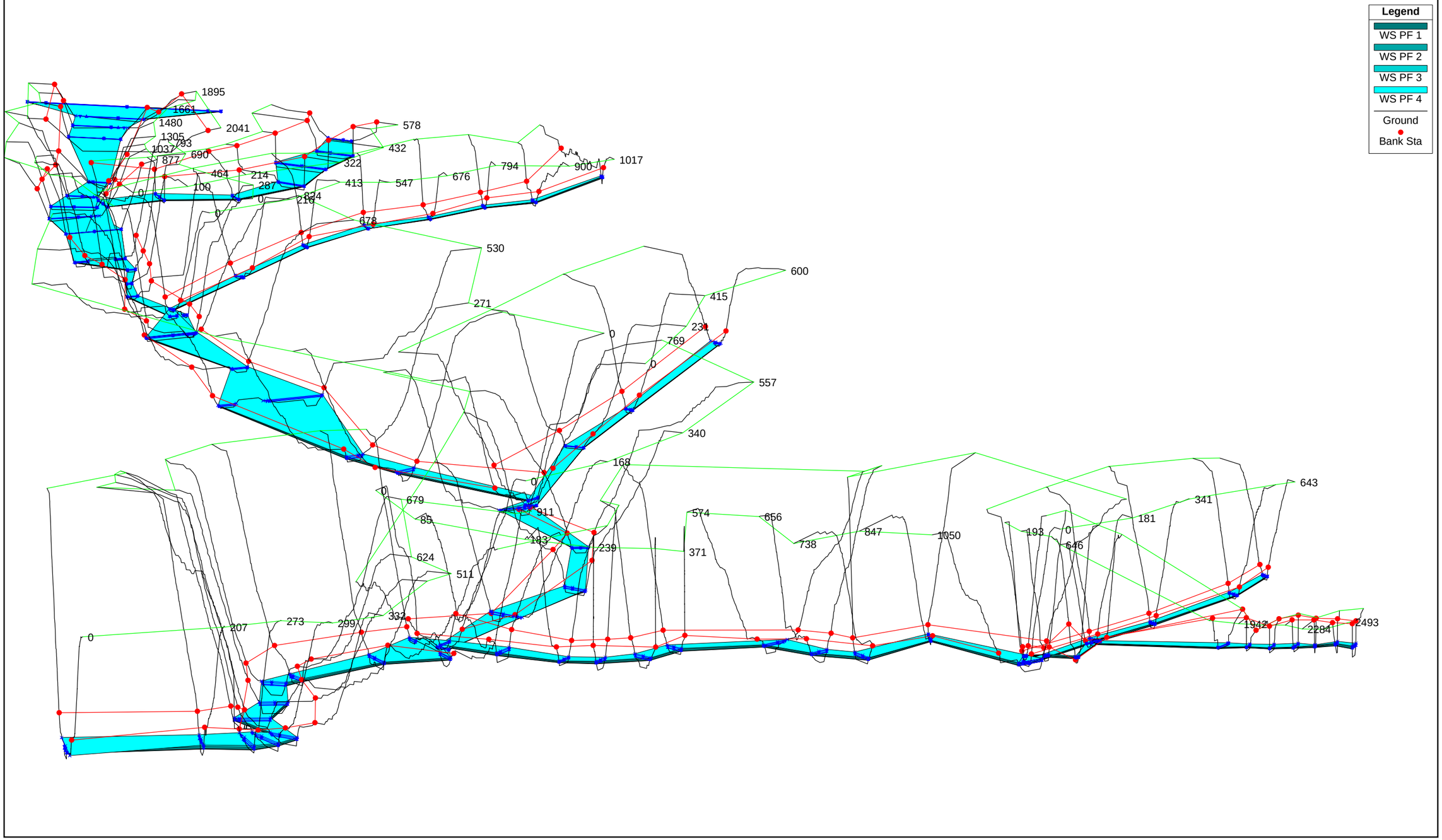
CHECKED BY	DATE
B. SMITH	03/31/11
REVISED BY	DATE
SCALE	
AS NOTED	

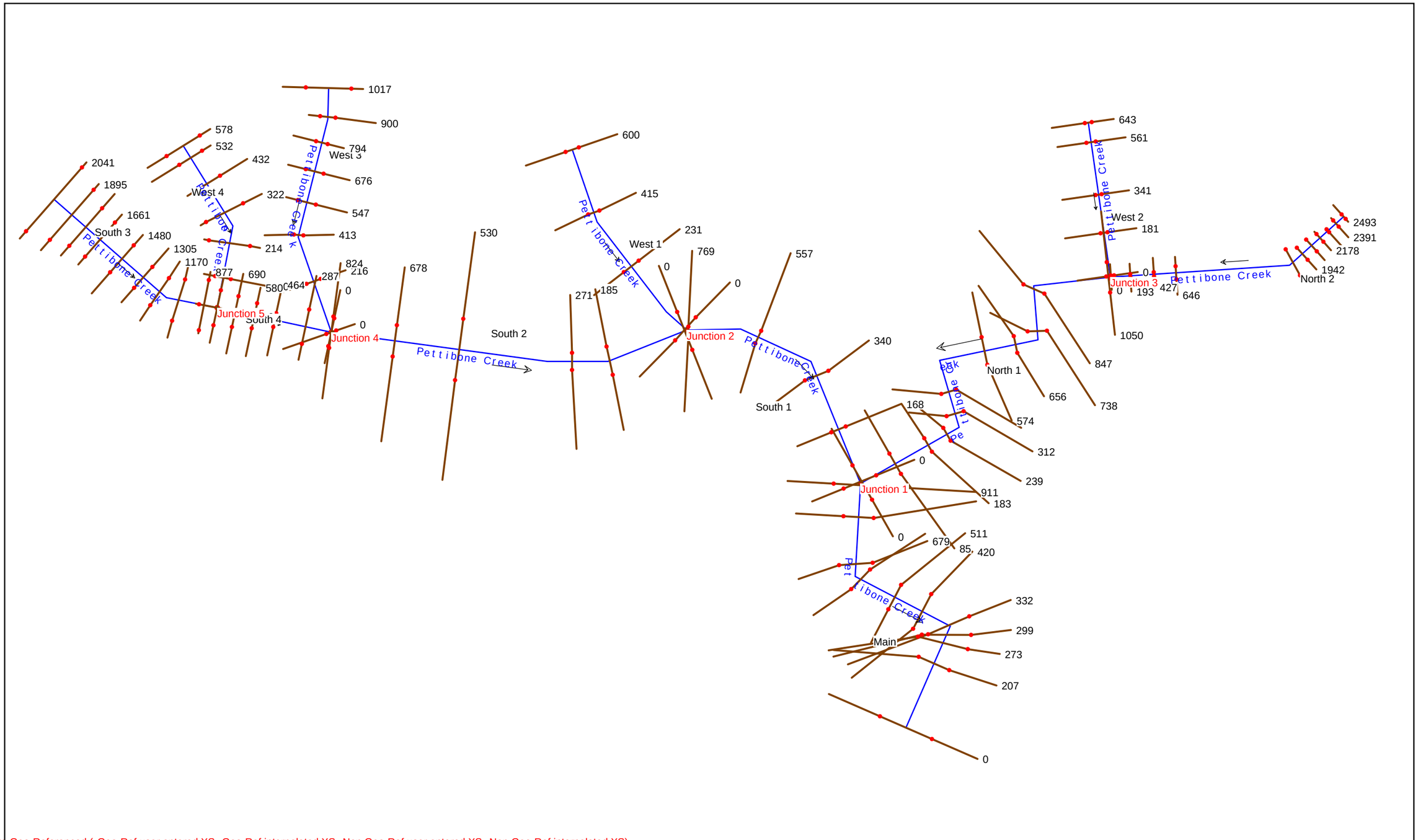
NAVFAC

CROSS SECTION LOCATIONS
SOUTHERN AREAS
NS GREAT LAKES
GREAT LAKES, ILLINOIS

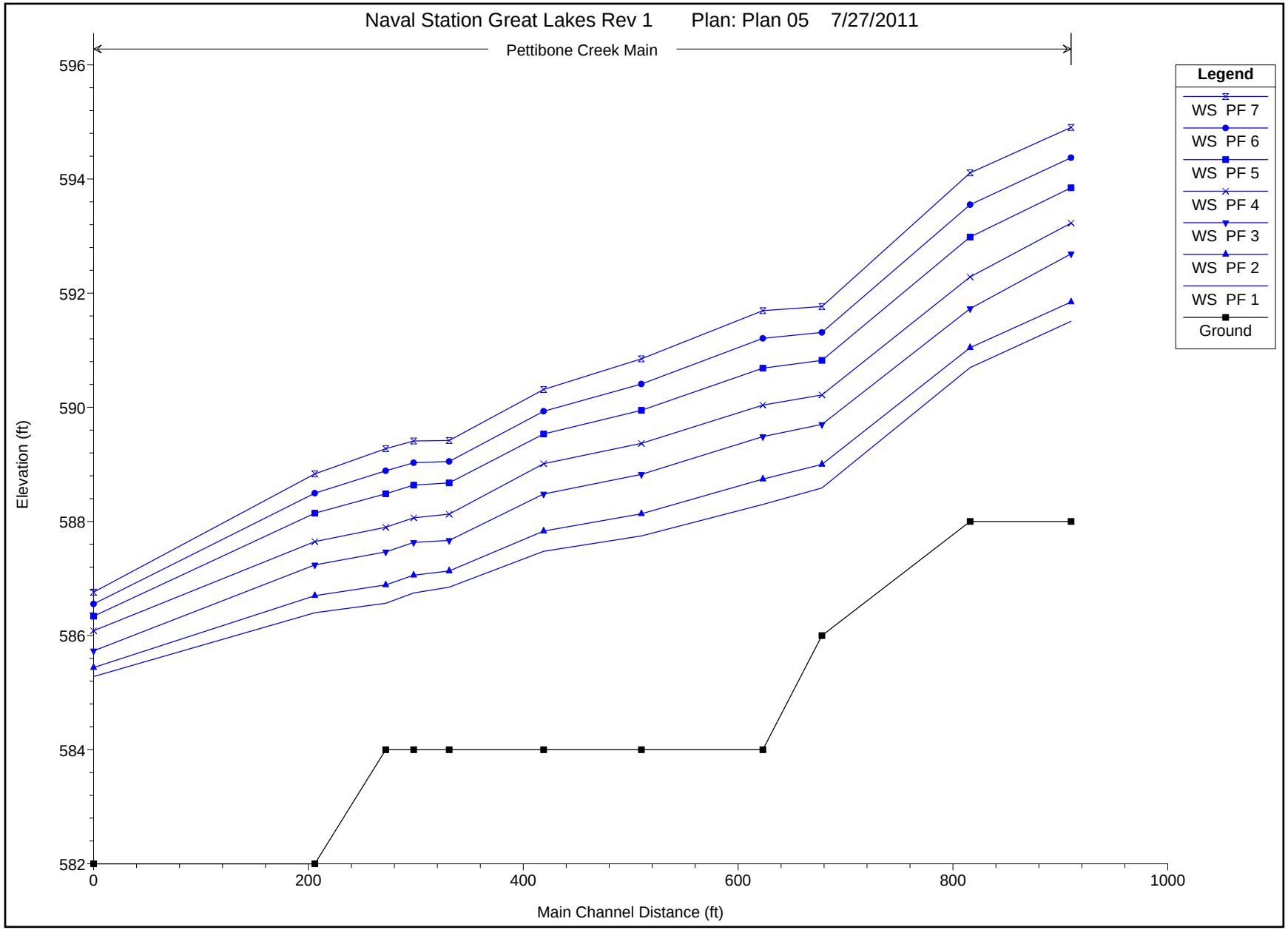
CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. FIGURE 2	REV 0

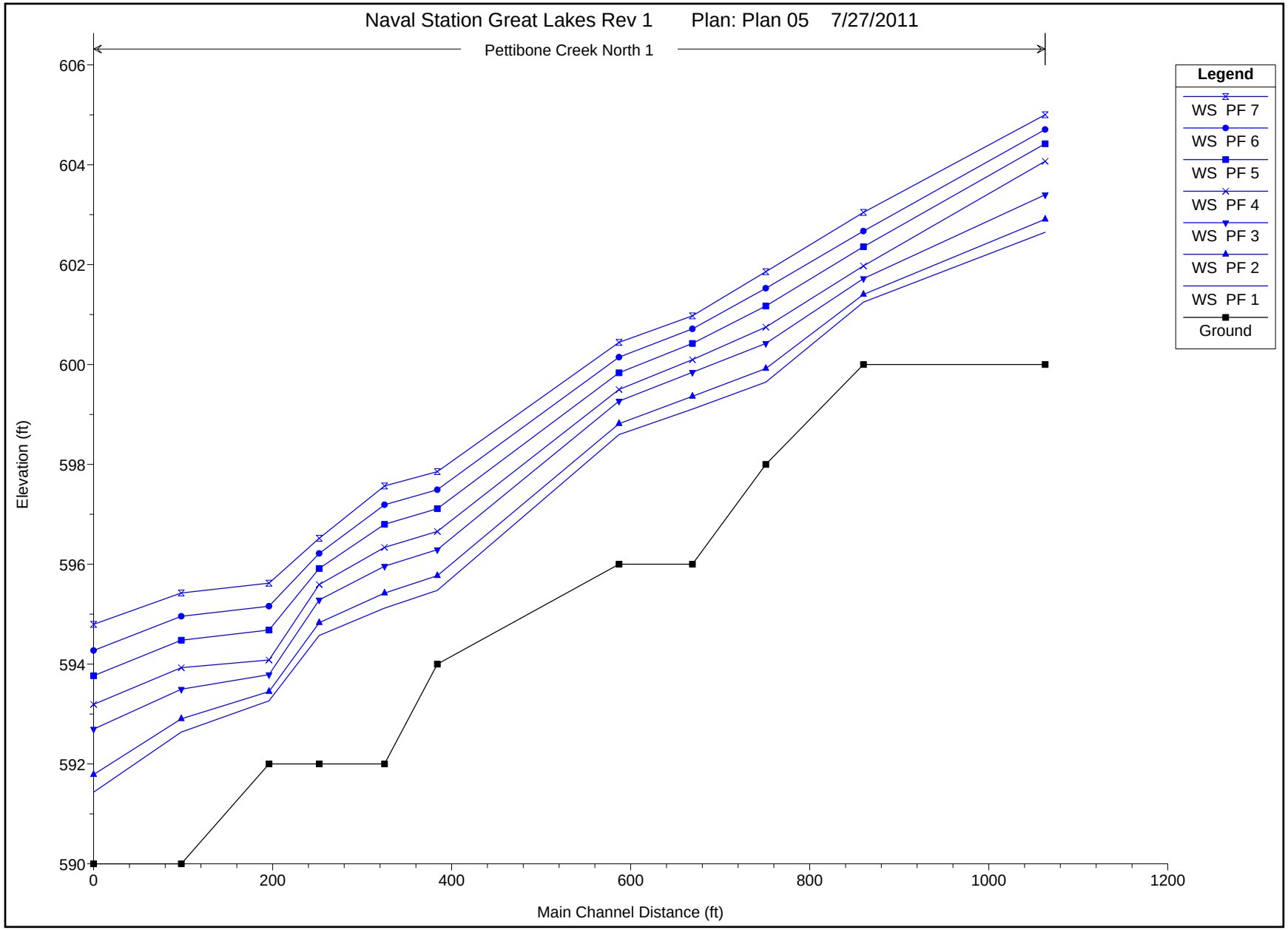
Naval Station Great Lakes Rev 2 Plan: Plan 06 3/30/2012

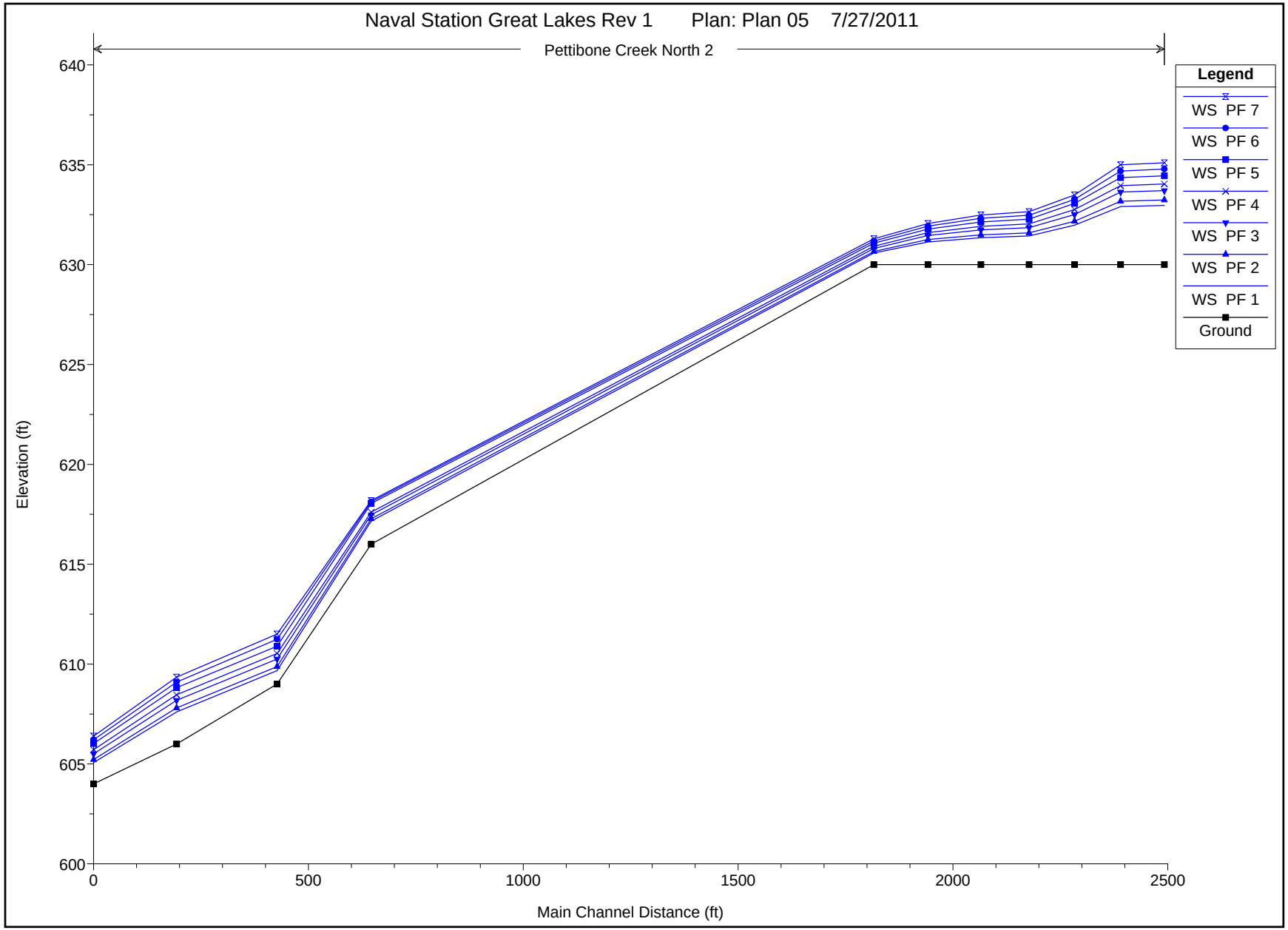


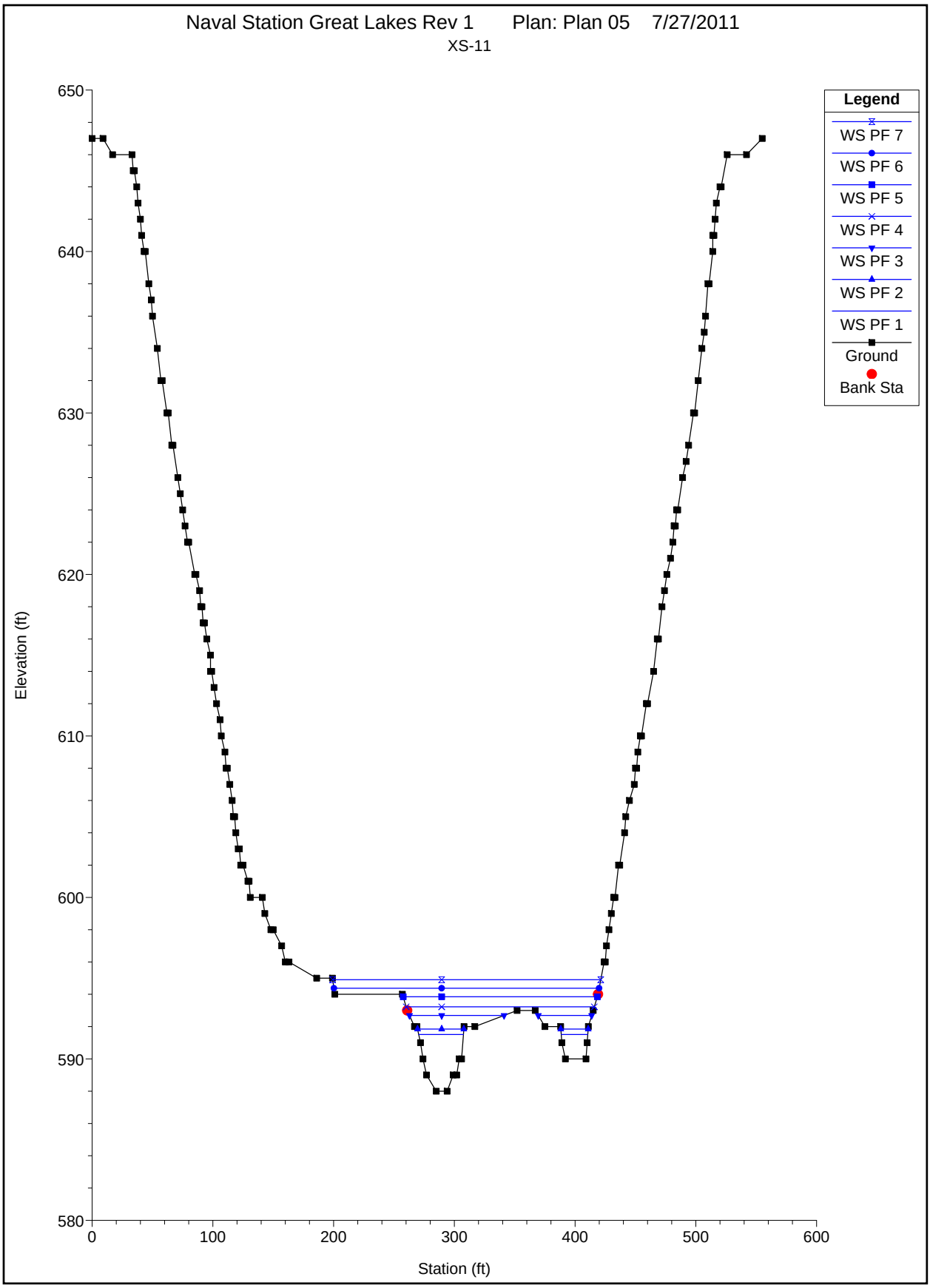


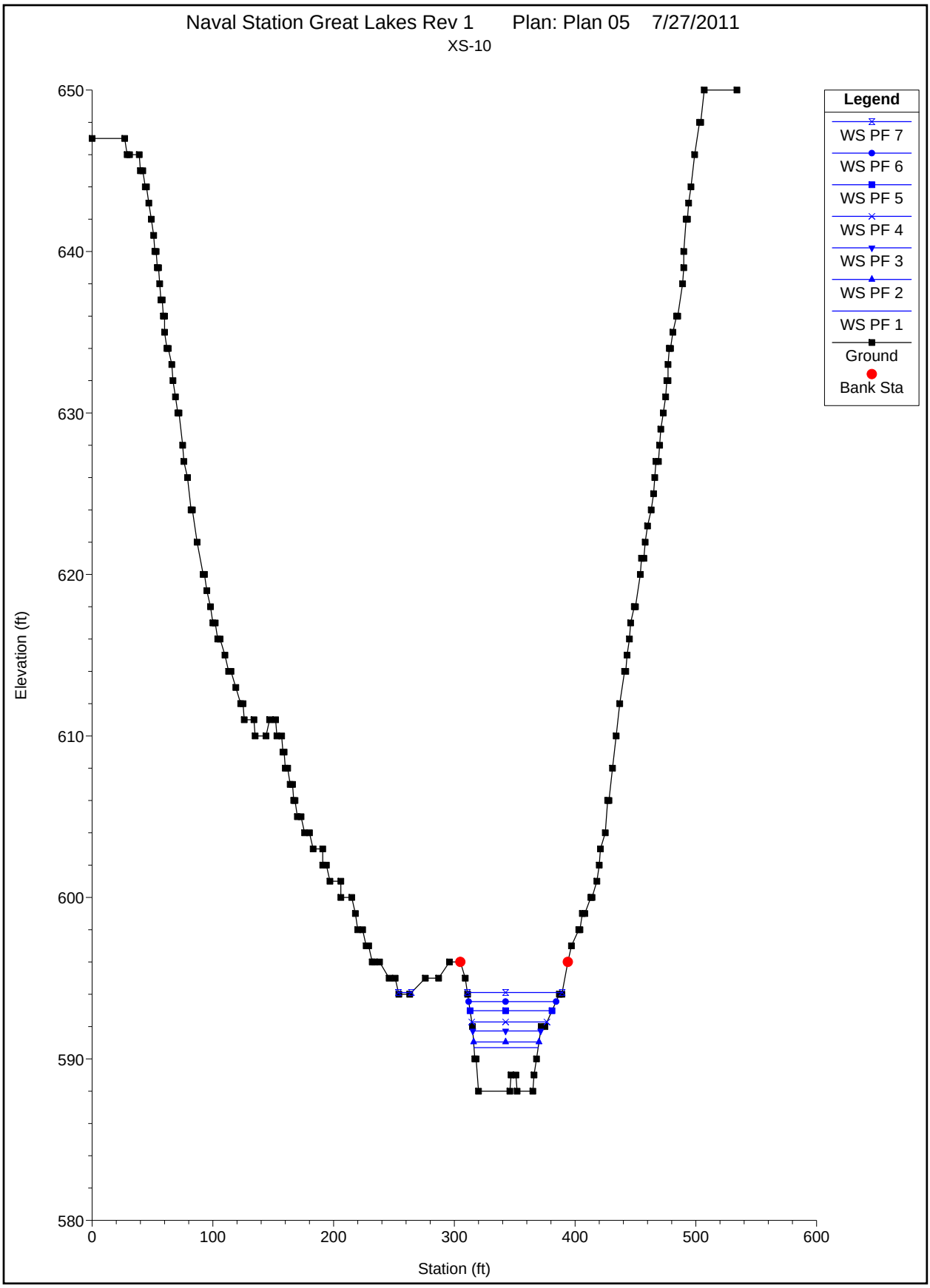
None of the XS's are Geo-Referenced (• Geo-Ref user entered XS • Geo-Ref interpolated XS • Non Geo-Ref user entered XS • Non Geo-Ref interpolated XS)

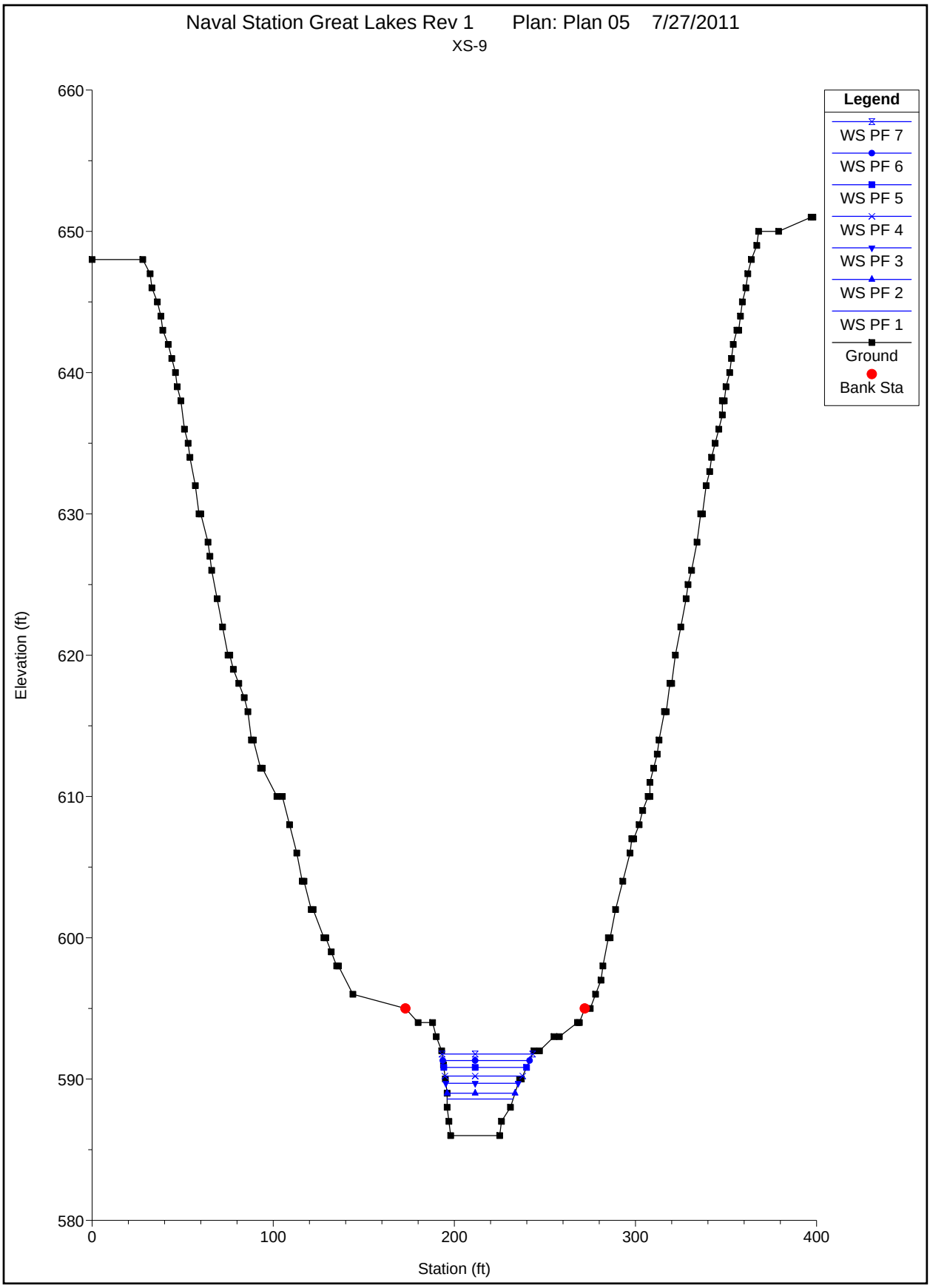

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
Pettibone Creek Main
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Elevation (ft)
596
594
592
590
588
586
584
582
0
200
400
600
800
1000
Main Channel Distance (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
Pettibone Creek North 1
Elevation (ft)
606
604
602
600
598
596
594
592
590
0
200
400
600
800
1000
1200
Main Channel Distance (ft)
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
Pettibone Creek North 2
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Elevation (ft)
640
635
630
625
620
615
610
605
600
0
500
1000
1500
2000
2500
Main Channel Distance (ft)

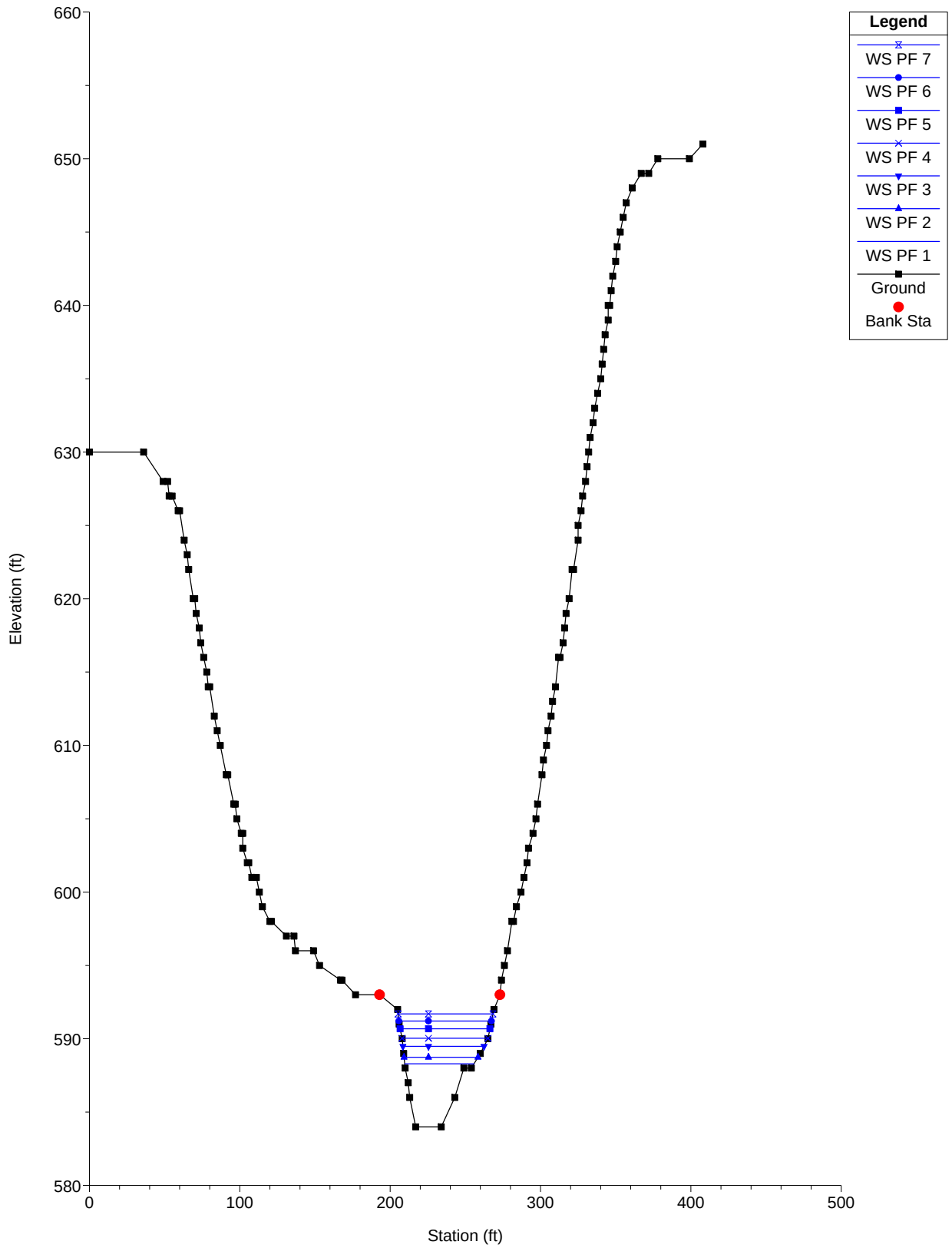

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-11
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
650
640
630
620
610
600
590
580
0
100
200
300
400
500
600

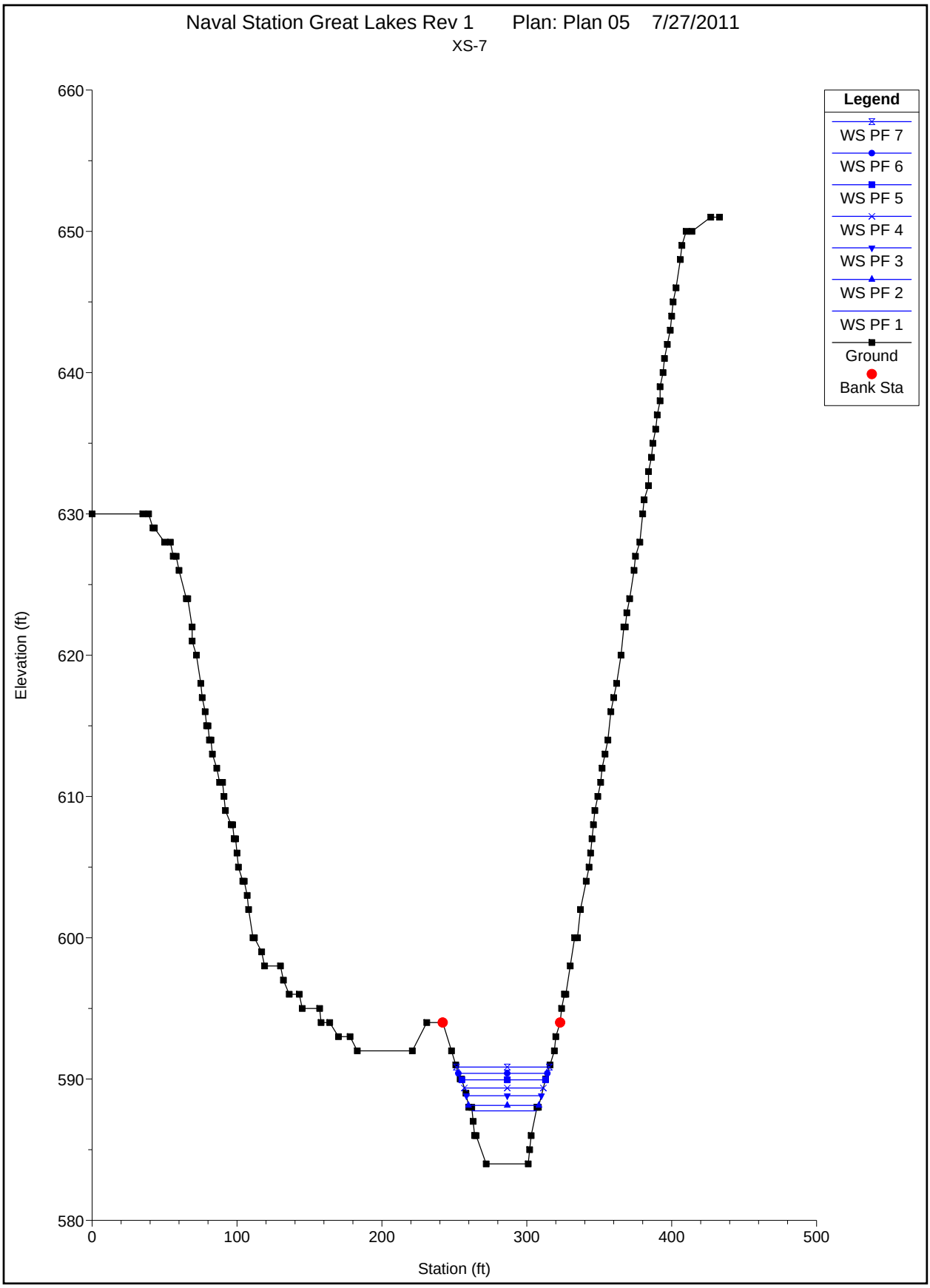

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-10
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
650
640
630
620
610
600
590
580
0
100
200
300
400
500
600

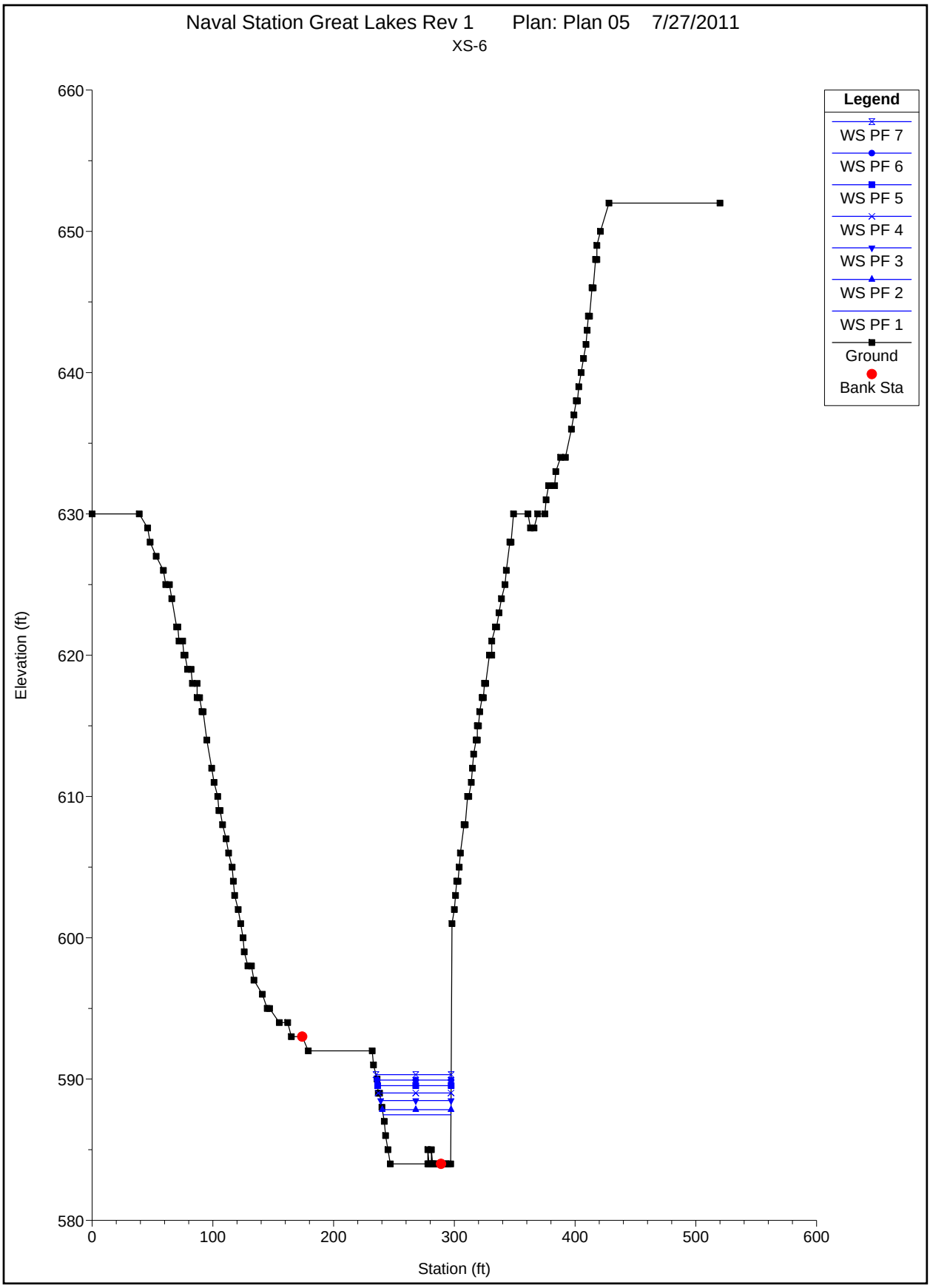

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-9
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
660
650
640
630
620
610
600
590
580
0
100
200
300
400

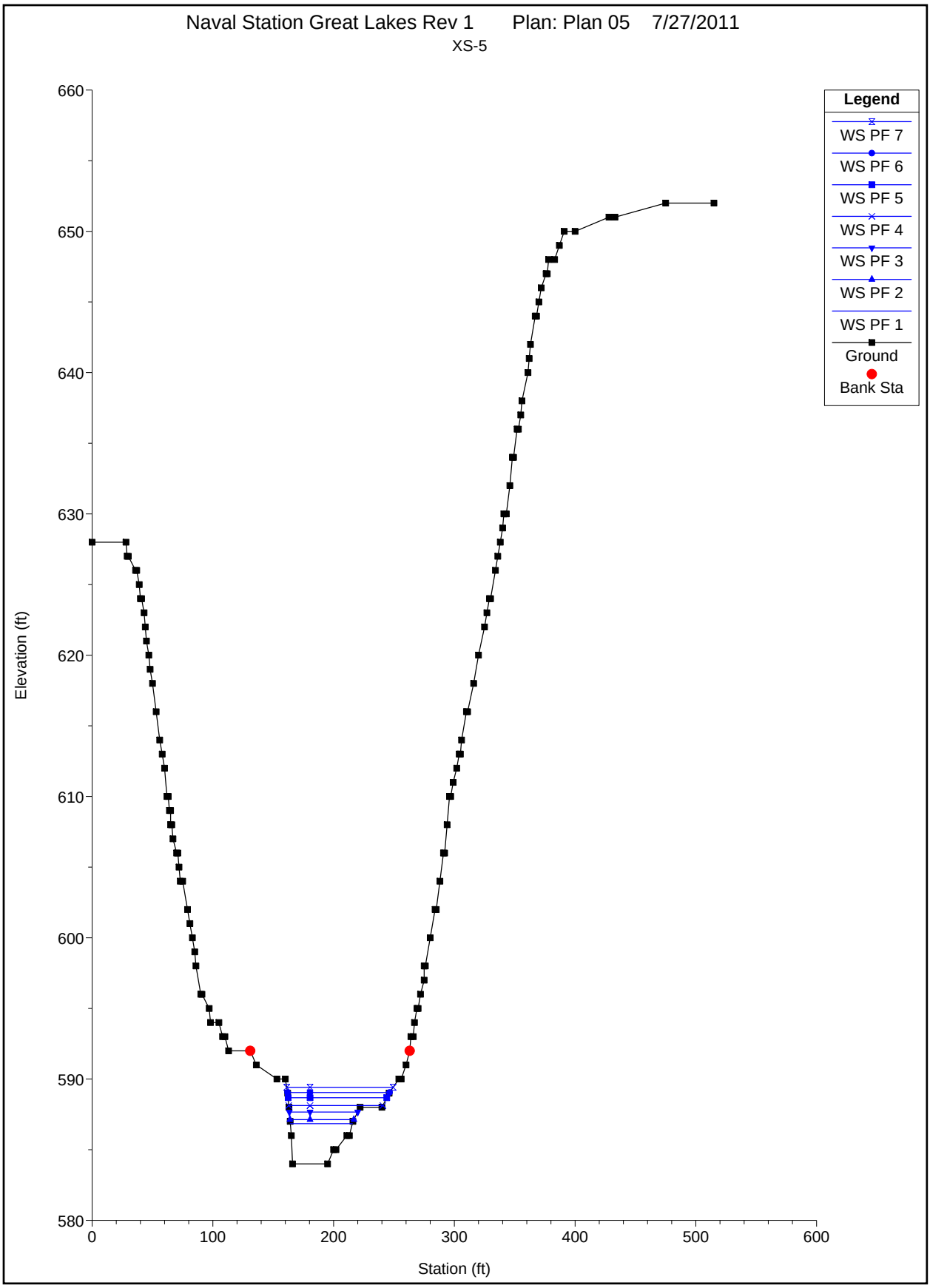
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

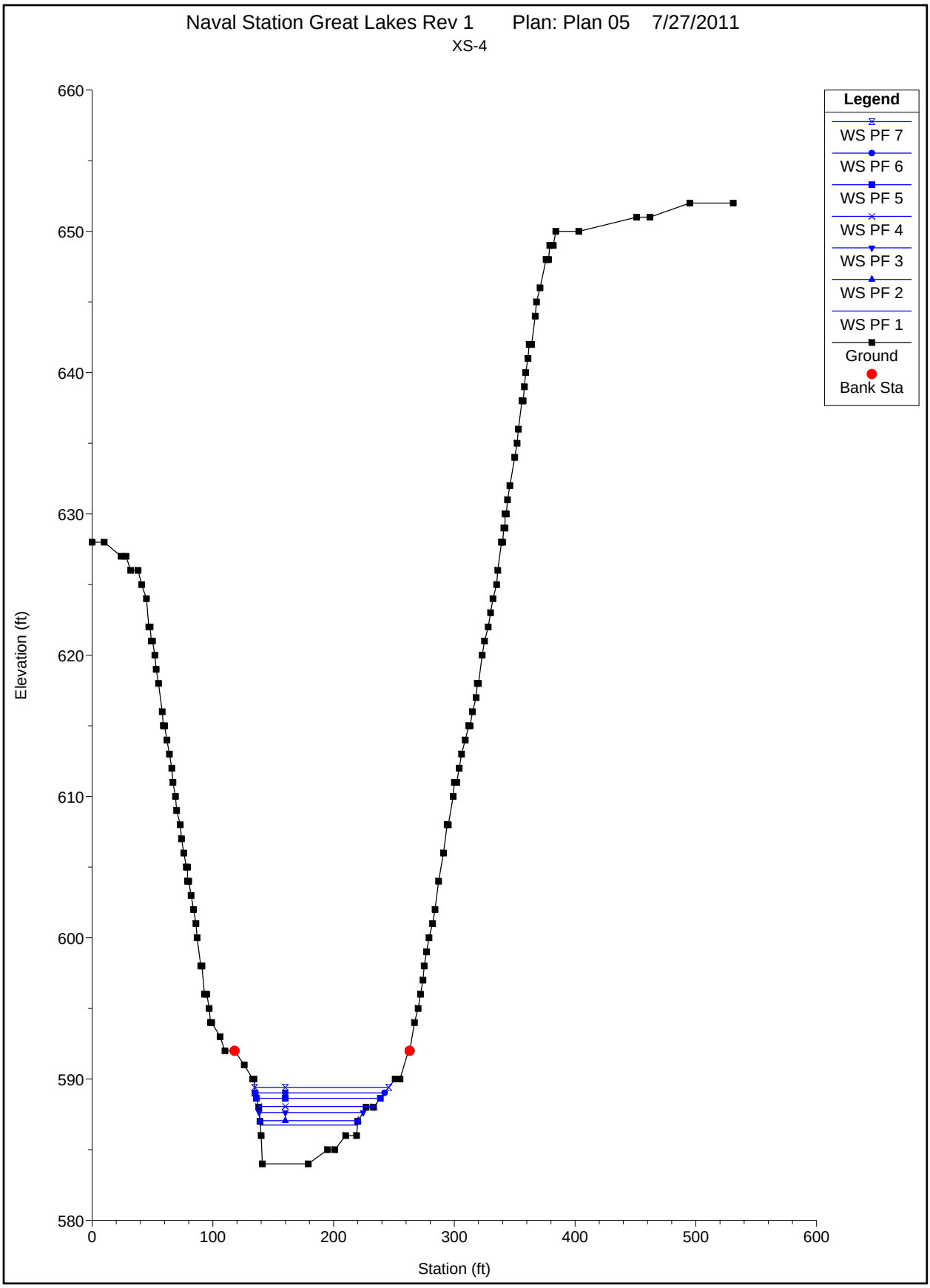
XS-8




Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-7
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
660
650
640
630
620
610
600
590
580
0
100
200
300
400
500

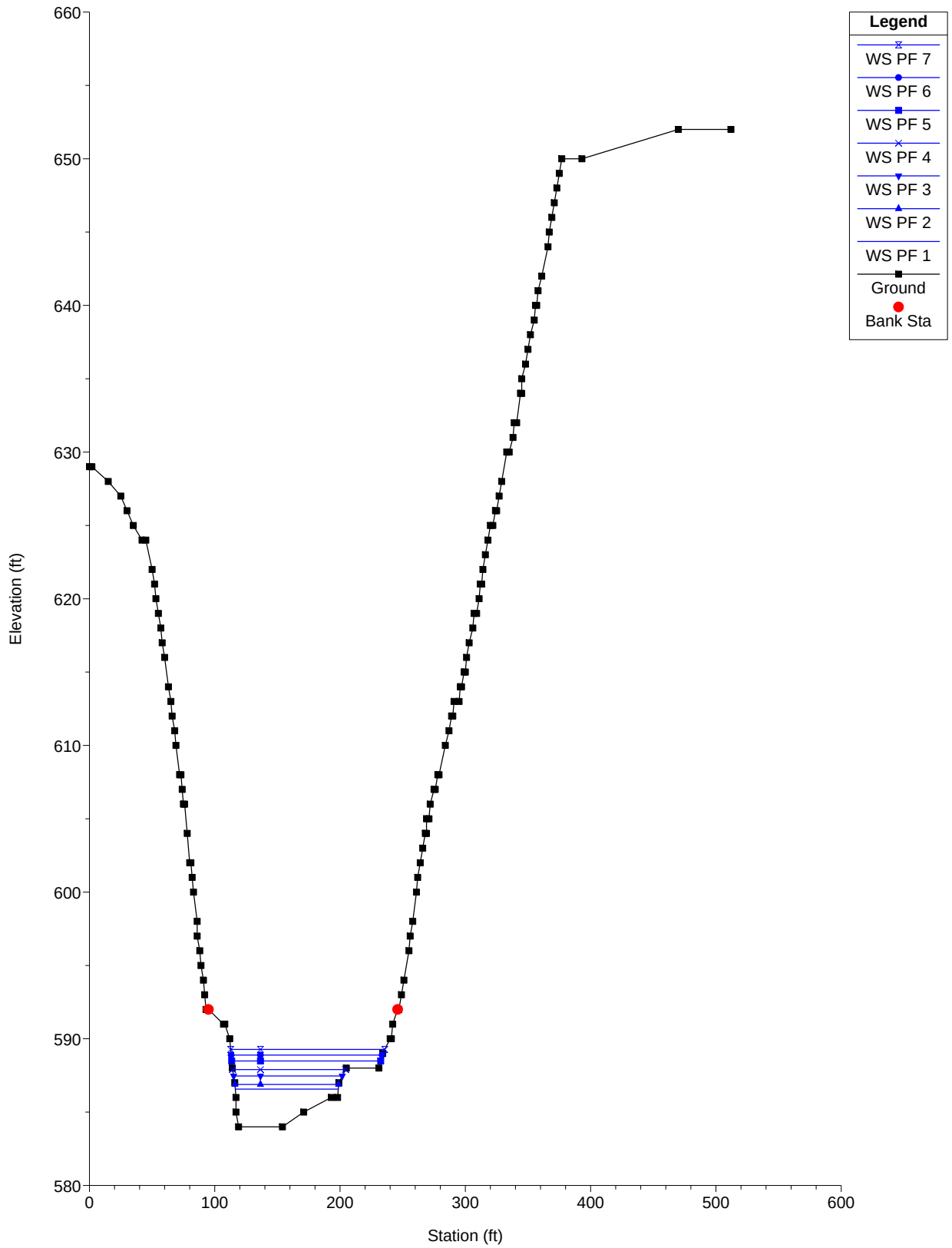

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-6
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
660
650
640
630
620
610
600
590
580
0
100
200
300
400
500
600

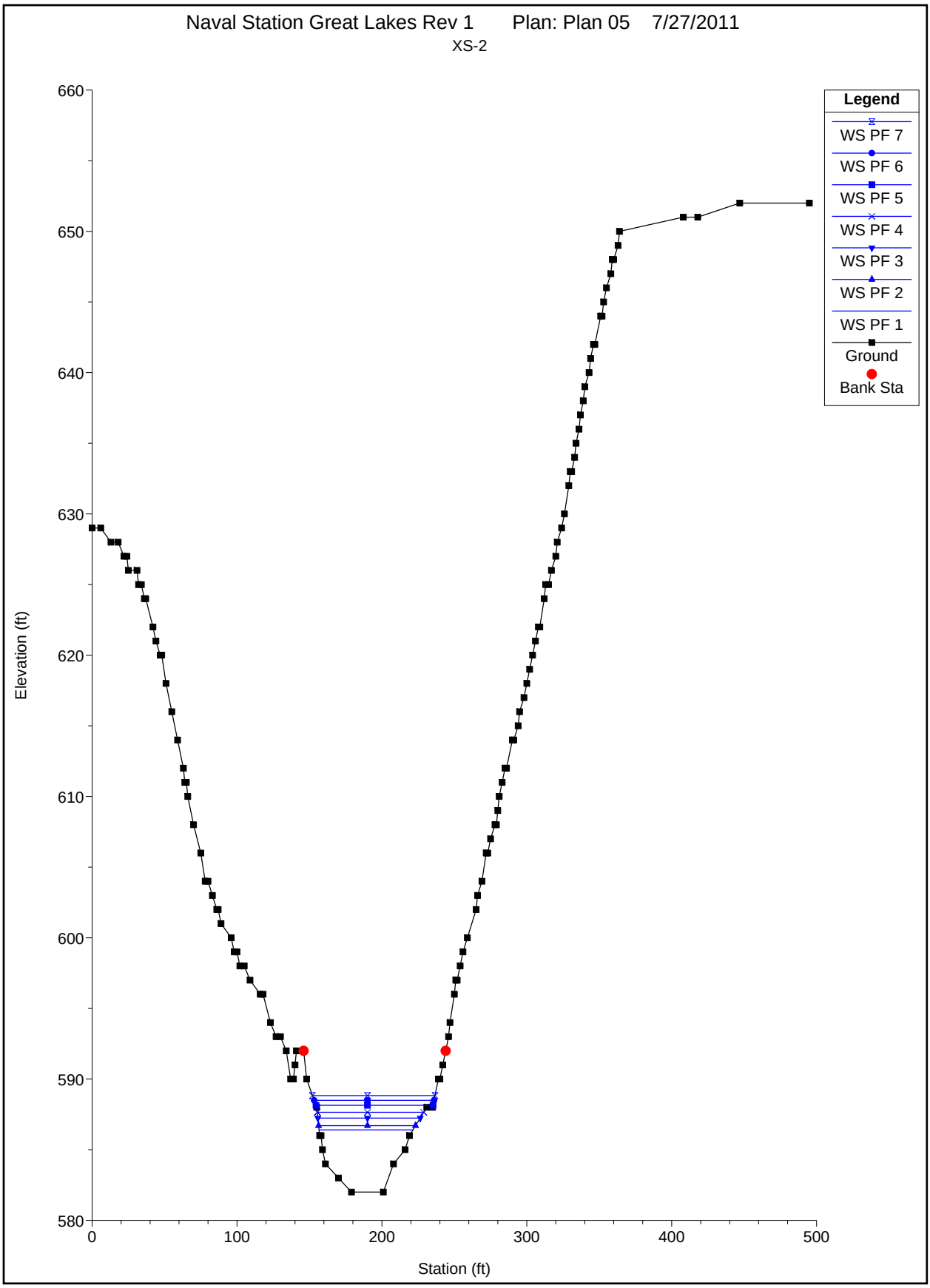

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-5
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
660
650
640
630
620
610
600
590
580
0
100
200
300
400
500
600

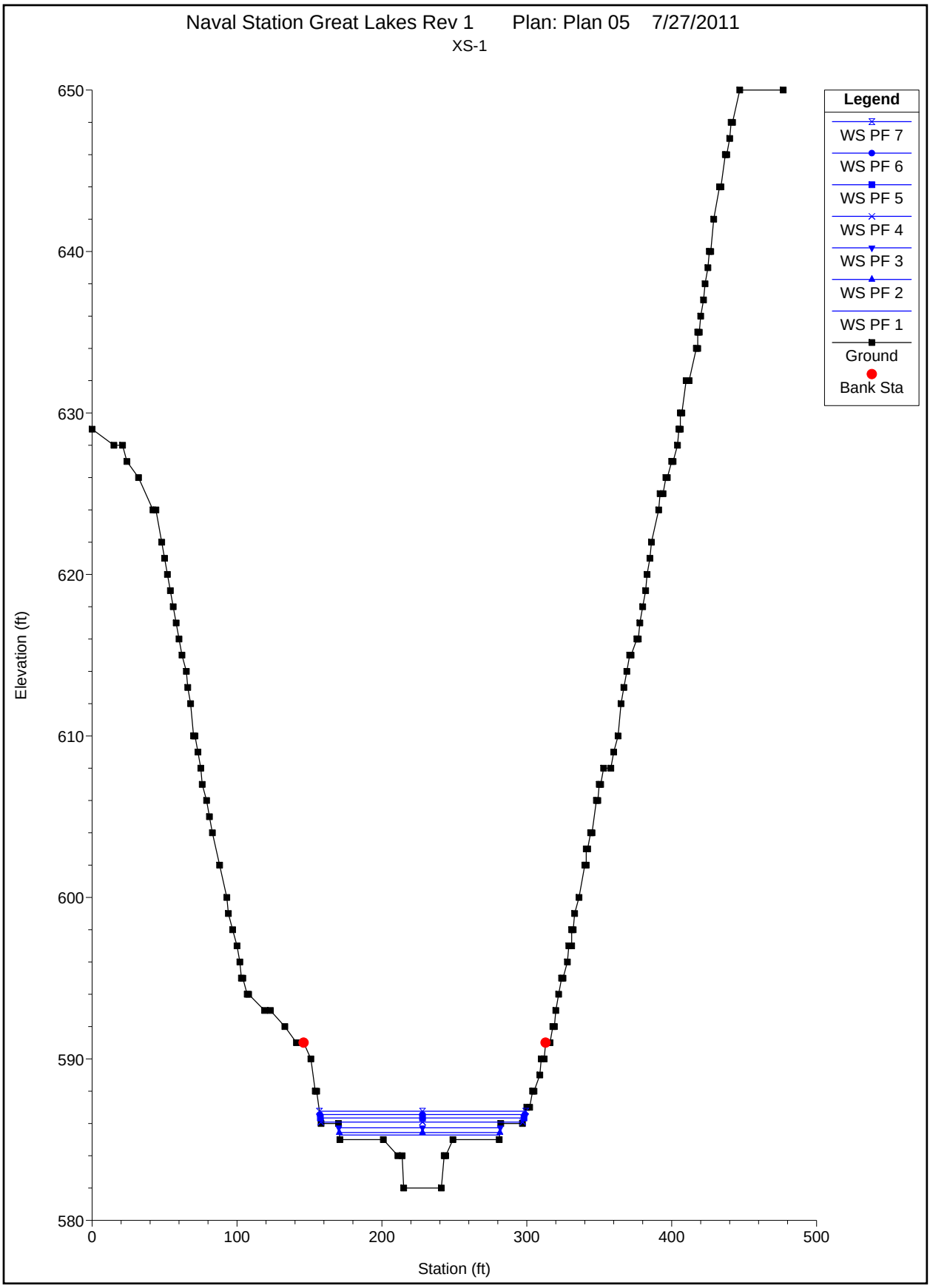

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-4
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
660
650
640
630
620
610
600
590
580
0
100
200
300
400
500
600

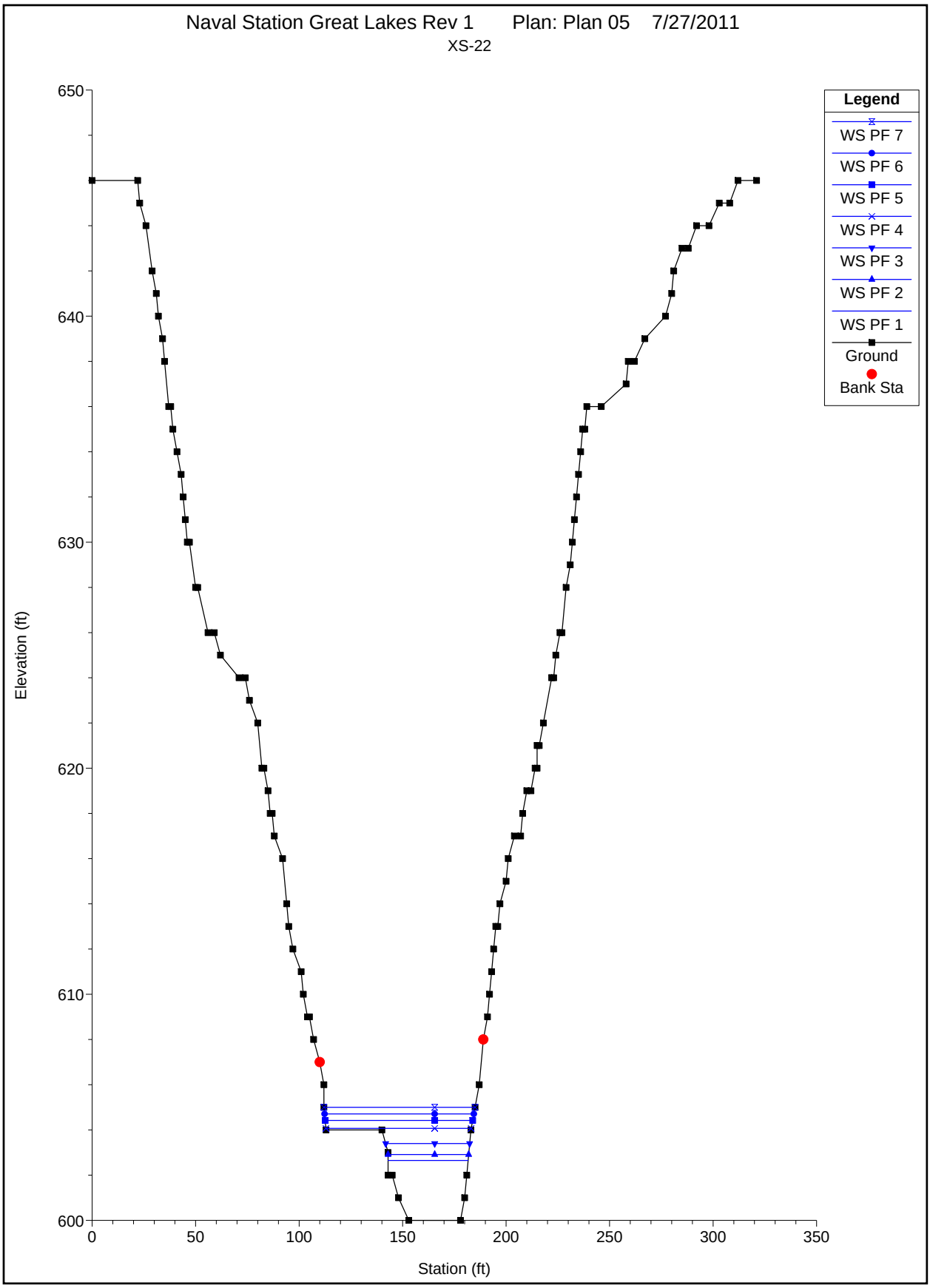
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

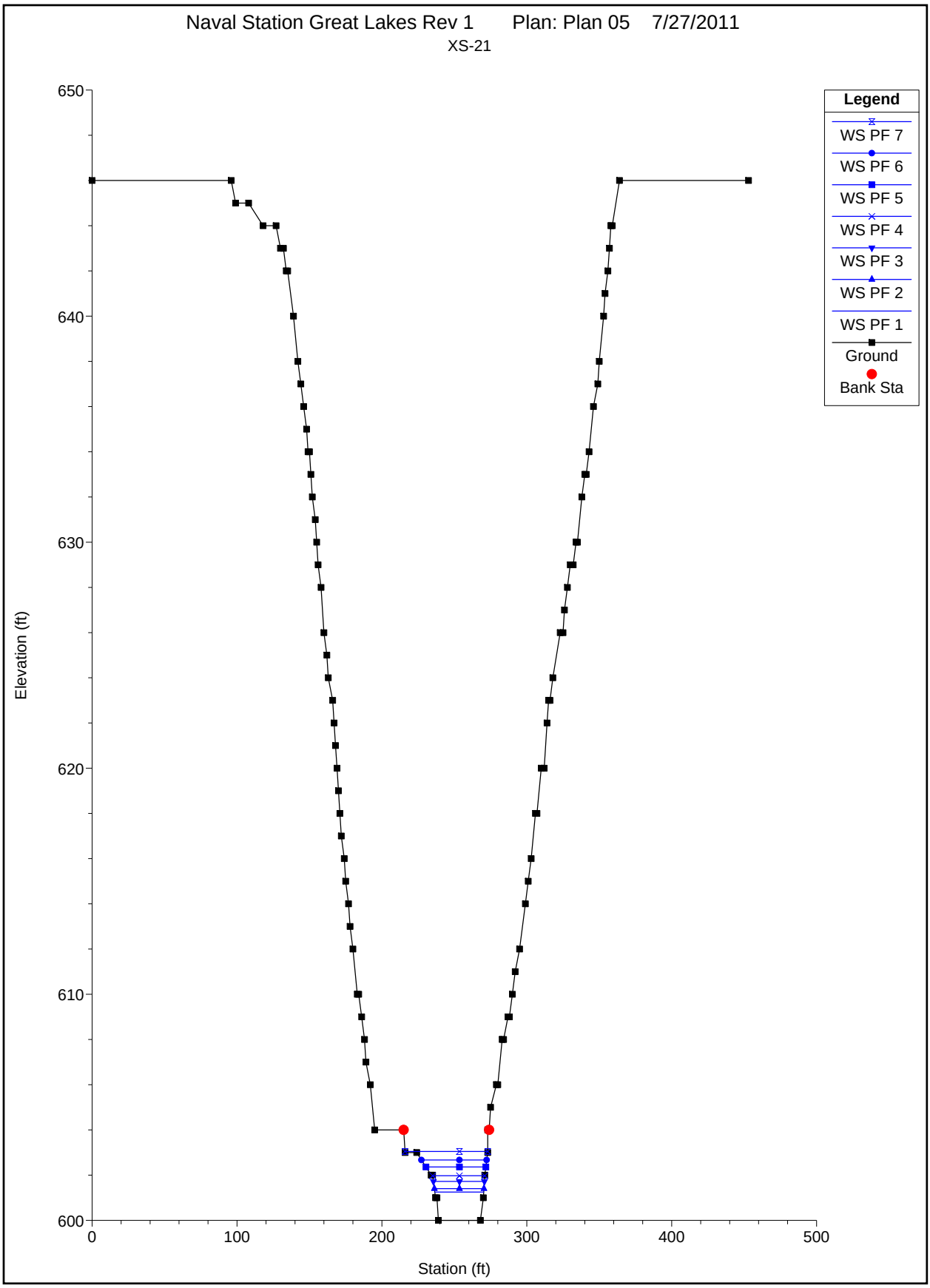
XS-3

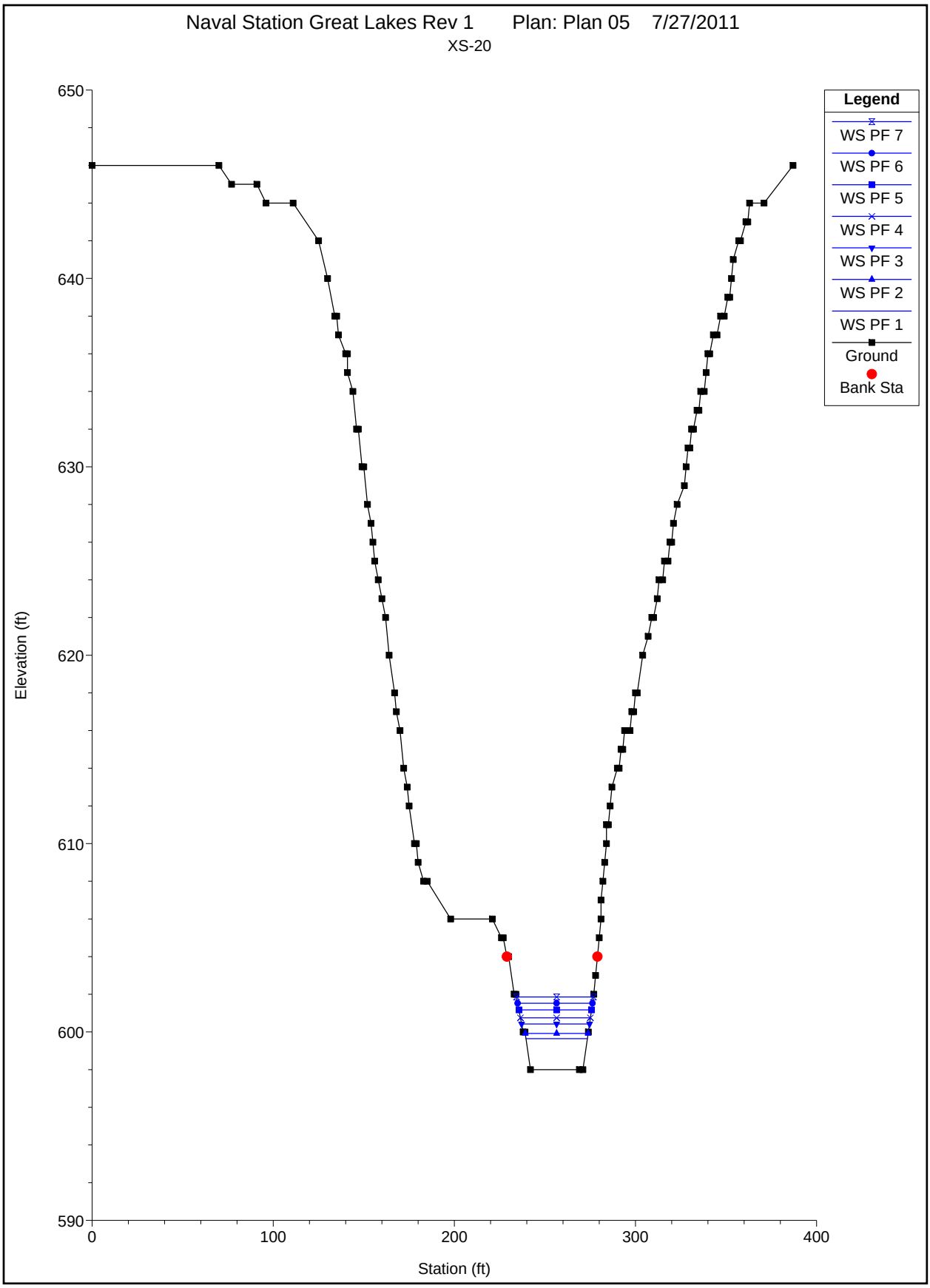



Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-2
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
660
650
640
630
620
610
600
590
580
0
100
200
300
400
500


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-1
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
650
640
630
620
610
600
590
580
0
100
200
300
400
500

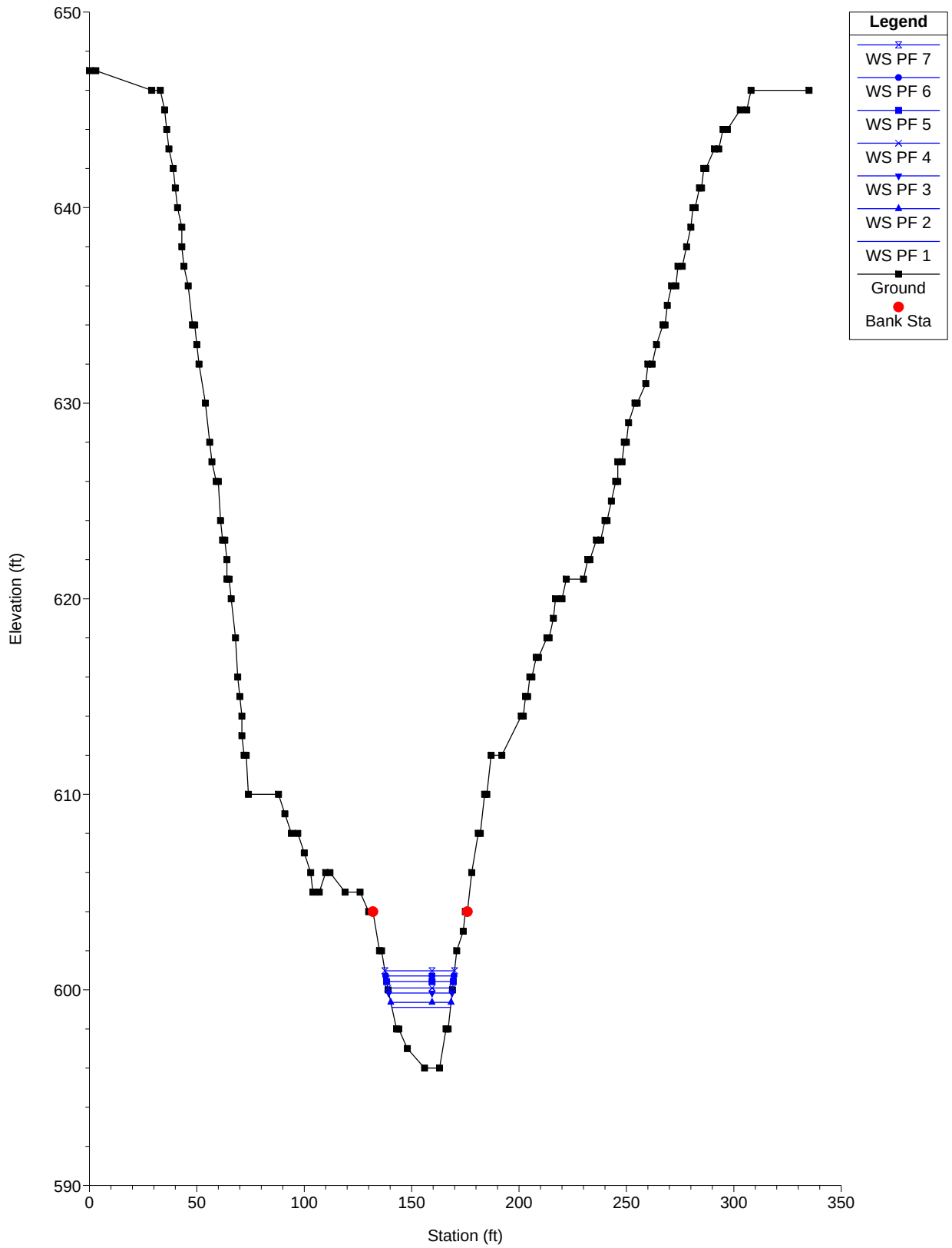

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-22
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
50
100
150
200
250
300
350
Station (ft)

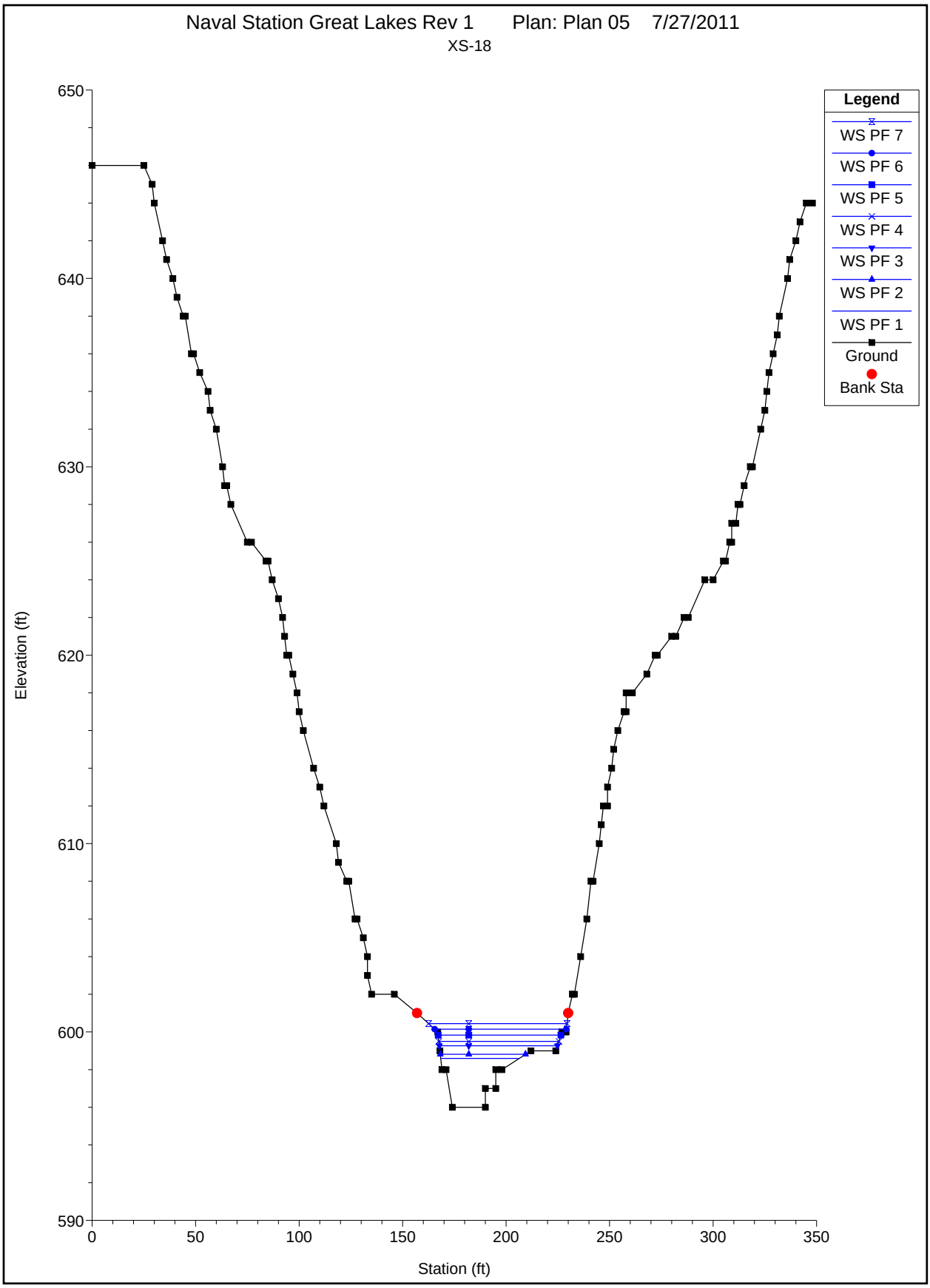

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-21
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
100
200
300
400
500
Station (ft)

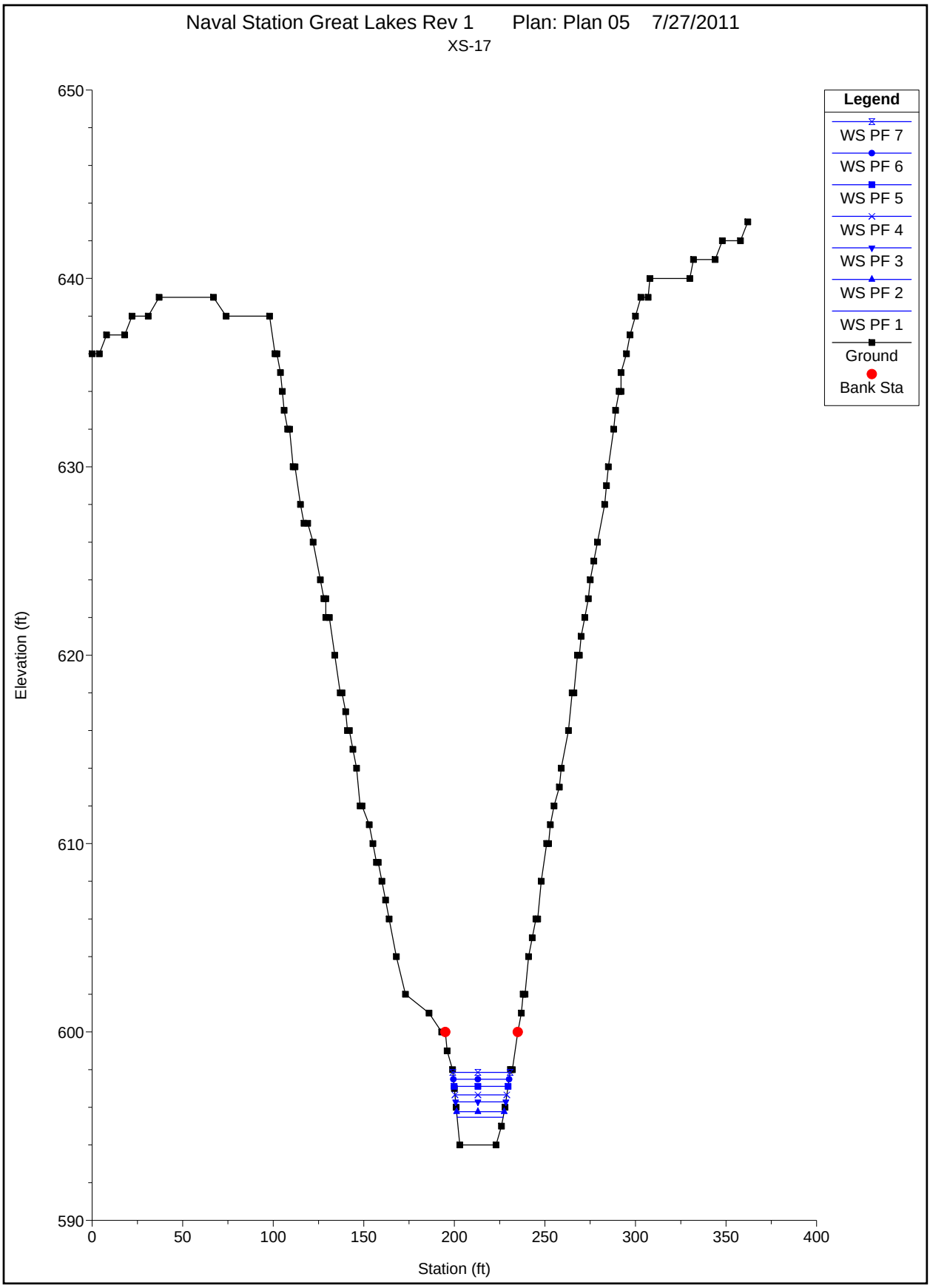

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-20
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
590
0
100
200
300
400
Station (ft)

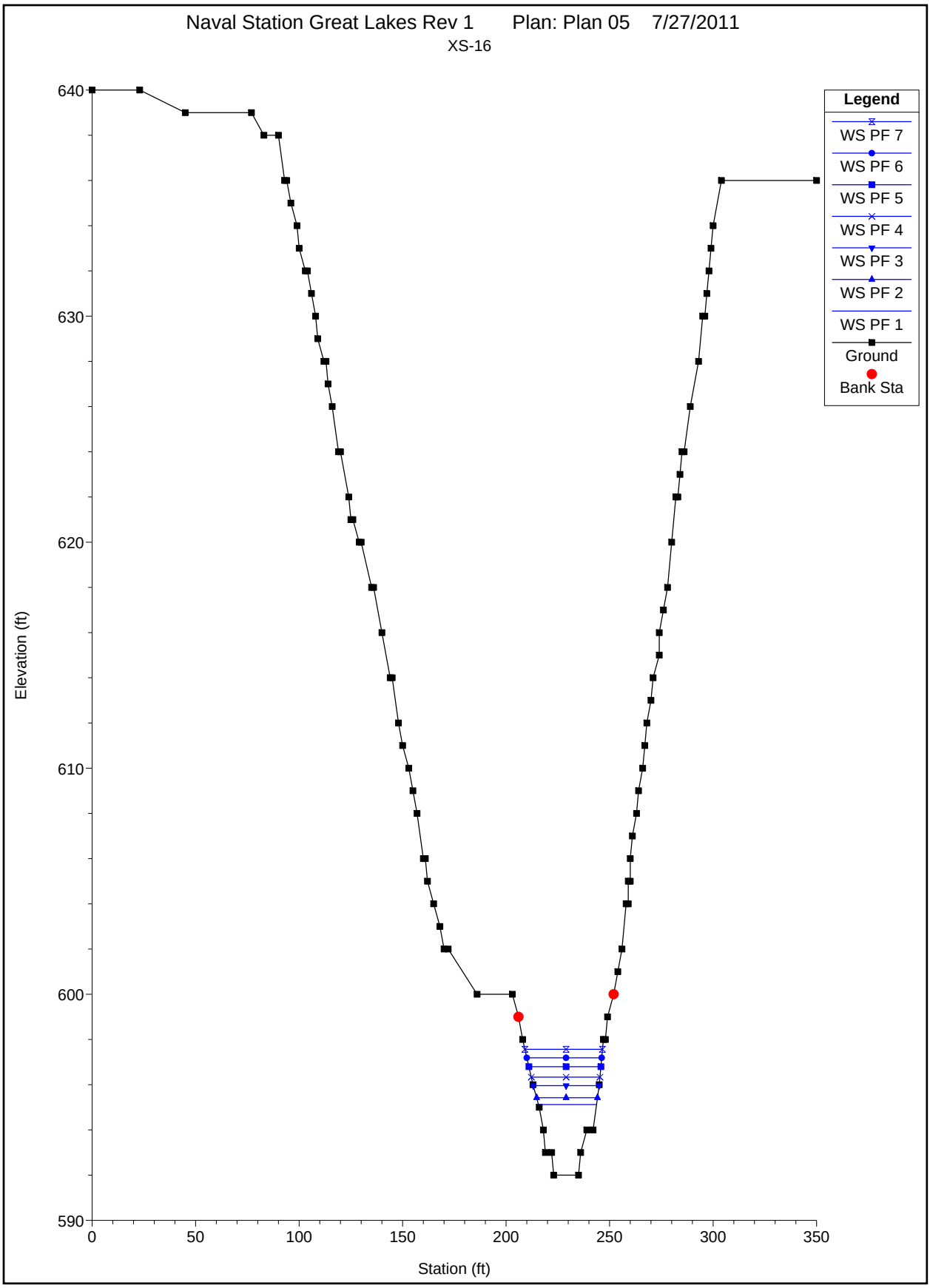
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

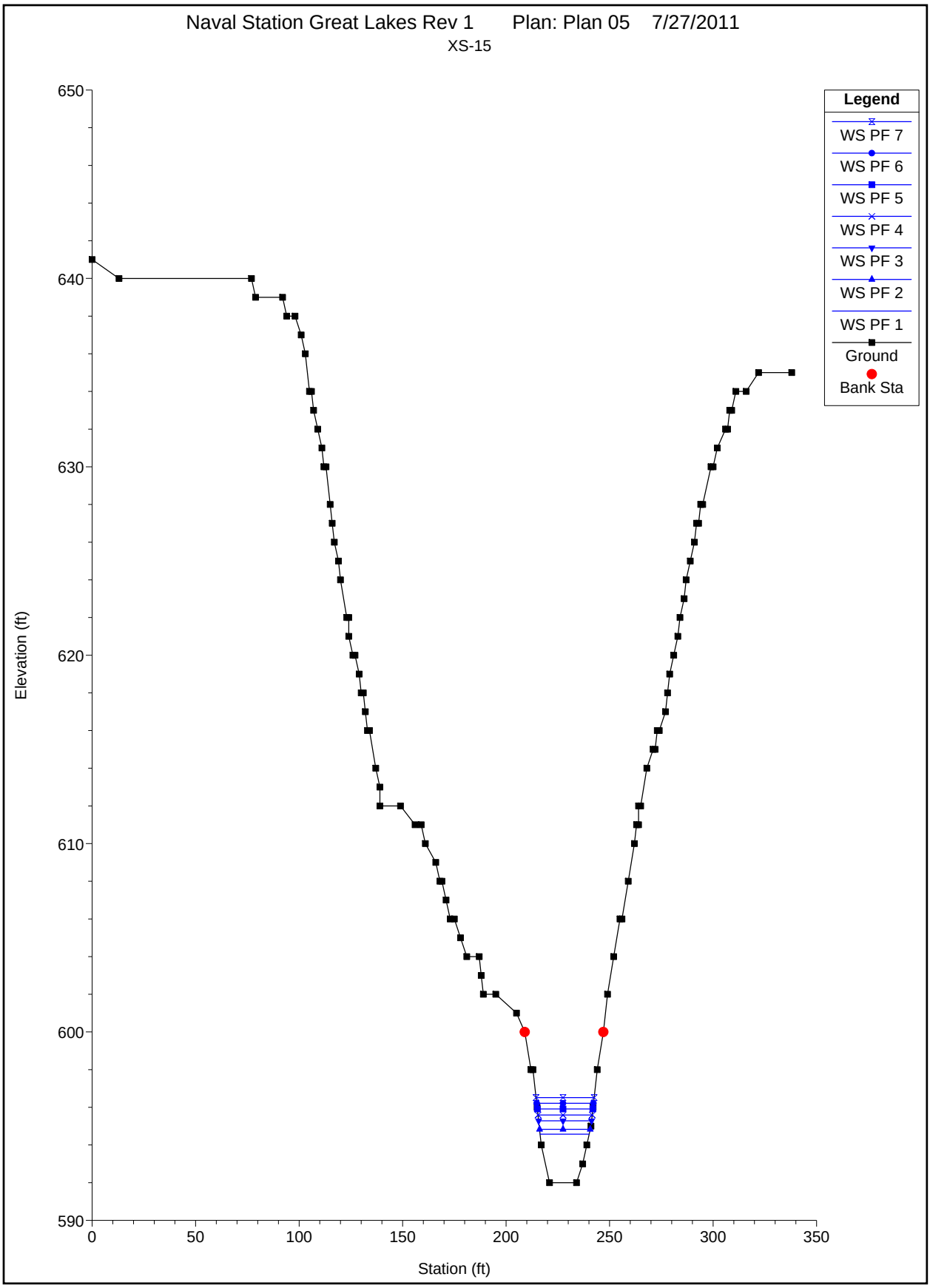
XS-19




Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-18
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
590
0
50
100
150
200
250
300
350
Station (ft)

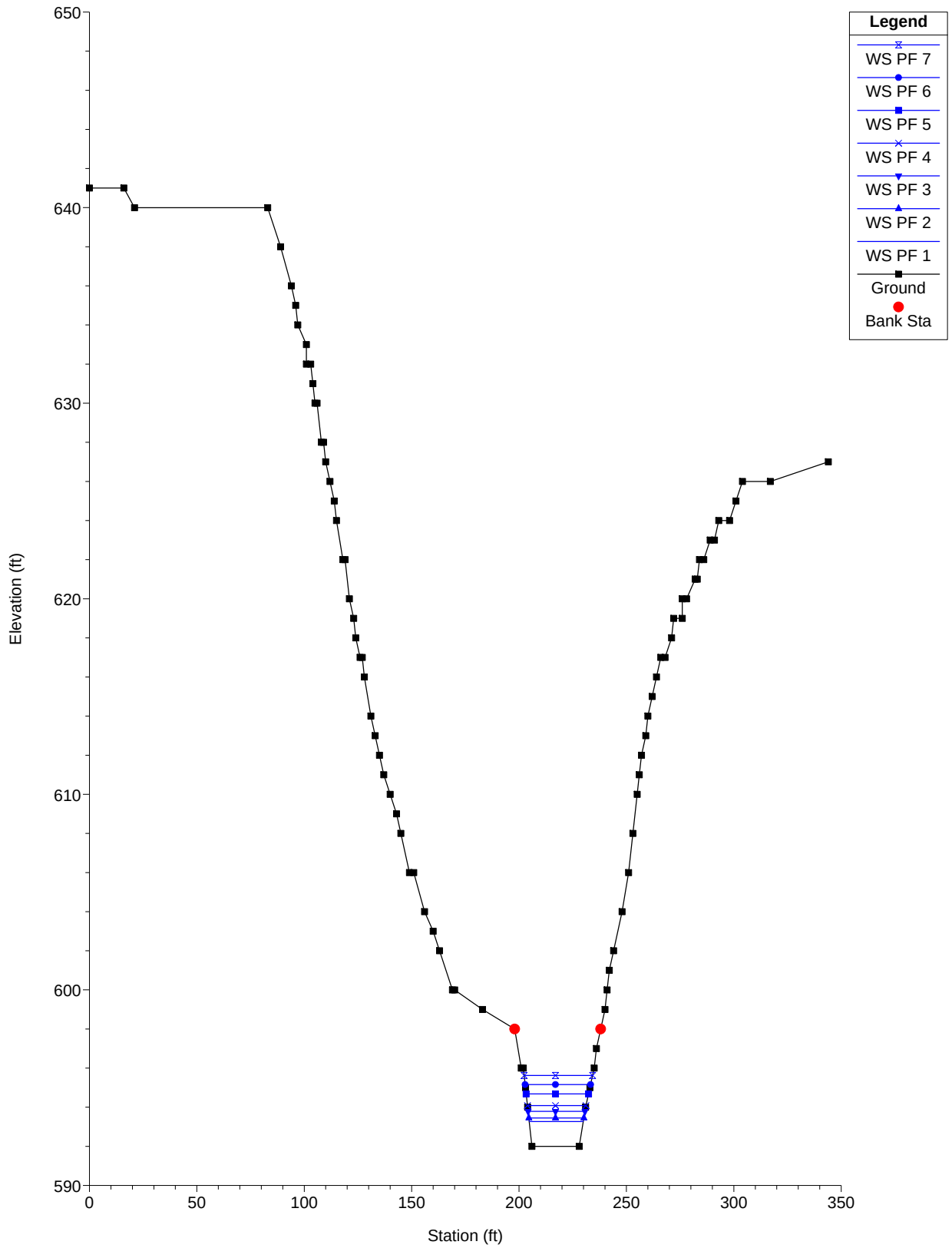

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-17
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
650
640
630
620
610
600
590
0
50
100
150
200
250
300
350
400


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-16
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
630
620
610
600
590
0
50
100
150
200
250
300
350
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-15
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
590
0
50
100
150
200
250
300
350
Station (ft)

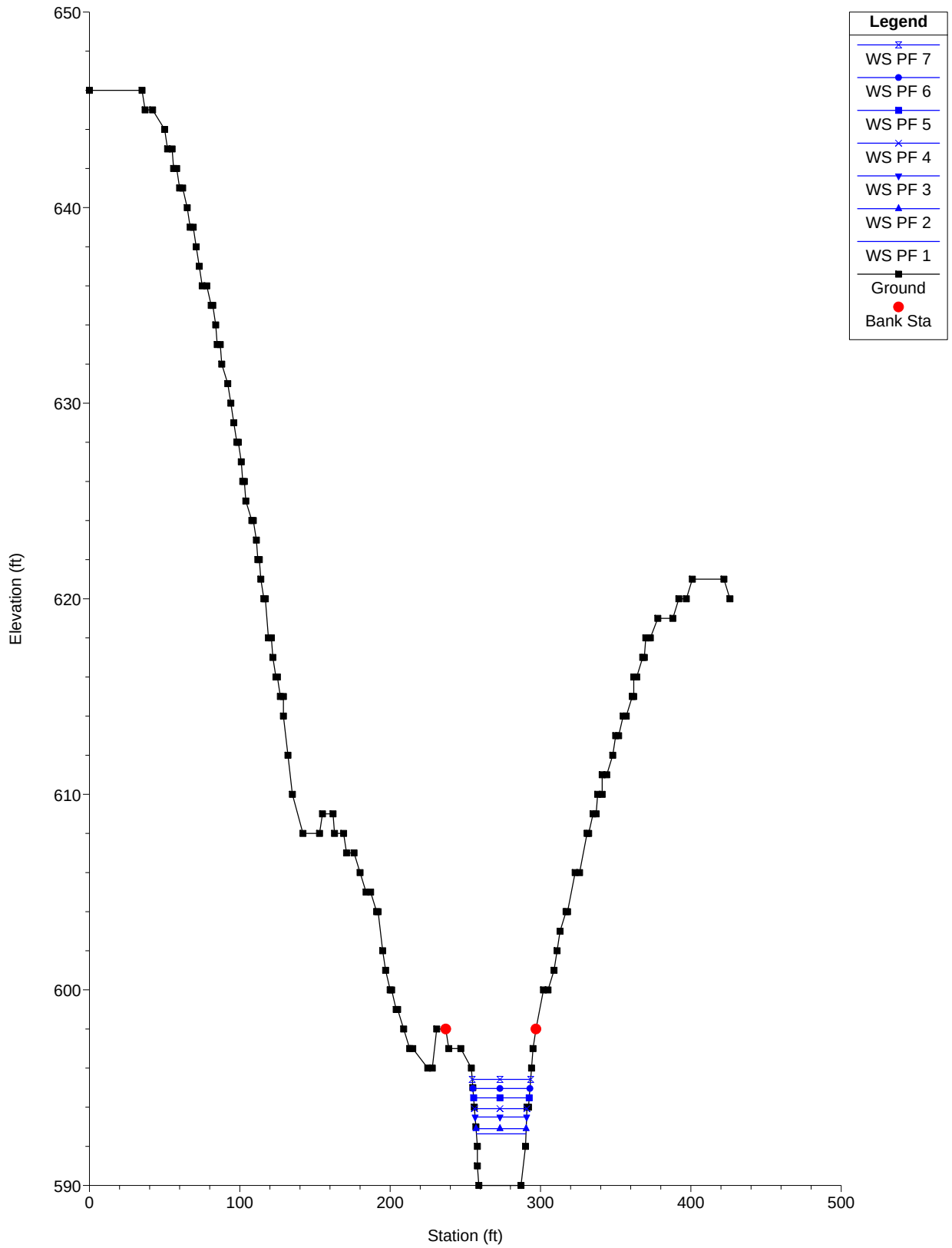
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

XS-14



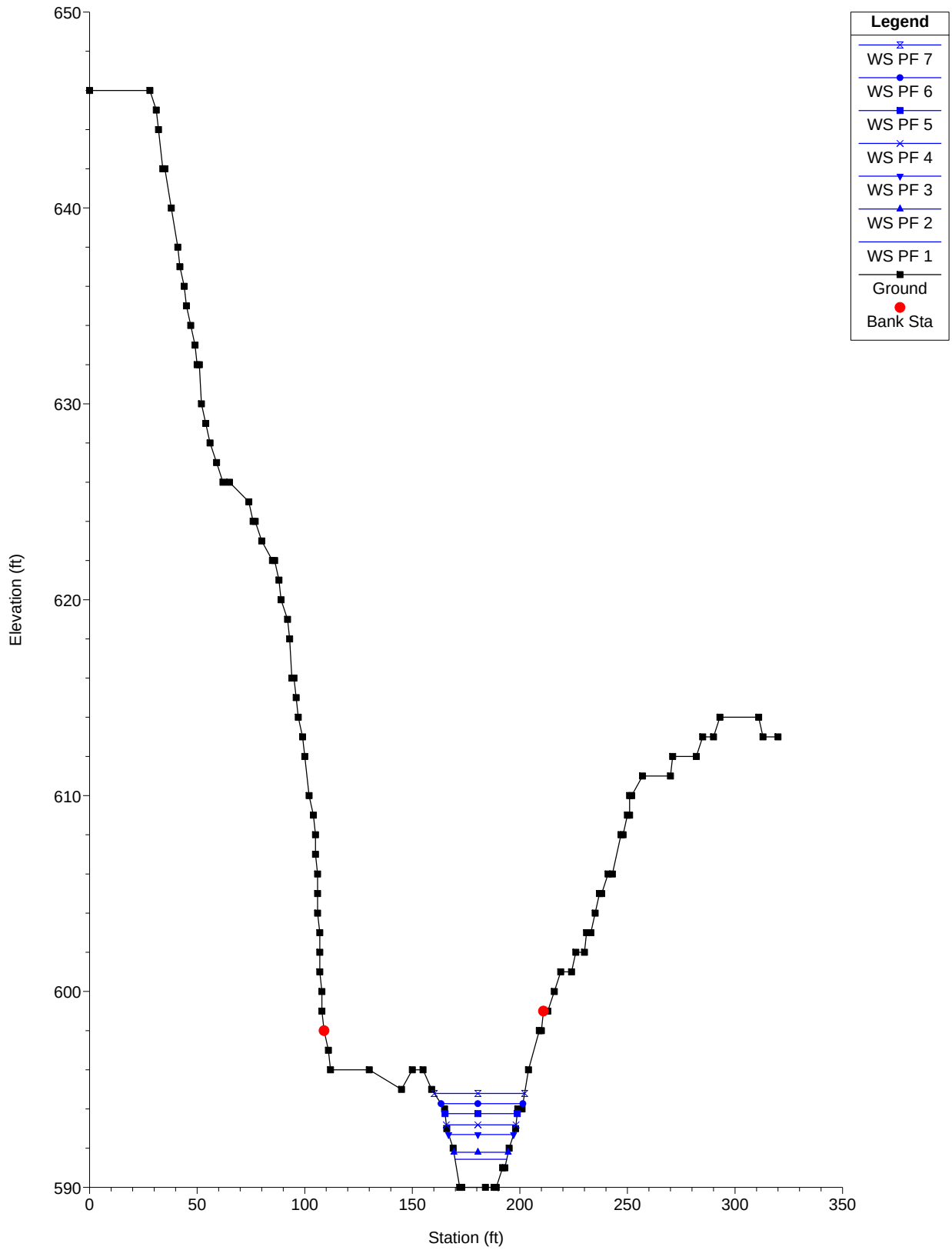
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

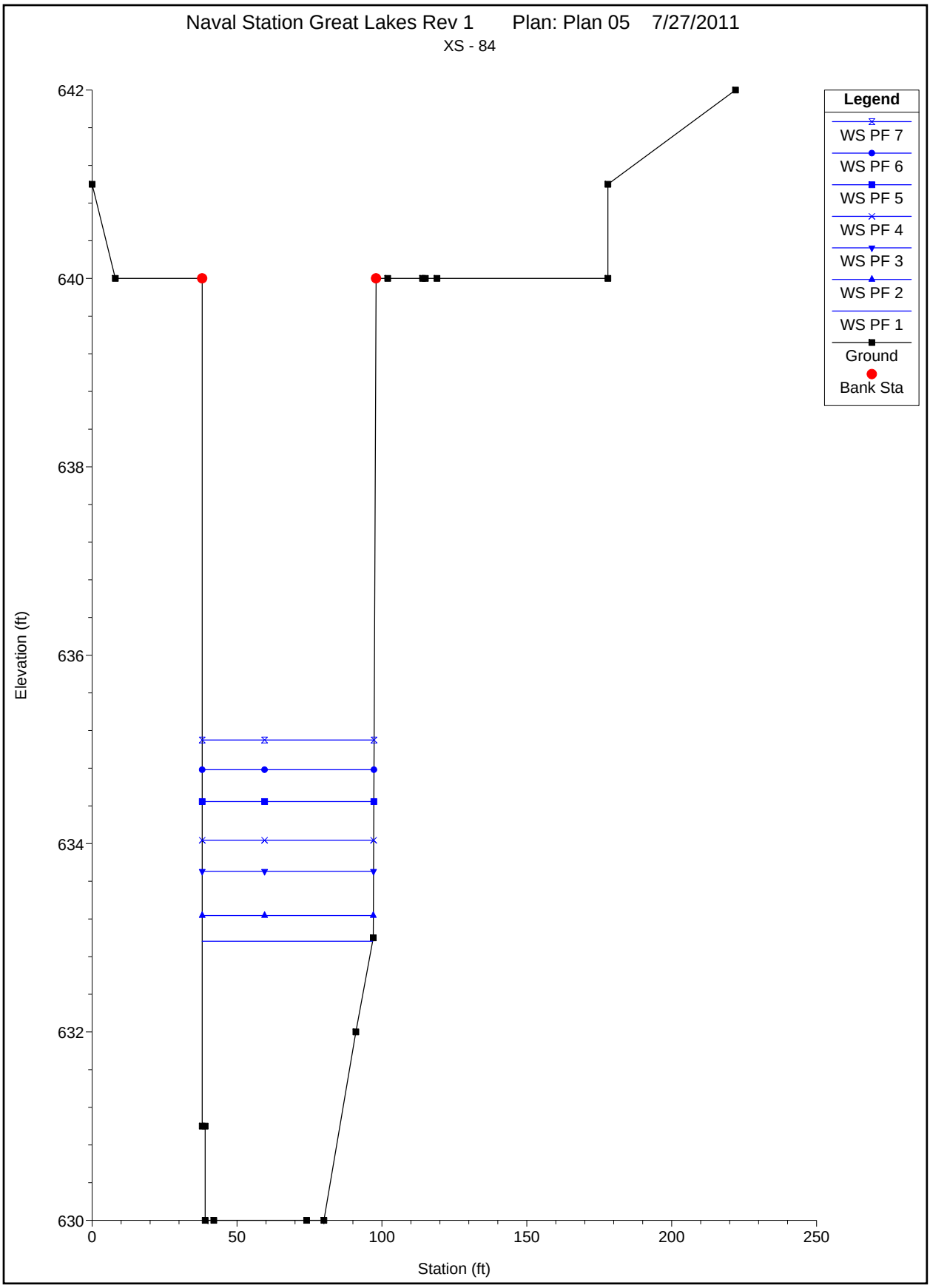
XS-13

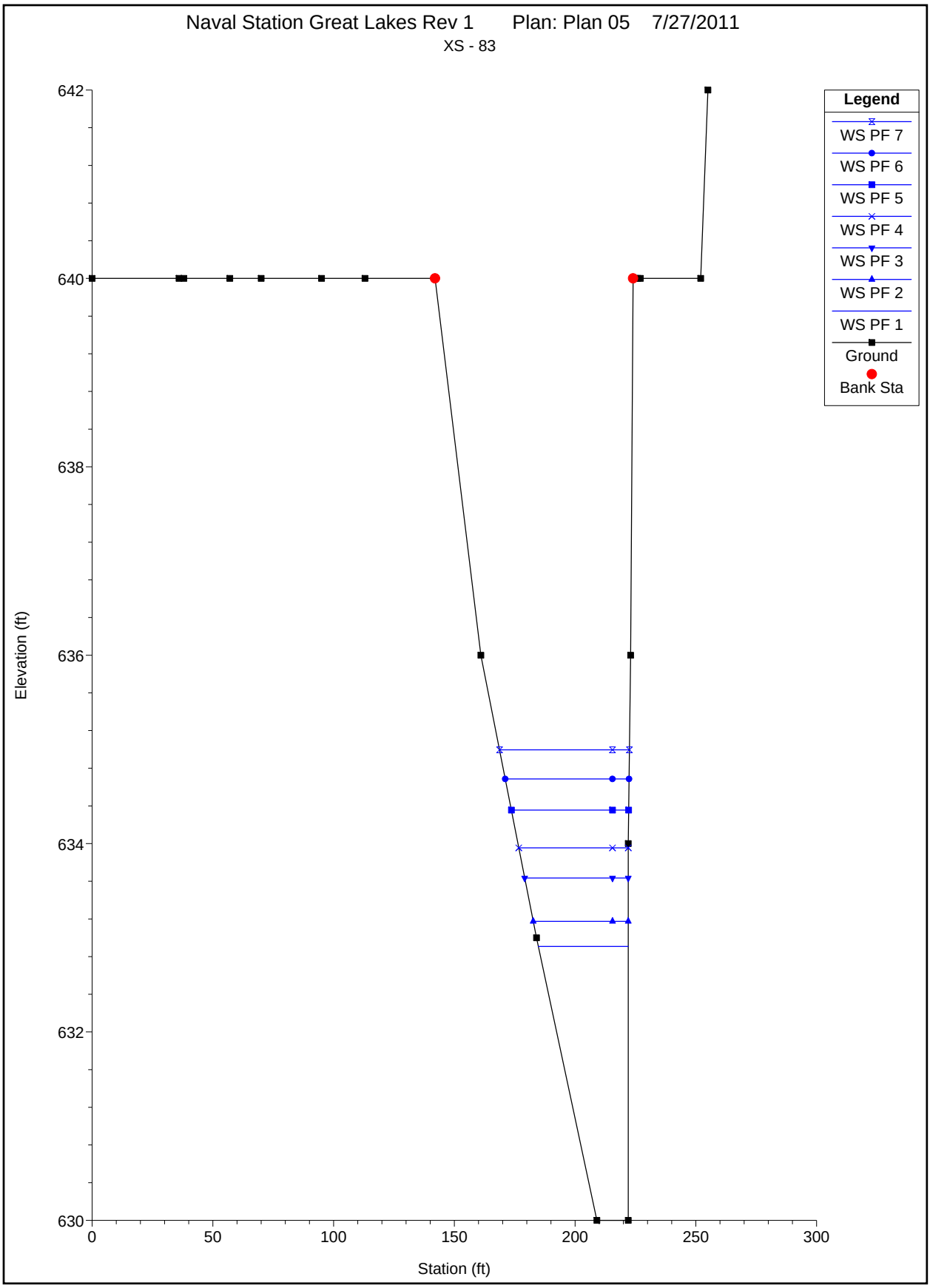


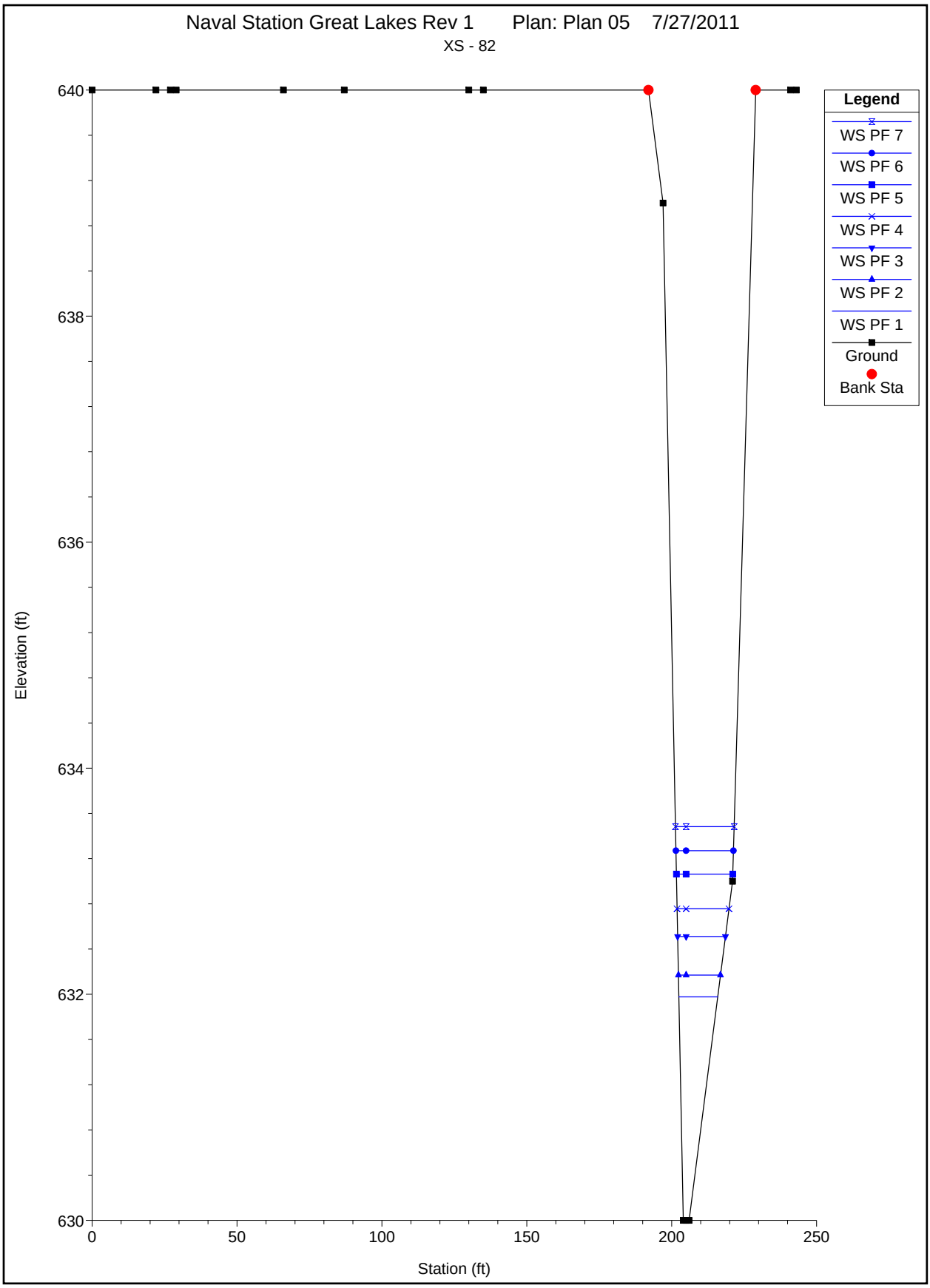
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

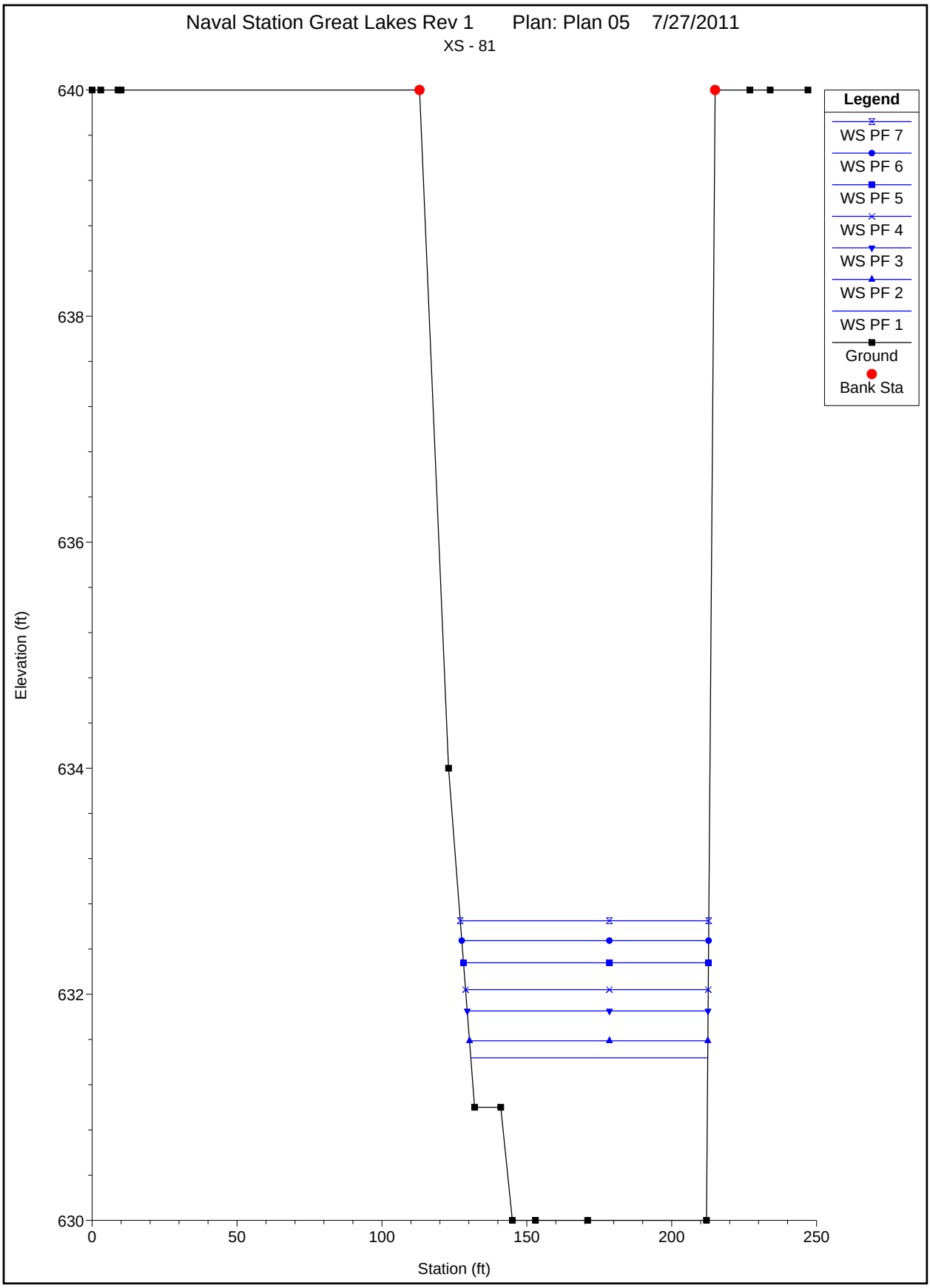
XS-12

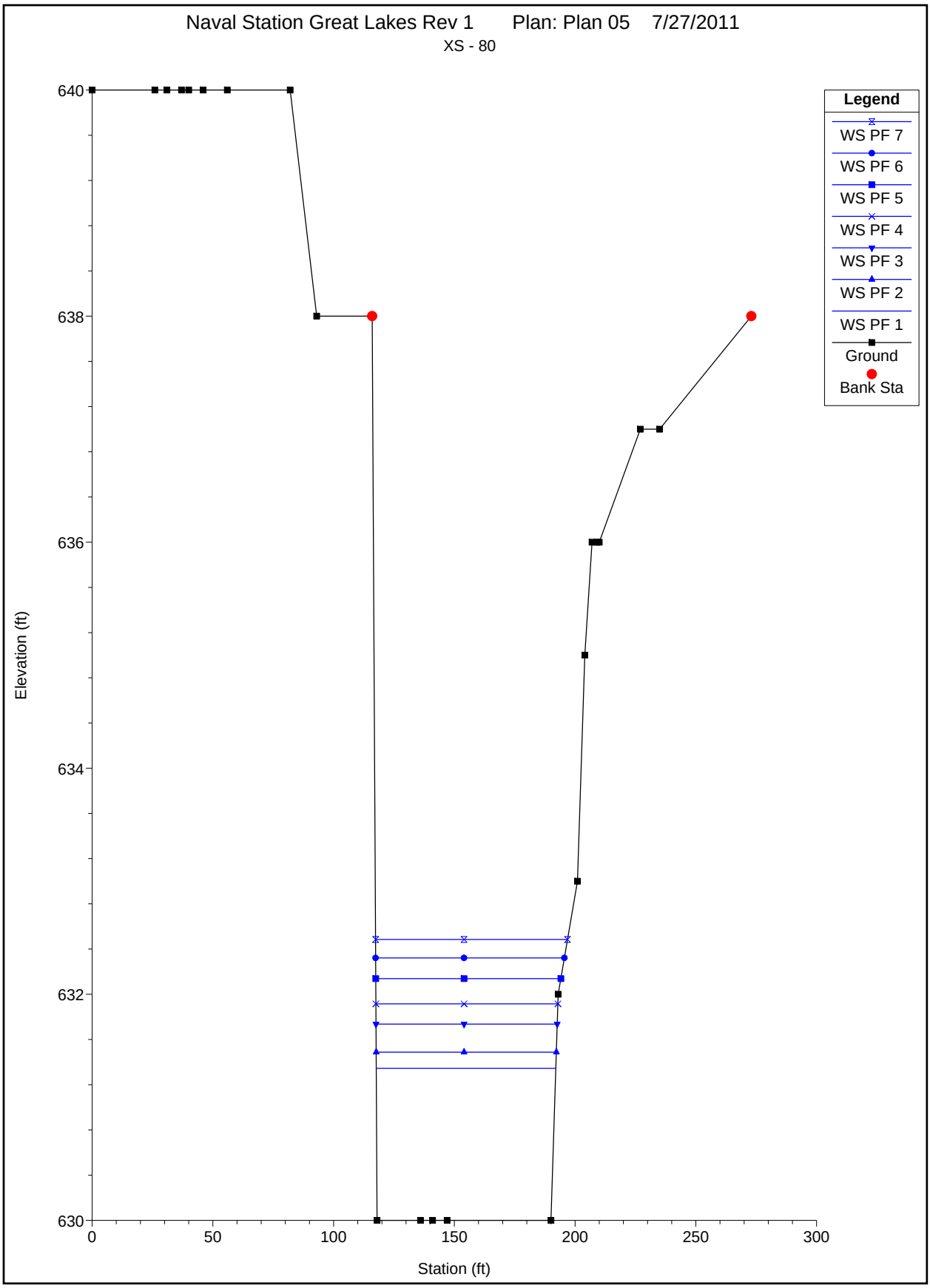



Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 84
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
642
640
638
636
634
632
630
0
50
100
150
200
250
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 83
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
642
640
638
636
634
632
630
0
50
100
150
200
250
300
Station (ft)

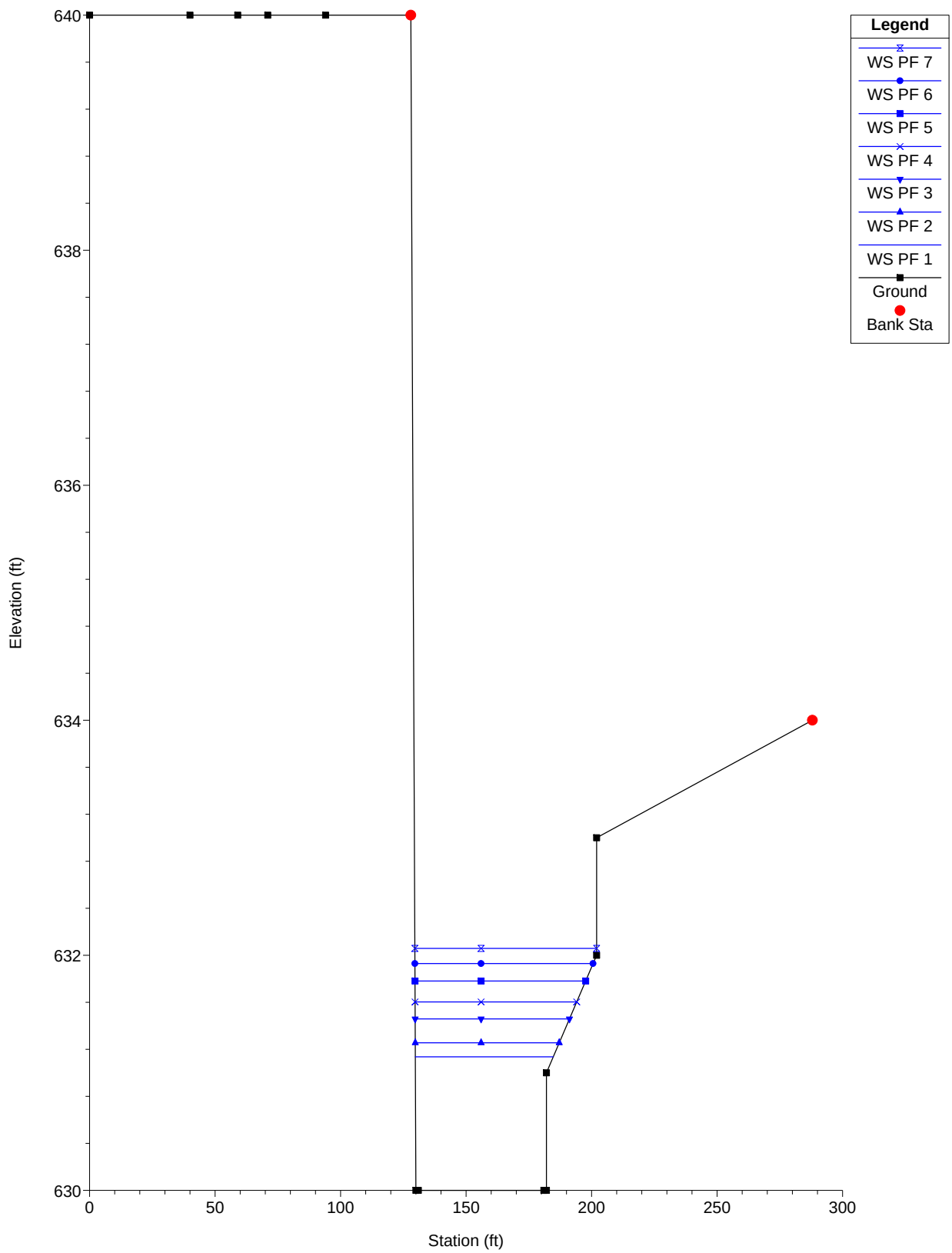

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 82
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
Station (ft)

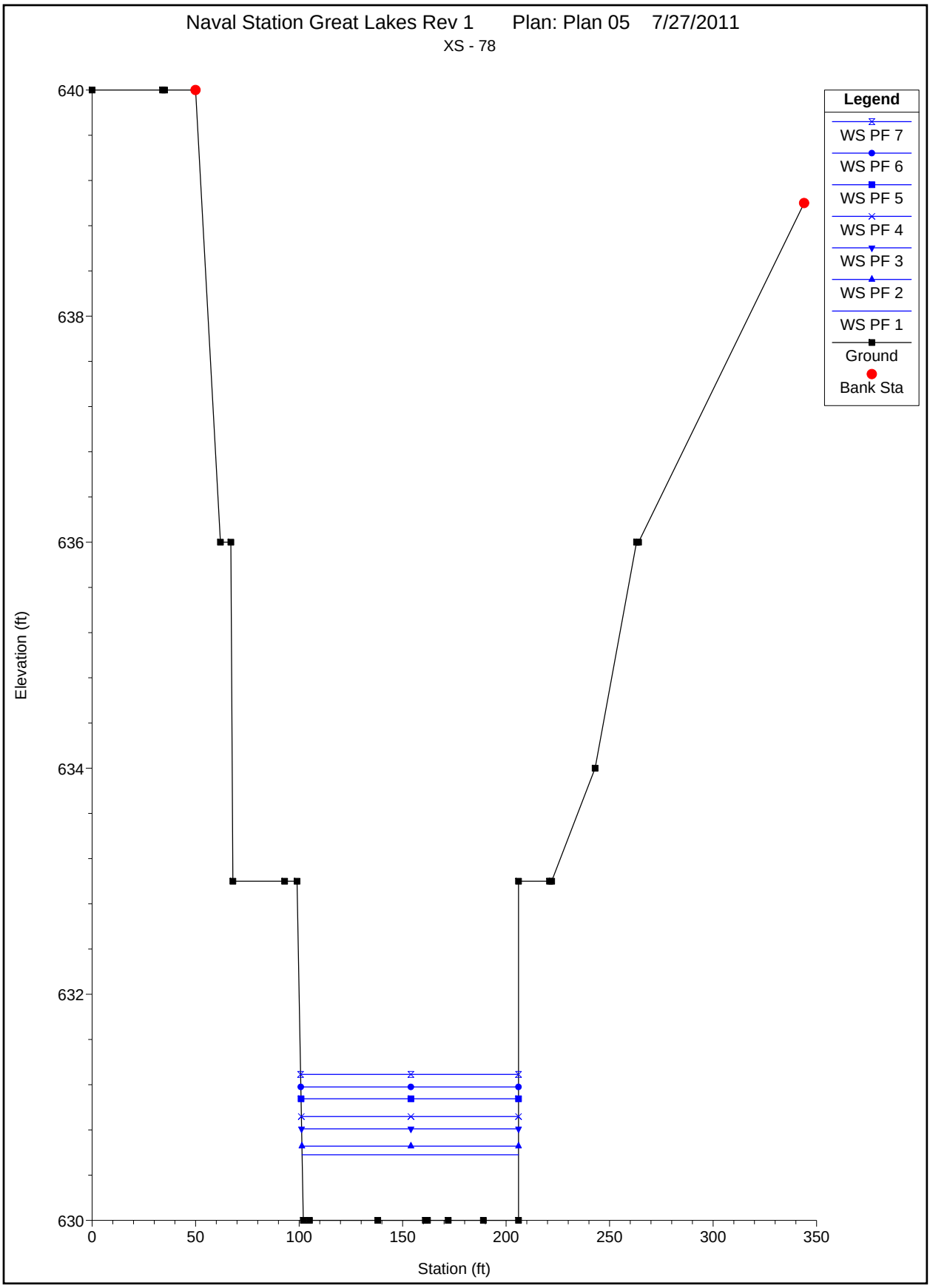

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 81
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
Station (ft)

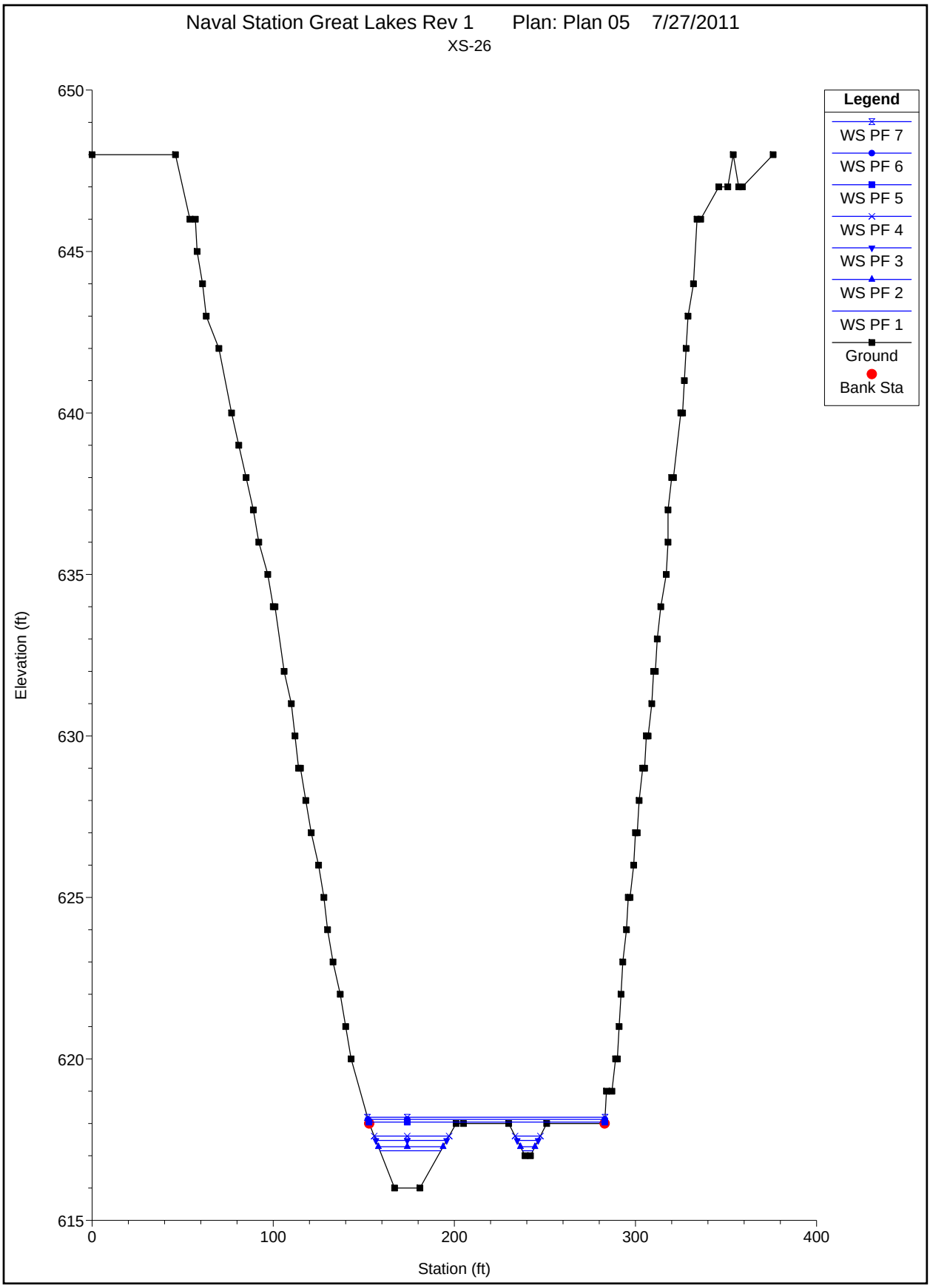

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 80
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
300
Station (ft)

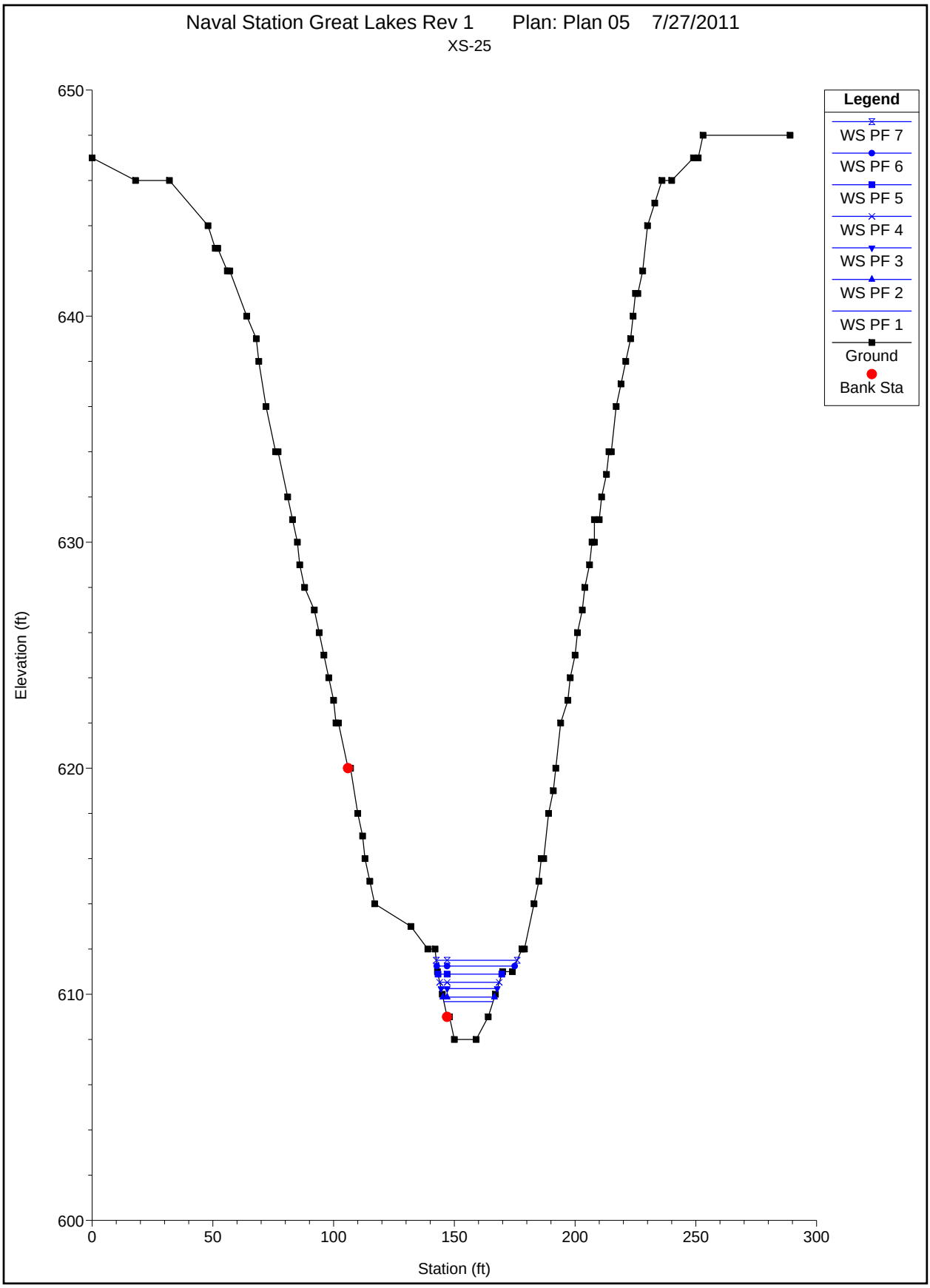
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

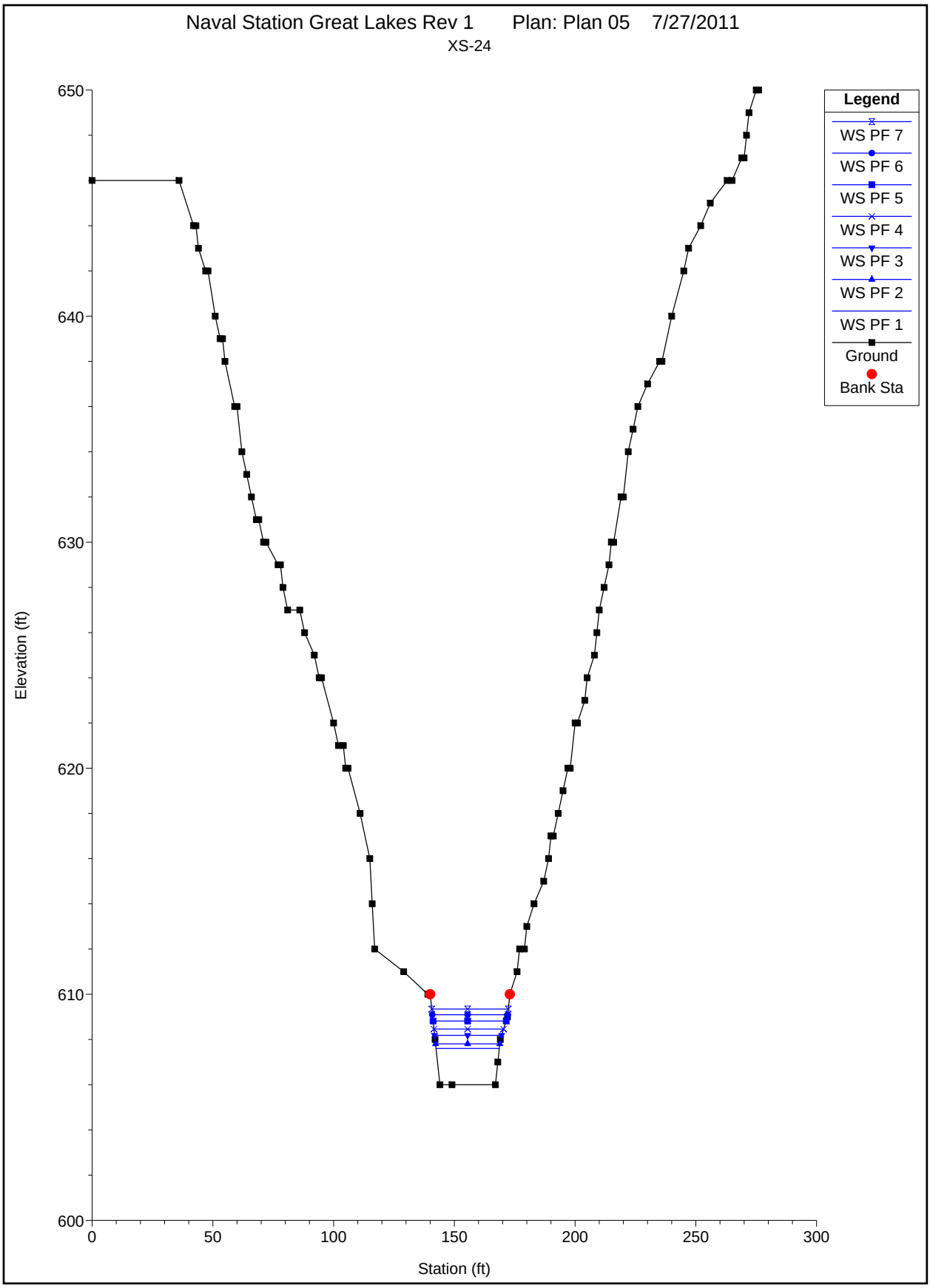
XS - 79

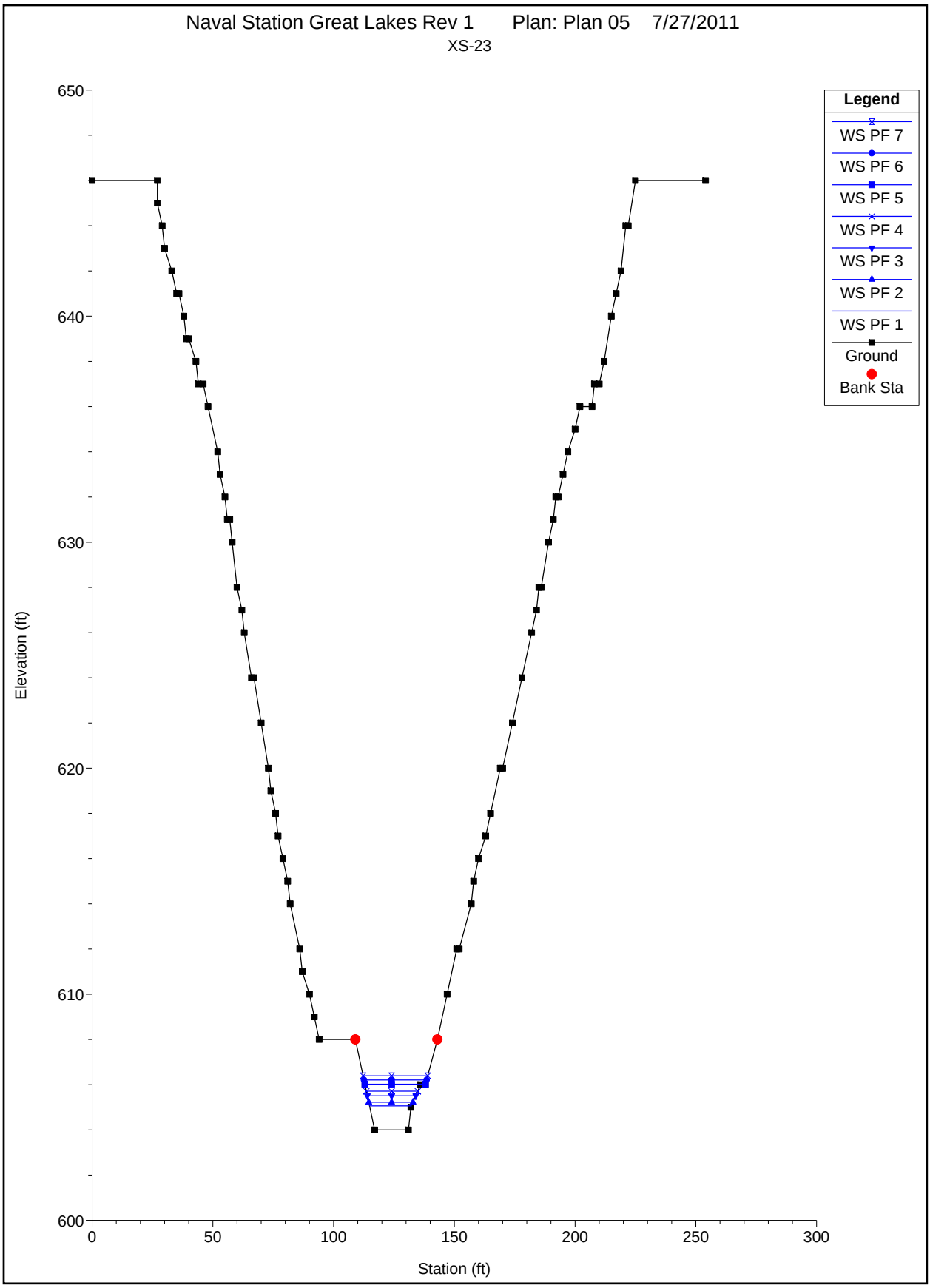



Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 78
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
300
350
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-26
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
650
645
640
635
630
625
620
615
0
100
200
300
400


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-25
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
50
100
150
200
250
300
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-24
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
50
100
150
200
250
300
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-23
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
50
100
150
200
250
300
Station (ft)

Plan: Plan 02 Pettibone Creek North 2 RS: 2493 Profile: PF 7

E.G. Elev (ft)	635.12	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.02	Wt. n-Val.		0.055	
W.S. Elev (ft)	635.10	Reach Len. (ft)	99.00	102.00	107.00
Crit W.S. (ft)		Flow Area (sq ft)		274.18	
E.G. Slope (ft/ft)	0.000322	Area (sq ft)		274.18	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	59.30	Top Width (ft)		59.30	
Vel Total (ft/s)	1.25	Avg. Vel. (ft/s)		1.25	
Max Chl Dpth (ft)	5.10	Hydr. Depth (ft)		4.62	
Conv. Total (cfs)	19049.6	Conv. (cfs)		19049.6	
Length Wtd. (ft)	102.00	Wetted Per. (ft)		66.48	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.08	
Alpha	1.00	Stream Power (lb/ft s)	222.00	0.00	0.00
Frctn Loss (ft)	0.06	Cum Volume (acre-ft)	0.00	6.37	0.32
C & E Loss (ft)	0.00	Cum SA (acres)	0.01	4.76	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2391 Profile: PF 7

E.G. Elev (ft)	635.06	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.06	Wt. n-Val.		0.055	
W.S. Elev (ft)	635.00	Reach Len. (ft)	104.00	107.00	110.00
Crit W.S. (ft)		Flow Area (sq ft)		167.82	
E.G. Slope (ft/ft)	0.001400	Area (sq ft)		167.82	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	53.79	Top Width (ft)		53.79	
Vel Total (ft/s)	2.04	Avg. Vel. (ft/s)		2.04	
Max Chl Dpth (ft)	5.00	Hydr. Depth (ft)		3.12	
Conv. Total (cfs)	9131.2	Conv. (cfs)		9131.2	
Length Wtd. (ft)	107.00	Wetted Per. (ft)		58.72	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.25	
Alpha	1.00	Stream Power (lb/ft s)	255.00	0.00	0.00
Frctn Loss (ft)	0.43	Cum Volume (acre-ft)	0.00	5.86	0.32
C & E Loss (ft)	0.10	Cum SA (acres)	0.01	4.63	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2284 Profile: PF 7

E.G. Elev (ft)	634.53	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.05	Wt. n-Val.		0.055	
W.S. Elev (ft)	633.48	Reach Len. (ft)	94.00	106.00	118.00
Crit W.S. (ft)	633.48	Flow Area (sq ft)		41.57	

Plan: Plan 02 Pettibone Creek North 2 RS: 2284 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.040686	Area (sq ft)		41.57	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	20.26	Top Width (ft)		20.26	
Vel Total (ft/s)	8.22	Avg. Vel. (ft/s)		8.22	
Max Chl Dpth (ft)	3.48	Hydr. Depth (ft)		2.05	
Conv. Total (cfs)	1694.0	Conv. (cfs)		1694.0	
Length Wtd. (ft)	106.00	Wetted Per. (ft)		22.44	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		4.70	
Alpha	1.00	Stream Power (lb/ft s)	243.00	0.00	0.00
Frctn Loss (ft)	0.37	Cum Volume (acre-ft)	0.00	5.60	0.32
C & E Loss (ft)	0.30	Cum SA (acres)	0.01	4.54	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2178 Profile: PF 7

E.G. Elev (ft)	632.69	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.04	Wt. n-Val.		0.055	
W.S. Elev (ft)	632.65	Reach Len. (ft)	117.00	112.00	109.00
Crit W.S. (ft)		Flow Area (sq ft)		206.20	
E.G. Slope (ft/ft)	0.001211	Area (sq ft)		206.20	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	85.75	Top Width (ft)		85.75	
Vel Total (ft/s)	1.66	Avg. Vel. (ft/s)		1.66	
Max Chl Dpth (ft)	2.65	Hydr. Depth (ft)		2.40	
Conv. Total (cfs)	9819.8	Conv. (cfs)		9819.8	
Length Wtd. (ft)	112.00	Wetted Per. (ft)		88.11	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.18	
Alpha	1.00	Stream Power (lb/ft s)	247.00	0.00	0.00
Frctn Loss (ft)	0.15	Cum Volume (acre-ft)	0.00	5.30	0.32
C & E Loss (ft)	0.00	Cum SA (acres)	0.01	4.41	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2066 Profile: PF 7

E.G. Elev (ft)	632.54	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.		0.055	
W.S. Elev (ft)	632.49	Reach Len. (ft)	121.00	123.00	127.00
Crit W.S. (ft)		Flow Area (sq ft)		185.11	
E.G. Slope (ft/ft)	0.001578	Area (sq ft)		185.11	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	79.50	Top Width (ft)		79.50	
Vel Total (ft/s)	1.85	Avg. Vel. (ft/s)		1.85	

Plan: Plan 02 Pettibone Creek North 2 RS: 2066 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	2.49	Hydr. Depth (ft)		2.33	
Conv. Total (cfs)	8600.6	Conv. (cfs)		8600.6	
Length Wtd. (ft)	123.00	Wetted Per. (ft)		82.08	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.22	
Alpha	1.00	Stream Power (lb/ft s)	273.00	0.00	0.00
Frctn Loss (ft)	0.34	Cum Volume (acre-ft)	0.00	4.79	0.32
C & E Loss (ft)	0.01	Cum SA (acres)	0.01	4.20	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 1942 Profile: PF 7

E.G. Elev (ft)	632.19	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.13	Wt. n-Val.		0.055	
W.S. Elev (ft)	632.06	Reach Len. (ft)	116.00	126.00	142.00
Crit W.S. (ft)		Flow Area (sq ft)		118.64	
E.G. Slope (ft/ft)	0.006186	Area (sq ft)		118.64	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	72.41	Top Width (ft)		72.41	
Vel Total (ft/s)	2.88	Avg. Vel. (ft/s)		2.88	
Max Chl Dpth (ft)	2.06	Hydr. Depth (ft)		1.64	
Conv. Total (cfs)	4344.4	Conv. (cfs)		4344.4	
Length Wtd. (ft)	126.00	Wetted Per. (ft)		75.18	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.61	
Alpha	1.00	Stream Power (lb/ft s)	288.00	0.00	0.00
Frctn Loss (ft)	0.79	Cum Volume (acre-ft)	0.00	4.36	0.32
C & E Loss (ft)	0.01	Cum SA (acres)	0.01	3.98	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 1816 Profile: PF 7

E.G. Elev (ft)	631.39	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.10	Wt. n-Val.		0.055	
W.S. Elev (ft)	631.29	Reach Len. (ft)	1170.00	1170.00	1170.00
Crit W.S. (ft)	630.69	Flow Area (sq ft)		135.09	
E.G. Slope (ft/ft)	0.006433	Area (sq ft)		135.09	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	105.29	Top Width (ft)		105.29	
Vel Total (ft/s)	2.53	Avg. Vel. (ft/s)		2.53	
Max Chl Dpth (ft)	1.29	Hydr. Depth (ft)		1.28	
Conv. Total (cfs)	4260.4	Conv. (cfs)		4260.4	
Length Wtd. (ft)	1170.00	Wetted Per. (ft)		107.12	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.51	

Plan: Plan 02 Pettibone Creek North 2 RS: 1816 Profile: PF 7 (Continued)

Alpha	1.00	Stream Power (lb/ft s)	344.00	0.00	0.00
Frctn Loss (ft)	13.00	Cum Volume (acre-ft)	0.00	4.00	0.32
C & E Loss (ft)	0.01	Cum SA (acres)	0.01	3.72	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 646 Profile: PF 7

E.G. Elev (ft)	618.38	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.19	Wt. n-Val.	0.100	0.055	0.100
W.S. Elev (ft)	618.19	Reach Len. (ft)	190.00	219.00	253.00
Crit W.S. (ft)	617.79	Flow Area (sq ft)	0.09	98.88	0.02
E.G. Slope (ft/ft)	0.023640	Area (sq ft)	0.09	98.88	0.02
Q Total (cfs)	341.70	Flow (cfs)	0.04	341.65	0.01
Top Width (ft)	131.15	Top Width (ft)	0.96	130.00	0.19
Vel Total (ft/s)	3.45	Avg. Vel. (ft/s)	0.47	3.46	0.38
Max Chl Dpth (ft)	2.19	Hydr. Depth (ft)	0.10	0.76	0.10
Conv. Total (cfs)	2222.4	Conv. (cfs)	0.3	2222.1	0.0
Length Wtd. (ft)	234.32	Wetted Per. (ft)	0.98	130.35	0.27
Min Ch El (ft)	616.00	Shear (lb/sq ft)	0.14	1.12	0.10
Alpha	1.00	Stream Power (lb/ft s)	376.00	0.00	0.00
Frctn Loss (ft)	6.51	Cum Volume (acre-ft)	0.00	0.86	0.32
C & E Loss (ft)	0.02	Cum SA (acres)	0.00	0.56	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 427 Profile: PF 7

E.G. Elev (ft)	611.85	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.35	Wt. n-Val.		0.055	0.100
W.S. Elev (ft)	611.50	Reach Len. (ft)	306.00	234.00	165.00
Crit W.S. (ft)		Flow Area (sq ft)		6.14	66.57
E.G. Slope (ft/ft)	0.033087	Area (sq ft)		6.14	66.57
Q Total (cfs)	341.70	Flow (cfs)		33.75	307.95
Top Width (ft)	33.51	Top Width (ft)		4.50	29.01
Vel Total (ft/s)	4.70	Avg. Vel. (ft/s)		5.50	4.63
Max Chl Dpth (ft)	3.50	Hydr. Depth (ft)		1.36	2.29
Conv. Total (cfs)	1878.5	Conv. (cfs)		185.5	1693.0
Length Wtd. (ft)	202.91	Wetted Per. (ft)		5.18	29.73
Min Ch El (ft)	609.00	Shear (lb/sq ft)		2.45	4.63
Alpha	1.01	Stream Power (lb/ft s)	289.00	0.00	0.00
Frctn Loss (ft)	2.24	Cum Volume (acre-ft)		0.59	0.13
C & E Loss (ft)	0.04	Cum SA (acres)		0.23	0.05

Plan: Plan 02 Pettibone Creek North 2 RS: 193 Profile: PF 7

E.G. Elev (ft)	609.57	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.22	Wt. n-Val.		0.055	
W.S. Elev (ft)	609.35	Reach Len. (ft)	135.00	193.00	251.00
Crit W.S. (ft)		Flow Area (sq ft)		89.94	
E.G. Slope (ft/ft)	0.005452	Area (sq ft)		89.94	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	31.70	Top Width (ft)		31.70	
Vel Total (ft/s)	3.80	Avg. Vel. (ft/s)		3.80	
Max Chl Dpth (ft)	3.35	Hydr. Depth (ft)		2.84	
Conv. Total (cfs)	4627.7	Conv. (cfs)		4627.7	
Length Wtd. (ft)	193.00	Wetted Per. (ft)		34.22	
Min Ch El (ft)	606.00	Shear (lb/sq ft)		0.89	
Alpha	1.00	Stream Power (lb/ft s)	276.00	0.00	0.00
Frctn Loss (ft)	2.24	Cum Volume (acre-ft)		0.33	
C & E Loss (ft)	0.06	Cum SA (acres)		0.13	

Plan: Plan 02 Pettibone Creek North 2 RS: 0 Profile: PF 7

E.G. Elev (ft)	607.26	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.87	Wt. n-Val.		0.055	
W.S. Elev (ft)	606.39	Reach Len. (ft)	10.00	10.00	10.00
Crit W.S. (ft)	606.39	Flow Area (sq ft)		45.67	
E.G. Slope (ft/ft)	0.039832	Area (sq ft)		45.67	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	26.77	Top Width (ft)		26.77	
Vel Total (ft/s)	7.48	Avg. Vel. (ft/s)		7.48	
Max Chl Dpth (ft)	2.39	Hydr. Depth (ft)		1.71	
Conv. Total (cfs)	1712.1	Conv. (cfs)		1712.1	
Length Wtd. (ft)	10.00	Wetted Per. (ft)		27.95	
Min Ch El (ft)	604.00	Shear (lb/sq ft)		4.06	
Alpha	1.00	Stream Power (lb/ft s)	254.00	0.00	0.00
Frctn Loss (ft)	0.04	Cum Volume (acre-ft)		0.03	
C & E Loss (ft)	0.22	Cum SA (acres)			

Plan: Plan 02 Pettibone Creek North 1 RS: 1050 Profile: PF 7

E.G. Elev (ft)	604.75	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.12	Wt. n-Val.		0.055	
W.S. Elev (ft)	604.63	Reach Len. (ft)	65.00	203.00	349.00
Crit W.S. (ft)		Flow Area (sq ft)		244.55	

Plan: Plan 02 Pettibone Creek North 1 RS: 1050 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.002294	Area (sq ft)		244.55	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	72.13	Top Width (ft)		72.13	
Vel Total (ft/s)	2.79	Avg. Vel. (ft/s)		2.79	
Max Chl Dpth (ft)	4.63	Hydr. Depth (ft)		3.39	
Conv. Total (cfs)	14265.9	Conv. (cfs)		14265.9	
Length Wtd. (ft)	203.00	Wetted Per. (ft)		77.08	
Min Ch El (ft)	600.00	Shear (lb/sq ft)		0.45	
Alpha	1.00	Stream Power (lb/ft s)	321.00	0.00	0.00
Frctn Loss (ft)	1.07	Cum Volume (acre-ft)	0.02	3.48	0.00
C & E Loss (ft)	0.05	Cum SA (acres)		1.13	

Plan: Plan 02 Pettibone Creek North 1 RS: 847 Profile: PF 7

E.G. Elev (ft)	603.64	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.59	Wt. n-Val.		0.055	
W.S. Elev (ft)	603.05	Reach Len. (ft)	53.00	109.00	208.00
Crit W.S. (ft)		Flow Area (sq ft)		110.62	
E.G. Slope (ft/ft)	0.022449	Area (sq ft)		110.62	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	57.05	Top Width (ft)		57.05	
Vel Total (ft/s)	6.18	Avg. Vel. (ft/s)		6.18	
Max Chl Dpth (ft)	3.05	Hydr. Depth (ft)		1.94	
Conv. Total (cfs)	4559.8	Conv. (cfs)		4559.8	
Length Wtd. (ft)	109.00	Wetted Per. (ft)		58.70	
Min Ch El (ft)	600.00	Shear (lb/sq ft)		2.64	
Alpha	1.00	Stream Power (lb/ft s)	453.00	0.00	0.00
Frctn Loss (ft)	1.33	Cum Volume (acre-ft)	0.02	2.65	0.00
C & E Loss (ft)	0.06	Cum SA (acres)		0.83	

Plan: Plan 02 Pettibone Creek North 1 RS: 738 Profile: PF 7

E.G. Elev (ft)	602.24	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.39	Wt. n-Val.		0.055	
W.S. Elev (ft)	601.86	Reach Len. (ft)	88.00	82.00	38.00
Crit W.S. (ft)		Flow Area (sq ft)		136.91	
E.G. Slope (ft/ft)	0.007673	Area (sq ft)		136.91	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	42.50	Top Width (ft)		42.50	
Vel Total (ft/s)	4.99	Avg. Vel. (ft/s)		4.99	

Plan: Plan 02 Pettibone Creek North 1 RS: 738 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	3.86	Hydr. Depth (ft)		3.22	
Conv. Total (cfs)	7799.5	Conv. (cfs)		7799.5	
Length Wtd. (ft)	82.00	Wetted Per. (ft)		44.71	
Min Ch El (ft)	598.00	Shear (lb/sq ft)		1.47	
Alpha	1.00	Stream Power (lb/ft s)	387.00	0.00	0.00
Frctn Loss (ft)	0.71	Cum Volume (acre-ft)	0.02	2.34	0.00
C & E Loss (ft)	0.02	Cum SA (acres)		0.70	

Plan: Plan 02 Pettibone Creek North 1 RS: 656 Profile: PF 7

E.G. Elev (ft)	601.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.54	Wt. n-Val.		0.055	
W.S. Elev (ft)	600.97	Reach Len. (ft)	195.00	82.00	28.00
Crit W.S. (ft)		Flow Area (sq ft)		115.43	
E.G. Slope (ft/ft)	0.009861	Area (sq ft)		115.43	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	32.44	Top Width (ft)		32.44	
Vel Total (ft/s)	5.92	Avg. Vel. (ft/s)		5.92	
Max Chl Dpth (ft)	4.97	Hydr. Depth (ft)		3.56	
Conv. Total (cfs)	6880.1	Conv. (cfs)		6880.1	
Length Wtd. (ft)	82.00	Wetted Per. (ft)		35.23	
Min Ch El (ft)	596.00	Shear (lb/sq ft)		2.02	
Alpha	1.00	Stream Power (lb/ft s)	335.00	0.00	0.00
Frctn Loss (ft)	0.72	Cum Volume (acre-ft)	0.02	2.11	0.00
C & E Loss (ft)	0.08	Cum SA (acres)		0.63	

Plan: Plan 02 Pettibone Creek North 1 RS: 574 Profile: PF 7

E.G. Elev (ft)	600.72	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.27	Wt. n-Val.		0.055	
W.S. Elev (ft)	600.44	Reach Len. (ft)	104.00	203.00	201.00
Crit W.S. (ft)		Flow Area (sq ft)		163.11	
E.G. Slope (ft/ft)	0.007888	Area (sq ft)		163.11	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	66.88	Top Width (ft)		66.88	
Vel Total (ft/s)	4.19	Avg. Vel. (ft/s)		4.19	
Max Chl Dpth (ft)	4.44	Hydr. Depth (ft)		2.44	
Conv. Total (cfs)	7692.2	Conv. (cfs)		7692.2	
Length Wtd. (ft)	203.00	Wetted Per. (ft)		70.72	
Min Ch El (ft)	596.00	Shear (lb/sq ft)		1.14	

Plan: Plan 02 Pettibone Creek North 1 RS: 574 Profile: PF 7 (Continued)

Alpha	1.00	Stream Power (lb/ft s)	348.00	0.00	0.00
Frctn Loss (ft)	2.11	Cum Volume (acre-ft)	0.02	1.84	0.00
C & E Loss (ft)	0.04	Cum SA (acres)		0.54	

Plan: Plan 02 Pettibone Creek North 1 RS: 371 Profile: PF 7

E.G. Elev (ft)	598.55	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.70	Wt. n-Val.		0.055	
W.S. Elev (ft)	597.85	Reach Len. (ft)	27.00	59.00	188.00
Crit W.S. (ft)		Flow Area (sq ft)		101.85	
E.G. Slope (ft/ft)	0.014381	Area (sq ft)		101.85	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	31.64	Top Width (ft)		31.64	
Vel Total (ft/s)	6.71	Avg. Vel. (ft/s)		6.71	
Max Chl Dpth (ft)	3.85	Hydr. Depth (ft)		3.22	
Conv. Total (cfs)	5697.2	Conv. (cfs)		5697.2	
Length Wtd. (ft)	59.00	Wetted Per. (ft)		34.19	
Min Ch El (ft)	594.00	Shear (lb/sq ft)		2.67	
Alpha	1.00	Stream Power (lb/ft s)	362.00	0.00	0.00
Frctn Loss (ft)	0.52	Cum Volume (acre-ft)	0.02	1.23	0.00
C & E Loss (ft)	0.10	Cum SA (acres)		0.31	

Plan: Plan 02 Pettibone Creek North 1 RS: 312 Profile: PF 7

E.G. Elev (ft)	597.93	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.36	Wt. n-Val.		0.055	
W.S. Elev (ft)	597.57	Reach Len. (ft)	19.00	73.00	156.00
Crit W.S. (ft)		Flow Area (sq ft)		141.93	
E.G. Slope (ft/ft)	0.006031	Area (sq ft)		141.93	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	37.48	Top Width (ft)		37.48	
Vel Total (ft/s)	4.81	Avg. Vel. (ft/s)		4.81	
Max Chl Dpth (ft)	5.57	Hydr. Depth (ft)		3.79	
Conv. Total (cfs)	8797.2	Conv. (cfs)		8797.2	
Length Wtd. (ft)	73.00	Wetted Per. (ft)		40.84	
Min Ch El (ft)	592.00	Shear (lb/sq ft)		1.31	
Alpha	1.00	Stream Power (lb/ft s)	350.00	0.00	0.00
Frctn Loss (ft)	0.64	Cum Volume (acre-ft)	0.02	1.06	0.00
C & E Loss (ft)	0.04	Cum SA (acres)		0.26	

Plan: Plan 02 Pettibone Creek North 1 RS: 239 Profile: PF 7

E.G. Elev (ft)	597.25	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.74	Wt. n-Val.		0.055	
W.S. Elev (ft)	596.52	Reach Len. (ft)	14.00	56.00	35.00
Crit W.S. (ft)		Flow Area (sq ft)		99.24	
E.G. Slope (ft/ft)	0.013653	Area (sq ft)		99.24	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	28.03	Top Width (ft)		28.03	
Vel Total (ft/s)	6.88	Avg. Vel. (ft/s)		6.88	
Max Chl Dpth (ft)	4.52	Hydr. Depth (ft)		3.54	
Conv. Total (cfs)	5846.9	Conv. (cfs)		5846.9	
Length Wtd. (ft)	56.00	Wetted Per. (ft)		30.81	
Min Ch El (ft)	592.00	Shear (lb/sq ft)		2.75	
Alpha	1.00	Stream Power (lb/ft s)	338.00	0.00	0.00
Frctn Loss (ft)	0.88	Cum Volume (acre-ft)	0.02	0.86	0.00
C & E Loss (ft)	0.01	Cum SA (acres)		0.21	

Plan: Plan 02 Pettibone Creek North 1 RS: 183 Profile: PF 7

E.G. Elev (ft)	596.37	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.80	Wt. n-Val.		0.055	
W.S. Elev (ft)	595.57	Reach Len. (ft)	227.00	98.00	25.00
Crit W.S. (ft)		Flow Area (sq ft)		94.94	
E.G. Slope (ft/ft)	0.018145	Area (sq ft)		94.94	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	31.70	Top Width (ft)		31.70	
Vel Total (ft/s)	7.20	Avg. Vel. (ft/s)		7.20	
Max Chl Dpth (ft)	3.57	Hydr. Depth (ft)		3.00	
Conv. Total (cfs)	5071.9	Conv. (cfs)		5071.9	
Length Wtd. (ft)	98.00	Wetted Per. (ft)		34.15	
Min Ch El (ft)	592.00	Shear (lb/sq ft)		3.15	
Alpha	1.00	Stream Power (lb/ft s)	344.00	0.00	0.00
Frctn Loss (ft)	0.61	Cum Volume (acre-ft)	0.02	0.73	0.00
C & E Loss (ft)	0.17	Cum SA (acres)		0.17	

Plan: Plan 02 Pettibone Creek North 1 RS: 85 Profile: PF 7

E.G. Elev (ft)	595.58	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.23	Wt. n-Val.		0.055	
W.S. Elev (ft)	595.36	Reach Len. (ft)	213.00	98.00	26.00
Crit W.S. (ft)		Flow Area (sq ft)		178.18	

Plan: Plan 02 Pettibone Creek North 1 RS: 85 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.003113	Area (sq ft)		178.18	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	38.71	Top Width (ft)		38.71	
Vel Total (ft/s)	3.83	Avg. Vel. (ft/s)		3.83	
Max Chl Dpth (ft)	5.36	Hydr. Depth (ft)		4.60	
Conv. Total (cfs)	12244.3	Conv. (cfs)		12244.3	
Length Wtd. (ft)	98.00	Wetted Per. (ft)		43.92	
Min Ch El (ft)	590.00	Shear (lb/sq ft)		0.79	
Alpha	1.00	Stream Power (lb/ft s)	426.00	0.00	0.00
Frctn Loss (ft)	0.47	Cum Volume (acre-ft)	0.02	0.43	0.00
C & E Loss (ft)	0.02	Cum SA (acres)		0.09	

Plan: Plan 02 Pettibone Creek North 1 RS: 0 Profile: PF 7

E.G. Elev (ft)	595.09	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.42	Wt. n-Val.		0.055	
W.S. Elev (ft)	594.67	Reach Len. (ft)	10.00	10.00	10.00
Crit W.S. (ft)		Flow Area (sq ft)		131.44	
E.G. Slope (ft/ft)	0.008465	Area (sq ft)		131.44	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	41.05	Top Width (ft)		41.05	
Vel Total (ft/s)	5.20	Avg. Vel. (ft/s)		5.20	
Max Chl Dpth (ft)	4.67	Hydr. Depth (ft)		3.20	
Conv. Total (cfs)	7425.6	Conv. (cfs)		7425.6	
Length Wtd. (ft)	10.00	Wetted Per. (ft)		43.47	
Min Ch El (ft)	590.00	Shear (lb/sq ft)		1.60	
Alpha	1.00	Stream Power (lb/ft s)	320.00	0.00	0.00
Frctn Loss (ft)	0.03	Cum Volume (acre-ft)	0.02	0.08	0.00
C & E Loss (ft)	0.08	Cum SA (acres)			

Plan: Plan 02 Pettibone Creek Main RS: 911 Profile: PF 7

E.G. Elev (ft)	594.97	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.14	Wt. n-Val.	0.100	0.055	0.100
W.S. Elev (ft)	594.84	Reach Len. (ft)	31.00	94.00	128.00
Crit W.S. (ft)		Flow Area (sq ft)	170.88	555.18	0.87
E.G. Slope (ft/ft)	0.002608	Area (sq ft)	170.88	555.18	0.87
Q Total (cfs)	1995.20	Flow (cfs)	250.78	1744.06	0.35
Top Width (ft)	221.98	Top Width (ft)	61.89	158.00	2.09
Vel Total (ft/s)	2.74	Avg. Vel. (ft/s)	1.47	3.14	0.40

Plan: Plan 02 Pettibone Creek Main RS: 911 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	6.84	Hydr. Depth (ft)	2.76	3.51	0.42
Conv. Total (cfs)	39068.8	Conv. (cfs)	4910.7	34151.2	6.9
Length Wtd. (ft)	88.58	Wetted Per. (ft)	63.53	161.60	2.25
Min Ch El (ft)	588.00	Shear (lb/sq ft)	0.44	0.56	0.06
Alpha	1.18	Stream Power (lb/ft s)	555.00	0.00	0.00
Frctn Loss (ft)	0.34	Cum Volume (acre-ft)	0.21	7.36	0.00
C & E Loss (ft)	0.03	Cum SA (acres)	0.13	1.82	0.00

Plan: Plan 02 Pettibone Creek Main RS: 817 Profile: PF 7

E.G. Elev (ft)	594.60	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.45	Wt. n-Val.	0.100	0.055	
W.S. Elev (ft)	594.15	Reach Len. (ft)	171.00	138.00	135.00
Crit W.S. (ft)		Flow Area (sq ft)	64.64	345.44	
E.G. Slope (ft/ft)	0.006209	Area (sq ft)	64.64	345.44	
Q Total (cfs)	1995.20	Flow (cfs)	92.39	1902.81	
Top Width (ft)	125.99	Top Width (ft)	47.30	78.69	
Vel Total (ft/s)	4.87	Avg. Vel. (ft/s)	1.43	5.51	
Max Chl Dpth (ft)	6.15	Hydr. Depth (ft)	1.37	4.39	
Conv. Total (cfs)	25320.0	Conv. (cfs)	1172.5	24147.4	
Length Wtd. (ft)	138.76	Wetted Per. (ft)	47.93	83.00	
Min Ch El (ft)	588.00	Shear (lb/sq ft)	0.52	1.61	
Alpha	1.23	Stream Power (lb/ft s)	534.00	0.00	0.00
Frctn Loss (ft)	1.32	Cum Volume (acre-ft)	0.13	6.39	
C & E Loss (ft)	0.07	Cum SA (acres)	0.09	1.57	

Plan: Plan 02 Pettibone Creek Main RS: 679 Profile: PF 7

E.G. Elev (ft)	593.21	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.15	Wt. n-Val.		0.055	
W.S. Elev (ft)	592.06	Reach Len. (ft)	57.00	55.00	54.00
Crit W.S. (ft)		Flow Area (sq ft)		231.90	
E.G. Slope (ft/ft)	0.016332	Area (sq ft)		231.90	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	54.69	Top Width (ft)		54.69	
Vel Total (ft/s)	8.60	Avg. Vel. (ft/s)		8.60	
Max Chl Dpth (ft)	6.06	Hydr. Depth (ft)		4.24	
Conv. Total (cfs)	15612.1	Conv. (cfs)		15612.1	
Length Wtd. (ft)	55.00	Wetted Per. (ft)		58.95	
Min Ch El (ft)	586.00	Shear (lb/sq ft)		4.01	

Plan: Plan 02 Pettibone Creek Main RS: 679 Profile: PF 7 (Continued)

Alpha	1.00	Stream Power (lb/ft s)	398.00	0.00	0.00
Frctn Loss (ft)	0.49	Cum Volume (acre-ft)		5.47	
C & E Loss (ft)	0.18	Cum SA (acres)		1.35	

Plan: Plan 02 Pettibone Creek Main RS: 624 Profile: PF 7

E.G. Elev (ft)	592.54	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.54	Wt. n-Val.		0.055	
W.S. Elev (ft)	592.00	Reach Len. (ft)	7.00	113.00	264.00
Crit W.S. (ft)		Flow Area (sq ft)		338.44	
E.G. Slope (ft/ft)	0.005581	Area (sq ft)		338.44	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	64.00	Top Width (ft)		64.00	
Vel Total (ft/s)	5.90	Avg. Vel. (ft/s)		5.90	
Max Chl Dpth (ft)	8.00	Hydr. Depth (ft)		5.29	
Conv. Total (cfs)	26707.7	Conv. (cfs)		26707.7	
Length Wtd. (ft)	113.00	Wetted Per. (ft)		67.80	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		1.74	
Alpha	1.00	Stream Power (lb/ft s)	408.00	0.00	0.00
Frctn Loss (ft)	0.63	Cum Volume (acre-ft)		5.11	
C & E Loss (ft)	0.00	Cum SA (acres)		1.28	

Plan: Plan 02 Pettibone Creek Main RS: 511 Profile: PF 7

E.G. Elev (ft)	591.90	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.52	Wt. n-Val.		0.055	
W.S. Elev (ft)	591.38	Reach Len. (ft)	5.00	91.00	70.00
Crit W.S. (ft)		Flow Area (sq ft)		343.32	
E.G. Slope (ft/ft)	0.005647	Area (sq ft)		343.32	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	67.25	Top Width (ft)		67.25	
Vel Total (ft/s)	5.81	Avg. Vel. (ft/s)		5.81	
Max Chl Dpth (ft)	7.38	Hydr. Depth (ft)		5.10	
Conv. Total (cfs)	26550.1	Conv. (cfs)		26550.1	
Length Wtd. (ft)	91.00	Wetted Per. (ft)		70.89	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		1.71	
Alpha	1.00	Stream Power (lb/ft s)	433.00	0.00	0.00
Frctn Loss (ft)	0.83	Cum Volume (acre-ft)		4.23	
C & E Loss (ft)	0.08	Cum SA (acres)		1.11	

Plan: Plan 02 Pettibone Creek Main RS: 420 Profile: PF 7

E.G. Elev (ft)	590.99	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.33	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.66	Reach Len. (ft)	122.00	88.00	30.00
Crit W.S. (ft)		Flow Area (sq ft)		215.19	
E.G. Slope (ft/ft)	0.017091	Area (sq ft)		215.19	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	45.66	Top Width (ft)		45.66	
Vel Total (ft/s)	9.27	Avg. Vel. (ft/s)		9.27	
Max Chl Dpth (ft)	5.66	Hydr. Depth (ft)		4.71	
Conv. Total (cfs)	15261.6	Conv. (cfs)		15261.6	
Length Wtd. (ft)	88.00	Wetted Per. (ft)		50.60	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		4.54	
Alpha	1.00	Stream Power (lb/ft s)	520.00	0.00	0.00
Frctn Loss (ft)	0.94	Cum Volume (acre-ft)		3.65	
C & E Loss (ft)	0.25	Cum SA (acres)		0.99	

Plan: Plan 02 Pettibone Creek Main RS: 332 Profile: PF 7

E.G. Elev (ft)	589.80	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.50	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.29	Reach Len. (ft)	149.00	33.00	26.00
Crit W.S. (ft)		Flow Area (sq ft)		350.67	
E.G. Slope (ft/ft)	0.007343	Area (sq ft)		350.67	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	86.94	Top Width (ft)		86.94	
Vel Total (ft/s)	5.69	Avg. Vel. (ft/s)		5.69	
Max Chl Dpth (ft)	5.29	Hydr. Depth (ft)		4.03	
Conv. Total (cfs)	23283.3	Conv. (cfs)		23283.3	
Length Wtd. (ft)	33.00	Wetted Per. (ft)		91.02	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		1.77	
Alpha	1.00	Stream Power (lb/ft s)	515.00	0.00	0.00
Frctn Loss (ft)	0.15	Cum Volume (acre-ft)		3.07	
C & E Loss (ft)	0.08	Cum SA (acres)		0.86	

Plan: Plan 02 Pettibone Creek Main RS: 299 Profile: PF 7

E.G. Elev (ft)	589.56	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.22	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.34	Reach Len. (ft)	135.00	26.00	25.00
Crit W.S. (ft)		Flow Area (sq ft)		526.48	

Plan: Plan 02 Pettibone Creek Main RS: 299 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.003240	Area (sq ft)		526.48	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	128.00	Top Width (ft)		128.00	
Vel Total (ft/s)	3.79	Avg. Vel. (ft/s)		3.79	
Max Chl Dpth (ft)	5.34	Hydr. Depth (ft)		4.11	
Conv. Total (cfs)	35052.1	Conv. (cfs)		35052.1	
Length Wtd. (ft)	26.00	Wetted Per. (ft)		136.09	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		0.78	
Alpha	1.00	Stream Power (lb/ft s)	531.00	0.00	0.00
Frctn Loss (ft)	0.07	Cum Volume (acre-ft)		2.74	
C & E Loss (ft)	0.02	Cum SA (acres)		0.78	

Plan: Plan 02 Pettibone Creek Main RS: 273 Profile: PF 7

E.G. Elev (ft)	589.48	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.17	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.31	Reach Len. (ft)	134.00	66.00	27.00
Crit W.S. (ft)		Flow Area (sq ft)		602.16	
E.G. Slope (ft/ft)	0.002102	Area (sq ft)		602.16	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	129.06	Top Width (ft)		129.06	
Vel Total (ft/s)	3.31	Avg. Vel. (ft/s)		3.31	
Max Chl Dpth (ft)	5.31	Hydr. Depth (ft)		4.67	
Conv. Total (cfs)	43523.1	Conv. (cfs)		43523.1	
Length Wtd. (ft)	66.00	Wetted Per. (ft)		137.61	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		0.57	
Alpha	1.00	Stream Power (lb/ft s)	512.00	0.00	0.00
Frctn Loss (ft)	0.20	Cum Volume (acre-ft)		2.40	
C & E Loss (ft)	0.02	Cum SA (acres)		0.70	

Plan: Plan 02 Pettibone Creek Main RS: 207 Profile: PF 7

E.G. Elev (ft)	589.25	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.41	Wt. n-Val.		0.055	
W.S. Elev (ft)	588.83	Reach Len. (ft)	144.00	206.00	134.00
Crit W.S. (ft)		Flow Area (sq ft)		386.62	
E.G. Slope (ft/ft)	0.005006	Area (sq ft)		386.62	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	84.59	Top Width (ft)		84.59	
Vel Total (ft/s)	5.16	Avg. Vel. (ft/s)		5.16	

Plan: Plan 02 Pettibone Creek Main RS: 207 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	6.83	Hydr. Depth (ft)		4.57	
Conv. Total (cfs)	28198.3	Conv. (cfs)		28198.3	
Length Wtd. (ft)	206.00	Wetted Per. (ft)		87.16	
Min Ch El (ft)	582.00	Shear (lb/sq ft)		1.39	
Alpha	1.00	Stream Power (lb/ft s)	495.00	0.00	0.00
Frctn Loss (ft)	1.83	Cum Volume (acre-ft)		1.66	
C & E Loss (ft)	0.02	Cum SA (acres)		0.54	

Plan: Plan 02 Pettibone Creek Main RS: 0 Profile: PF 7

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	587.39				
Vel Head (ft)	0.63	Wt. n-Val.		0.055	
W.S. Elev (ft)	586.76	Reach Len. (ft)			
Crit W.S. (ft)	586.37	Flow Area (sq ft)		313.48	
E.G. Slope (ft/ft)	0.020003	Area (sq ft)		313.48	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	142.42	Top Width (ft)		142.42	
Vel Total (ft/s)	6.36	Avg. Vel. (ft/s)		6.36	
Max Chl Dpth (ft)	4.76	Hydr. Depth (ft)		2.20	
Conv. Total (cfs)	14107.0	Conv. (cfs)		14107.0	
Length Wtd. (ft)		Wetted Per. (ft)		145.82	
Min Ch El (ft)	582.00	Shear (lb/sq ft)		2.68	
Alpha	1.00	Stream Power (lb/ft s)	477.00	0.00	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

APPENDIX K

DESIGN FLOW CALCULATIONS

K.1 DESIGN FLOW CALCULATIONS

K.2 ILLINOIS DEPARTMENT OF TRANSPORTATION FLOW CALCULATIONS

K.1 DESIGN FLOW CALCULATIONS

CLIENT: LANTDIV		JOB NUMBER: 112G01021	
SUBJECT: Pettibone Creek Drainage Area Flow Calculations			
BASED ON: TR-55 and Hec-HMS		DRAWING NUMBER:	
BY: SIL Date:	CHECKED BY: Date:	APPROVED BY:	DATE: 10-31-11

OBJECTIVE:

Find the design storm peak flows for all the tributaries that flow into Pettibone Creek, the flows in the North and South branches of Pettibone, and the total flow out of Pettibone Creek into the Inner Harbour using HEC HMS.

APPROACH:

1. Delineate the pre-construction drainage area (DA) and measure the areas.
2. Determine the longest time of concentration within the watershed to the creek.
3. Calculate the exisiting condition CN and Runoff based on the different areas and surface type.
4. Find the NOAA Point Precipitation Frequency Estimate for the site
5. Use the delineation information and rainfall data to determine the Tc using TR-55
6. Input the information into Hec-HMS to find the design storm peak flows into Pettibone Creek.

REFERENCES:

1) Natural Resources Conservation Service (NRCS), WinTR-55. Small Watershed Hidrology
2) National Oceanic and Atsmospheric Administration, NOAA Atlas 14, volume 2 Version 3, Precipitation-Frecuency Atlas of the United States
3) US Army Corp of Engineers HEC-HMS Hydrologic Modeling System Version 3.5

CALCULATIONS:

Drainage Area 1 was delineated North of the North Branch of Pettibone Creek (DA=886Ac)
Drainage Area 2 was delineated coming from the South Branch of Pettibone Creek (DA=1553 AC)
Use WinTR-55 to calculate Time of Concentration for Area 1 and Area 2
The total Peak Flow from Pettibone Creek going onto the Harbour

See attached Drainage Area Map
See Attached NOAA Point Precipitation Frecuency Estimates
See Attached TR-55 Results
See Attached Hec-HMS Results

CONCLUSIONS

With The Hec-HMS program we determined the design peak flows for all the tributaries flowing into Pettibone Creek; the flows are as follows:

	STORM EVENT FLOW PEAKS (CFS)						
	1YR	2YR	5YR	10YR	25YR	50YR	100YR
Area 1	117.4	143.7	200.6	248	316.6	378.3	441.8
Area 2	92.8	108.4	152.4	193.1	257.4	318.8	386.1
TOTAL	210.2	252.1	353	441.2	574.1	697.1	827.9

PGH P:\GIS\GREATLAKES_NS\MAPDOCS\MXD\PETTIBONE_CREEK_FLOWS_1.MXD 09/27/11 SS

DRAWN BY	DATE
S. STROZ	09/14/11
CHECKED BY	DATE
S. LOJEK	09/27/11
REVISED BY	DATE
SCALE AS NOTED	

NAVFAC

PETTIBONE CREEK WATERSHED
NS GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. 1	REV 0

SL

Pettibone Creek

Lake County, Illinois

Sub-Area Time of Concentration Details

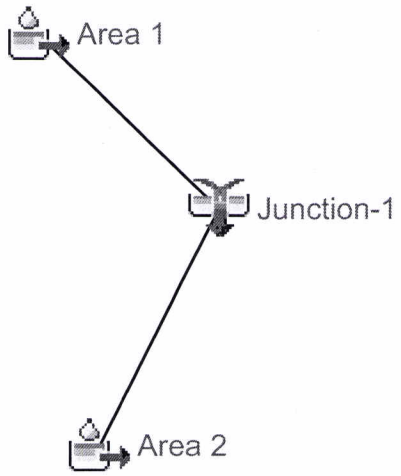
Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
Area 1							
SHEET	100	0.0150	0.150				0.192
SHALLOW	5581	0.0150	0.025				0.623
					Time of Concentration		0.815 hr → 48.9min
Area 2							
SHEET	100	0.0090	0.150				0.236
SHALLOW	7885	0.0090	0.025				1.136
					Time of Concentration		1.372 hr → 82.32min

HEC-HMS

Project : Pettibone Creek

Basin Model : Pettibone Creek

Oct 26 15:09:54 EDT 2011



Project: PC Nov Simulation Run: 1 yr

Start of Run: 28Jun2011, 00:00 Basin Model: Pettibone Creek
End of Run: 29Jun2011, 00:00 Meteorologic Model: 1 yr
Compute Time: 31Oct2011, 10:36:14 Control Specifications: 24Hr Storm 1 min

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
DA 2	2.42	92.8	29Jun2011, 00:00	0.33
DA 1	1.38	117.4	29Jun2011, 00:00	0.49
Junction-1	3.80	210.2	29Jun2011, 00:00	0.39

Project: PC Nov Simulation Run: 2 yr

Start of Run: 28Jun2011, 00:00 Basin Model: Pettibone Creek
End of Run: 29Jun2011, 00:00 Meteorologic Model: 2yr
Compute Time: 31Oct2011, 10:35:43 Control Specifications: 24Hr Storm 1 min

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
DA 2	2.42	108.4	29Jun2011, 00:00	0.40
DA 1	1.38	143.7	29Jun2011, 00:00	0.60
Junction-1	3.80	252.1	29Jun2011, 00:00	0.47

Project: PC Nov Simulation Run: 5 yr

Start of Run: 28Jun2011, 00:00 Basin Model: Pettibone Creek
End of Run: 29Jun2011, 00:00 Meteorologic Model: 5yr
Compute Time: 31Oct2011, 10:35:13 Control Specifications: 24Hr Storm 1 min

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
DA 2	2.42	152.4	29Jun2011, 00:00	0.54
DA 1	1.38	200.6	29Jun2011, 00:00	0.82
Junction-1	3.80	353.0	29Jun2011, 00:00	0.64

Project: PC Nov Simulation Run: 10 yr

Start of Run: 28Jun2011, 00:00 Basin Model: Pettibone Creek
End of Run: 29Jun2011, 00:00 Meteorologic Model: 10yr
Compute Time: 31Oct2011, 10:34:42 Control Specifications: 24Hr Storm 1 min

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
DA 2	2.42	193.1	29Jun2011, 00:00	0.53
DA 1	1.38	248.0	29Jun2011, 00:00	0.83
Junction-1	3.80	441.2	29Jun2011, 00:00	0.64

Project: PC Nov Simulation Run: 25 yr

Start of Run: 28Jun2011, 00:00 Basin Model: Pettibone Creek
End of Run: 29Jun2011, 00:00 Meteorologic Model: 25yr
Compute Time: 31Oct2011, 10:34:13 Control Specifications: 24Hr Storm 1 min

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
DA 2	2.42	257.4	29Jun2011, 00:00	0.61
DA 1	1.38	316.6	29Jun2011, 00:00	0.97
Junction-1	3.80	574.1	29Jun2011, 00:00	0.74

Project: PC Nov Simulation Run: 50YR

Start of Run: 28Jun2011, 00:00 Basin Model: Pettibone Creek
End of Run: 29Jun2011, 00:00 Meteorologic Model: 50yr
Compute Time: 31Oct2011, 10:33:41 Control Specifications: 24Hr Storm 1 min

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
DA 2	2.42	318.8	29Jun2011, 00:00	0.66
DA 1	1.38	378.3	29Jun2011, 00:00	1.07
Junction-1	3.80	697.1	29Jun2011, 00:00	0.81

Project: PC Nov Simulation Run: 100 Yr

Start of Run: 28Jun2011, 00:00 Basin Model: Pettibone Creek
End of Run: 29Jun2011, 00:00 Meteorologic Model: 100yr
Compute Time: 31Oct2011, 10:30:46 Control Specifications: 24Hr Storm 1 min

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
DA 2	2.42	386.1	29Jun2011, 00:00	0.71
DA 1	1.38	441.8	29Jun2011, 00:00	1.17
Junction-1	3.80	827.9	29Jun2011, 00:00	0.88

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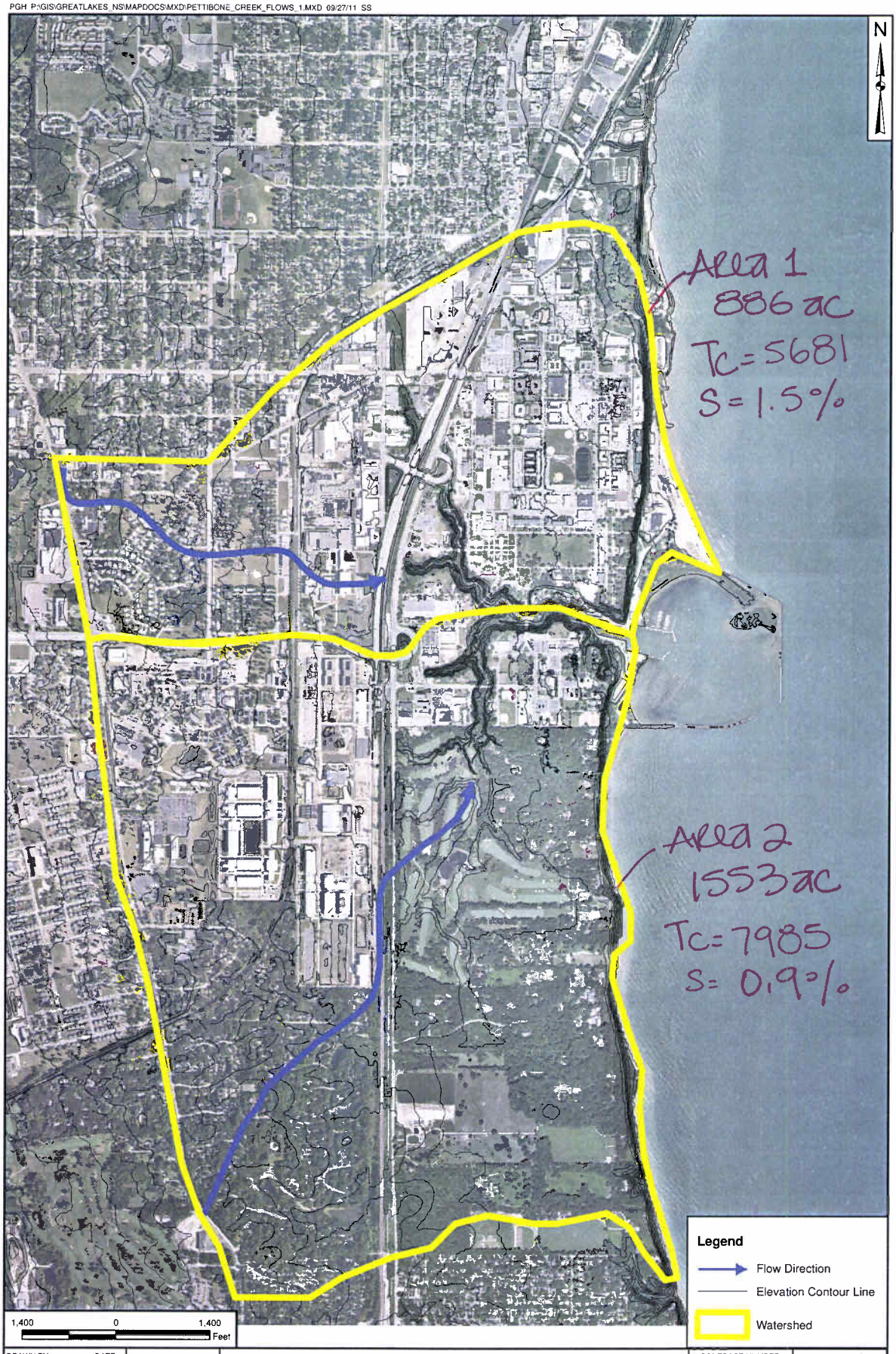


DRAWN BY	DATE
S. STROZ	09/14/11
CHECKED BY	DATE
S. LOJEK	09/27/11
REVISED BY	DATE
SCALE AS NOTED	

NAVFAC

PETTIBONE CREEK WATERSHED
NS GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. 1	REV 0

NOAA Atlas 14, Volume 2, Version 3
Location name: North Chicago, Illinois, US*
Coordinates: 42.3084, -87.8328
Elevation: 575ft*
* source: Google Maps

POINT PRECIPITATION FREQUENCY ESTIMATES

G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.373 (0.337–0.416)	0.442 (0.400–0.490)	0.526 (0.473–0.581)	0.597 (0.537–0.659)	0.686 (0.613–0.757)	0.759 (0.674–0.839)	0.830 (0.732–0.920)	0.905 (0.790–1.01)	1.01 (0.868–1.13)	1.09 (0.930–1.23)
10-min	0.580 (0.524–0.646)	0.690 (0.624–0.765)	0.817 (0.736–0.903)	0.922 (0.829–1.02)	1.05 (0.937–1.16)	1.15 (1.02–1.27)	1.25 (1.10–1.39)	1.35 (1.18–1.50)	1.48 (1.28–1.66)	1.59 (1.35–1.79)
15-min	0.711 (0.643–0.792)	0.843 (0.763–0.935)	1.00 (0.903–1.11)	1.13 (1.02–1.25)	1.30 (1.16–1.43)	1.42 (1.26–1.57)	1.55 (1.37–1.72)	1.68 (1.47–1.87)	1.85 (1.59–2.07)	1.99 (1.69–2.24)
30-min	0.941 (0.850–1.05)	1.13 (1.02–1.25)	1.37 (1.24–1.52)	1.58 (1.42–1.74)	1.83 (1.64–2.02)	2.04 (1.81–2.25)	2.24 (1.98–2.48)	2.45 (2.14–2.73)	2.74 (2.36–3.07)	2.98 (2.54–3.36)
60-min	1.15 (1.04–1.28)	1.39 (1.25–1.54)	1.72 (1.55–1.91)	2.00 (1.80–2.21)	2.37 (2.12–2.62)	2.68 (2.38–2.96)	3.00 (2.64–3.32)	3.33 (2.91–3.70)	3.79 (3.26–4.24)	4.18 (3.56–4.71)
2-hr	1.31 (1.17–1.47)	1.58 (1.41–1.77)	1.98 (1.77–2.22)	2.32 (2.07–2.59)	2.77 (2.45–3.09)	3.15 (2.77–3.52)	3.54 (3.09–3.96)	3.94 (3.41–4.41)	4.49 (3.84–5.06)	4.96 (4.19–5.62)
3-hr	1.37 (1.22–1.54)	1.65 (1.47–1.86)	2.08 (1.85–2.34)	2.45 (2.17–2.75)	2.94 (2.59–3.29)	3.35 (2.93–3.75)	3.77 (3.27–4.22)	4.20 (3.62–4.72)	4.80 (4.08–5.42)	5.29 (4.45–6.00)
6-hr	1.61 (1.41–1.84)	1.92 (1.69–2.21)	2.46 (2.16–2.82)	2.95 (2.58–3.37)	3.62 (3.14–4.12)	4.22 (3.62–4.80)	4.85 (4.12–5.52)	5.54 (4.64–6.32)	6.54 (5.38–7.49)	7.41 (6.00–8.54)
12-hr	1.86 (1.64–2.13)	2.23 (1.97–2.55)	2.83 (2.49–3.23)	3.37 (2.95–3.84)	4.11 (3.57–4.67)	4.77 (4.10–5.42)	5.46 (4.65–6.21)	6.22 (5.24–7.08)	7.31 (6.04–8.36)	8.25 (6.71–9.51)
24-hr	2.13 (1.98–2.32)	2.57 (2.38–2.80)	3.20 (2.96–3.48)	3.69 (3.40–4.01)	4.36 (4.00–4.73)	4.90 (4.47–5.47)	5.52 (4.95–6.27)	6.28 (5.43–7.15)	7.38 (6.06–8.44)	8.33 (6.78–9.60)
2-day	2.51 (2.33–2.72)	3.02 (2.80–3.27)	3.73 (3.45–4.04)	4.29 (3.96–4.64)	5.06 (4.64–5.47)	5.66 (5.17–6.13)	6.28 (5.70–6.81)	6.91 (6.23–7.51)	7.76 (6.94–8.46)	8.41 (7.48–9.70)
3-day	2.68 (2.49–2.89)	3.22 (2.99–3.47)	3.94 (3.66–4.24)	4.51 (4.18–4.86)	5.28 (4.87–5.69)	5.89 (5.40–6.35)	6.50 (5.94–7.03)	7.12 (6.46–7.73)	7.97 (7.16–8.68)	8.61 (7.68–9.75)
4-day	2.85 (2.66–3.05)	3.41 (3.18–3.66)	4.15 (3.87–4.45)	4.73 (4.40–5.07)	5.50 (5.10–5.91)	6.11 (5.64–6.57)	6.72 (6.17–7.25)	7.34 (6.69–7.94)	8.17 (7.38–8.90)	8.81 (7.89–9.79)
7-day	3.33 (3.13–3.56)	3.97 (3.72–4.24)	4.76 (4.46–5.08)	5.37 (5.03–5.72)	6.18 (5.76–6.59)	6.80 (6.31–7.26)	7.41 (6.85–7.94)	8.02 (7.37–8.62)	8.82 (8.05–9.54)	9.45 (8.56–10.3)
10-day	3.83 (3.60–4.09)	4.56 (4.28–4.86)	5.44 (5.10–5.80)	6.11 (5.72–6.52)	7.00 (6.54–7.47)	7.68 (7.15–8.23)	8.36 (7.74–8.98)	9.04 (8.31–9.73)	9.92 (9.05–10.8)	10.6 (9.58–11.5)
20-day	5.24 (4.94–5.57)	6.23 (5.87–6.62)	7.35 (6.93–7.81)	8.17 (7.69–8.68)	9.22 (8.65–9.80)	9.99 (9.34–10.6)	10.7 (9.99–11.4)	11.4 (10.6–12.2)	12.3 (11.4–13.2)	12.9 (11.9–14.0)
30-day	6.58 (6.20–6.97)	7.80 (7.35–8.26)	9.13 (8.61–9.67)	10.1 (9.50–10.7)	11.3 (10.6–11.9)	12.1 (11.4–12.9)	12.9 (12.1–13.7)	13.6 (12.7–14.5)	14.5 (13.5–15.6)	15.2 (14.0–16.3)
45-day	8.26 (7.83–8.72)	9.77 (9.25–10.3)	11.3 (10.7–12.0)	12.4 (11.8–13.1)	13.8 (13.0–14.5)	14.7 (13.9–15.6)	15.6 (14.7–16.5)	16.4 (15.4–17.4)	17.3 (16.2–18.4)	18.0 (16.8–19.2)
60-day	9.92 (9.41–10.4)	11.7 (11.1–12.3)	13.4 (12.7–14.1)	14.7 (13.9–15.4)	16.1 (15.2–16.9)	17.1 (16.2–18.0)	18.0 (17.0–19.0)	18.8 (17.7–19.9)	19.7 (18.5–20.9)	20.4 (19.1–21.7)

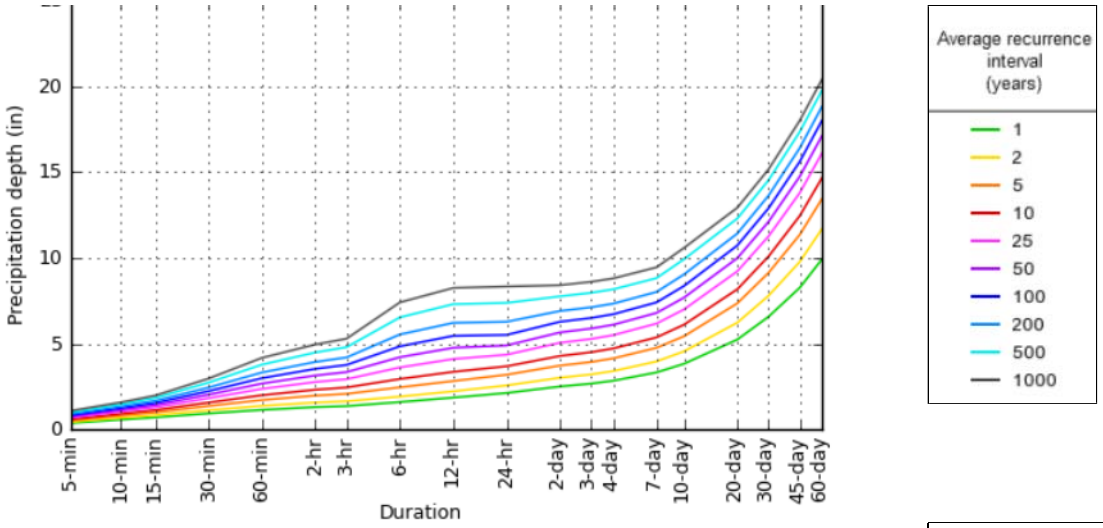
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

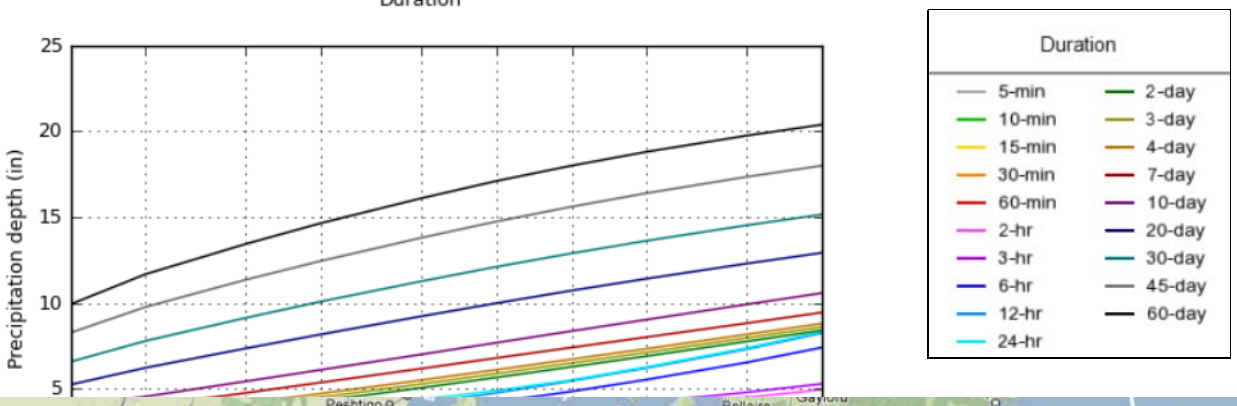
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

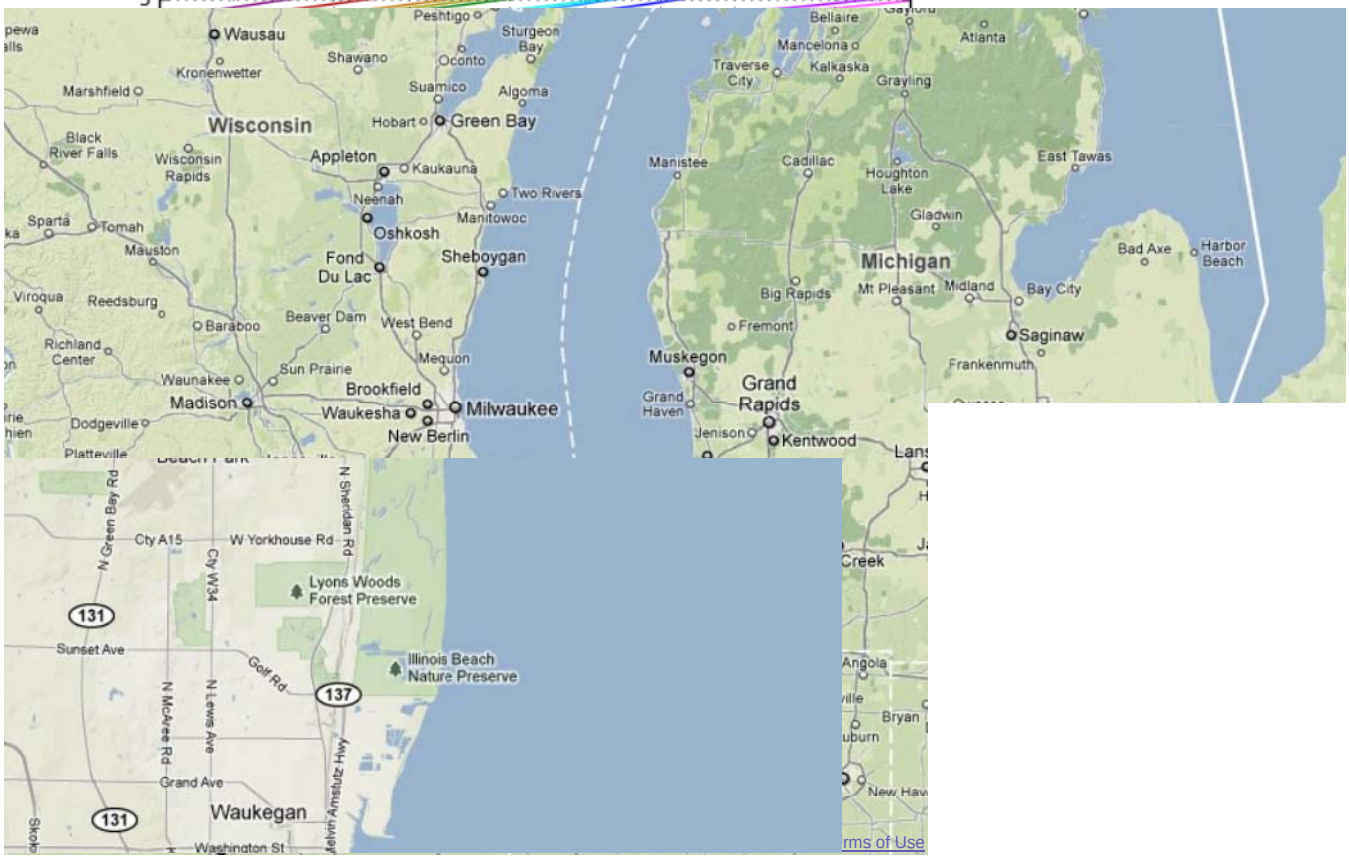
Please refer to NOAA Atlas 14 document for more information.

Back to Top

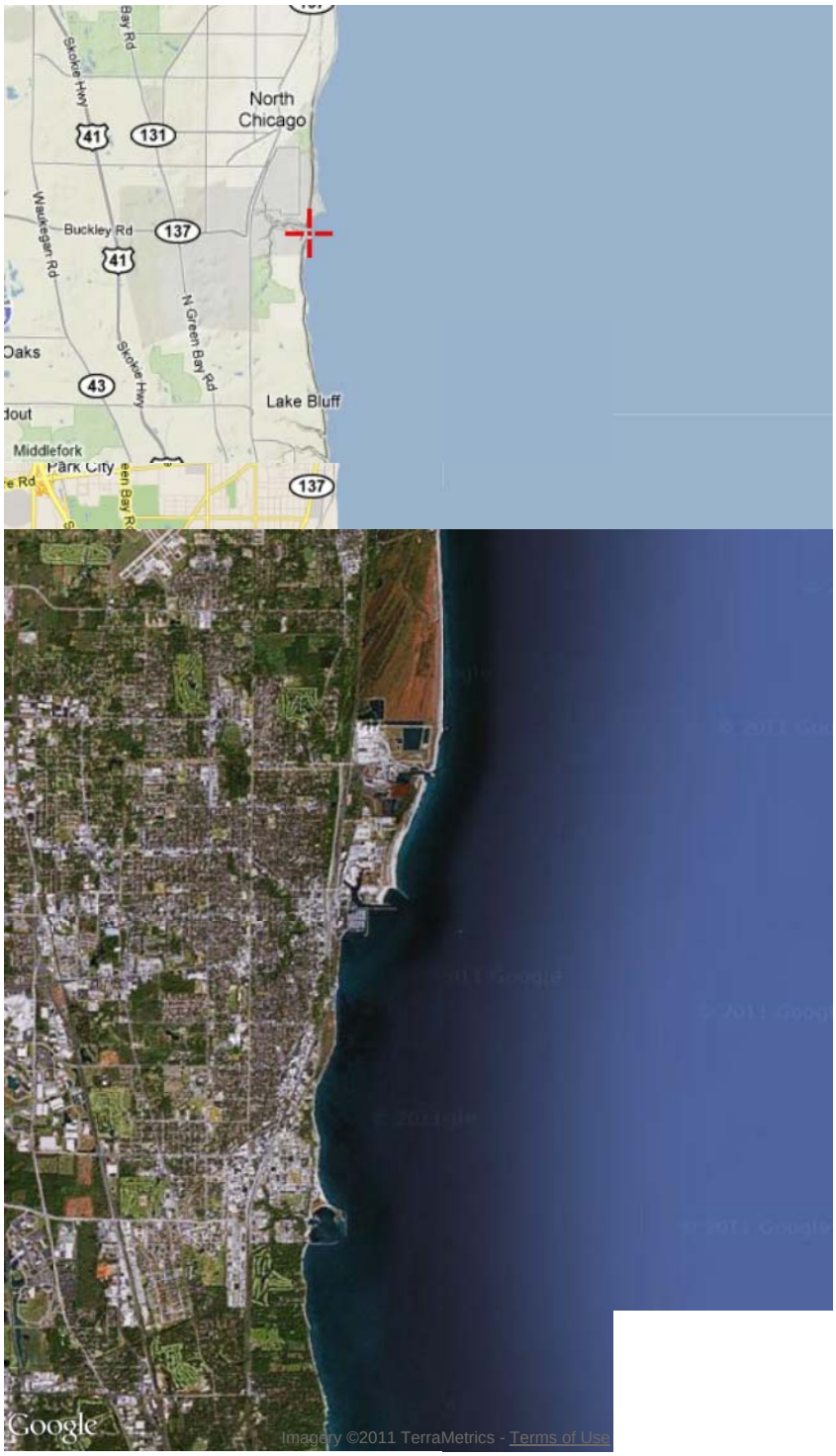
PF graphical







Large scale terrain



Back to Top

US Department of Commerce
National Oceanic and Atmospheric Administration
National Weather Service
Office of Hydrologic Development
1325 East West Highway
Silver Spring, MD 20910
Questions?: HDSC.Questions@noaa.gov

Disclaimer

WinTR-55 Current Data Description

--- Identification Data ---

User: SIL
Project: Pettibone Creek
SubTitle:
State: Illinois
County: Lake
Filename: C:\Users\Owner\AppData\Roaming\WinTR-55\Pettibone Creek.w55

Date: 6/29/2011
Units: English
Areal Units: Square Miles

--- Sub-Area Data ---

Name	Description	Reach	Area(mi^2)	RCN	Tc
DA 1	Area 1	Outlet	1.8	79	.698
DA 2	Area 2	Outlet	0.73	79	.446
DA 3	Area 3	Outlet	2.81	69	.679

Total area: 5.34 (mi^2)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
2.57	3.2	3.69	4.36	4.9	5.52	2.13

Storm Data Source: User-provided custom storm data
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

SIL

Pettibone Creek

Lake County, Illinois

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
2.57	3.2	3.69	4.36	4.9	5.52	2.13

Storm Data Source: User-provided custom storm data
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

SIL

Pettibone Creek

Lake County, Illinois

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (mi^2)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA 1	1.80	0.698	79	Outlet	Area 1
DA 2	.73	0.446	79	Outlet	Area 2
DA 3	2.81	0.679	69	Outlet	Area 3

Total Area: 5.34 (mi^2)

Pettibone Creek

Lake County, Illinois

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA 1							
SHEET	100	0.0200	0.150				0.182
SHALLOW	1516	0.0150	0.025				0.169
CHANNEL	10000					8.000	0.347
					Time of Concentration		.698
DA 2							
SHEET	100	0.0150	0.150				0.204
SHALLOW	708	0.0200	0.025				0.068
CHANNEL	5000					8.000	0.174
					Time of Concentration		.446
DA 3							
SHEET	100	0.0200	0.150				0.182
SHALLOW	2640	0.0150	0.050				0.371
CHANNEL	3168					7.000	0.126
					Time of Concentration		.679

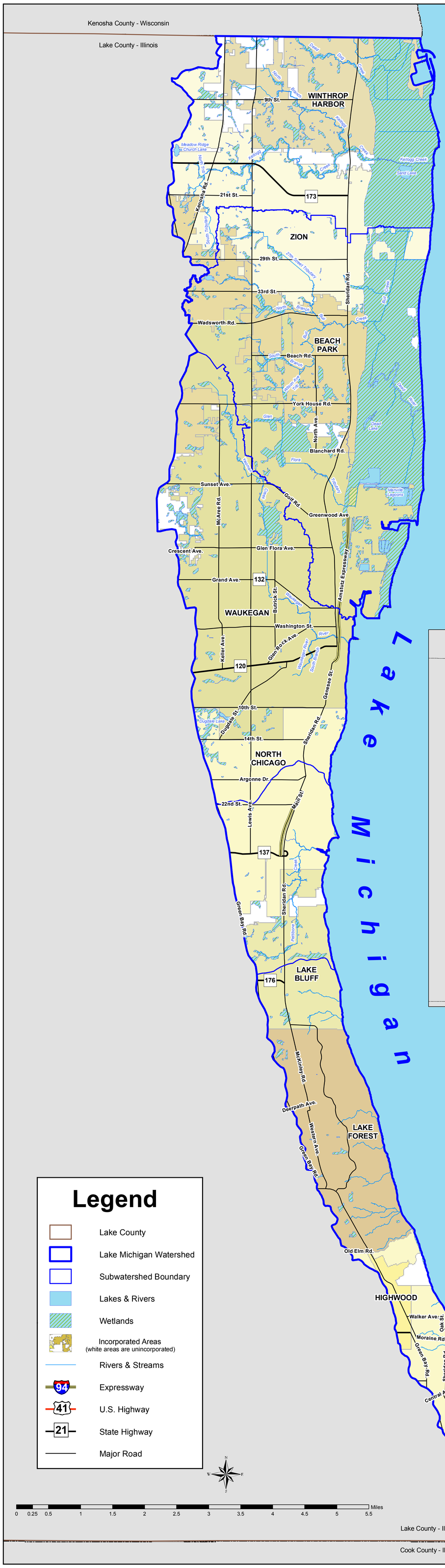
Pettibone Creek

Lake County, Illinois

Sub-Area Land Use and Curve Number Details

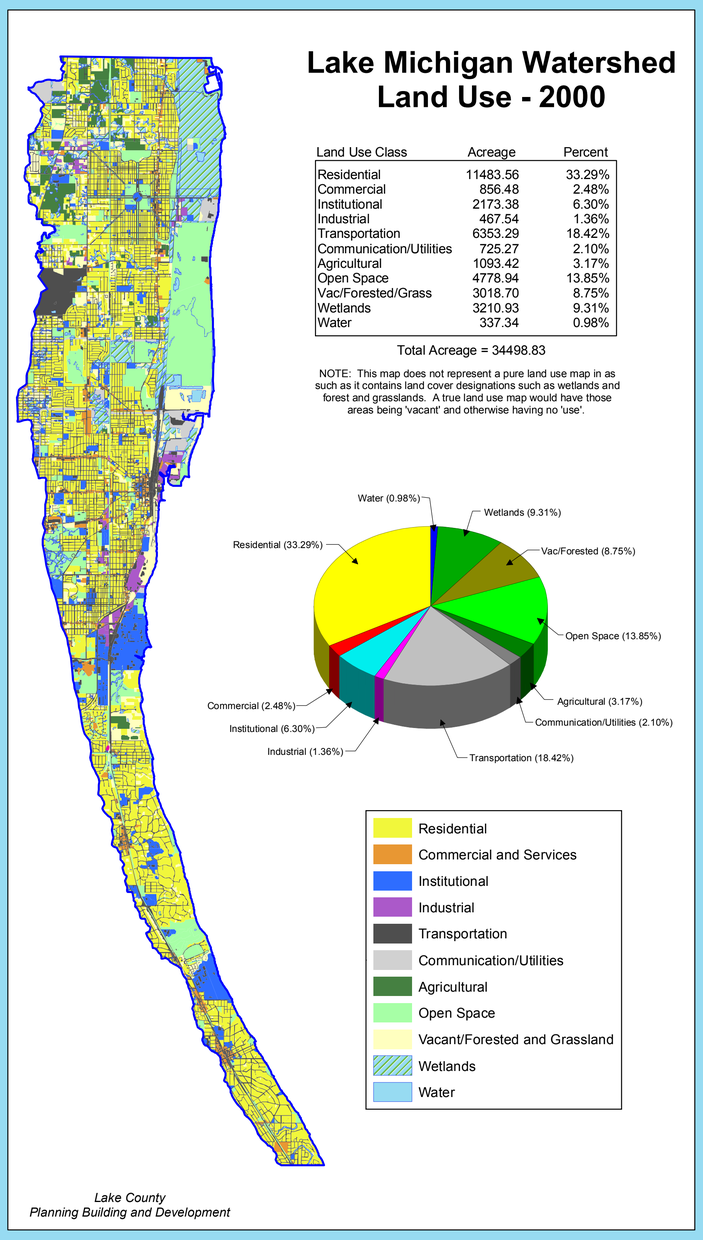
Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (mi^2)	Curve Number
DA 1	Open space; grass cover < 50%	(poor)	B	1.8	79
	Total Area / Weighted Curve Number			1.8	79
				===	==
DA 2	Open space; grass cover < 50%	(poor)	B	.73	79
	Total Area / Weighted Curve Number			.73	79
				===	==
DA 3	Open space; grass cover 50% to 75%	(fair)	B	2.81	69
	Total Area / Weighted Curve Number			2.81	69
				====	==

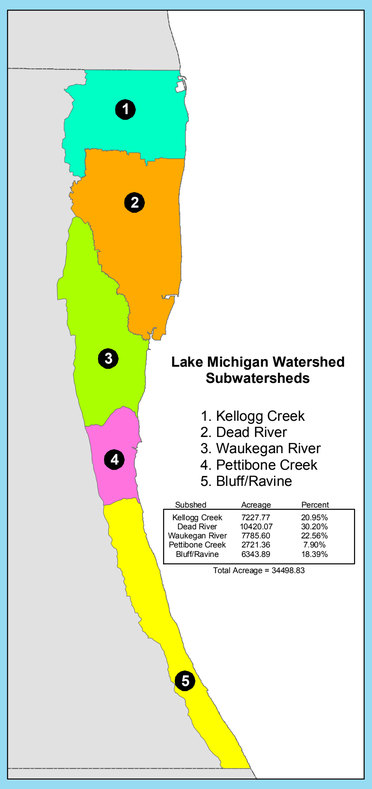
Lake Michigan Watershed
Lake County, Illinois

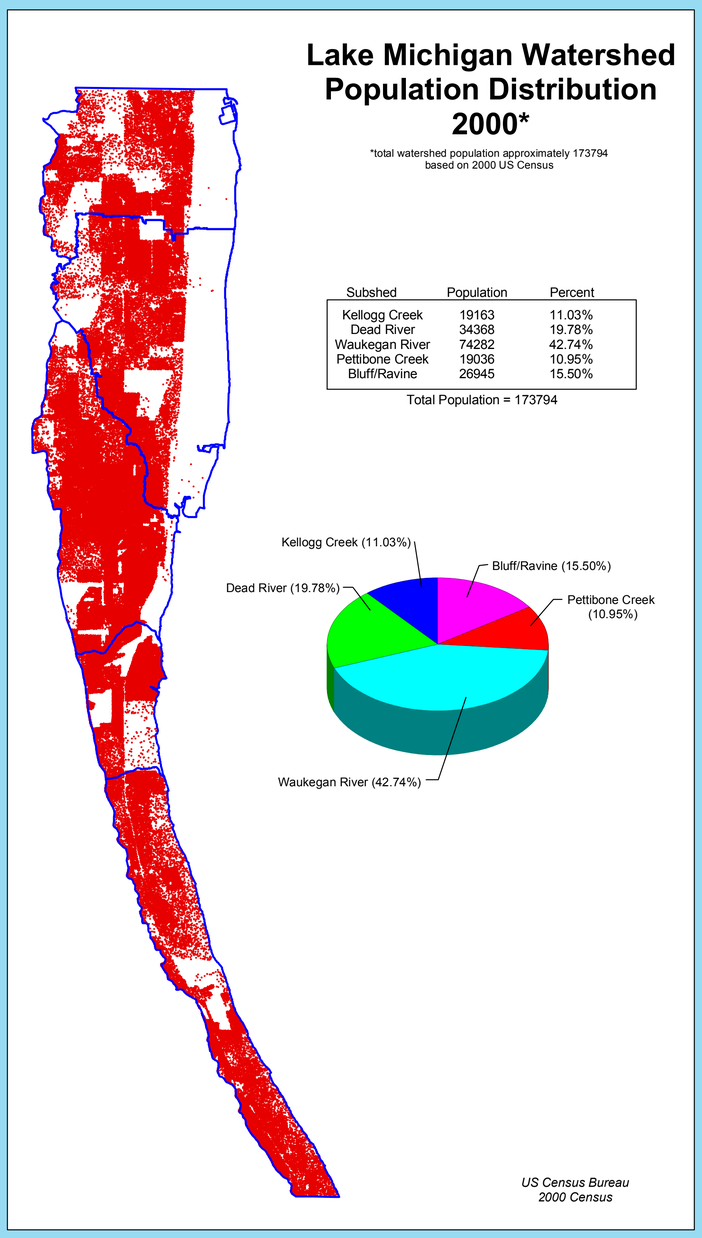


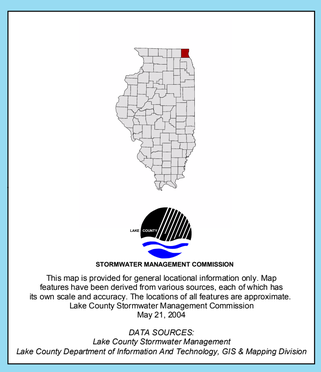
Legend

- Lake County
- Lake Michigan Watershed
- Subwatershed Boundary
- Lakes & Rivers
- Wetlands
- Incorporated Areas (white areas are unincorporated)
- Rivers & Streams
- Expressway
- U.S. Highway
- State Highway
- Major Road









K.2 ILLINOIS DEPARTMENT OF TRANSPORTATION FLOW CALCULATIONS

BY S.M.T. DATE 10/30/85 PROJECT Lake Front Highway SHEET NO 1 OF 10

CHKD. BY DPH DATE Nov 86 SUBJECT Pettibone Creek Tributary JOB NO

Flood Frequency Estimation (Revised D.A.)

1) $D.A. = 1093 \text{ AC} \approx 1.71 \text{ mi}^2$

$S = 41.74 \text{ ft/mile}$

$If = 37.5\%$

2)

$Q_{50} = 42.7 \; A^{0.664} \; S^{0.338} \; If^{0.186}$

$= (42.7)(1.71)^{0.664}(41.74)^{0.338}(37.5)^{0.186}$

$= (42.7)(1.428)(3.53)(1.862)$

$= \underline{\underline{422 \text{ cfs.}}}$ *

3) $Q_{100} = 48.0 \; A^{0.660} \; S^{0.349} \; If^{0.172}$

$= (48.0)(1.71)^{0.660}(41.74)^{0.349}(37.5)^{0.172}$

$= (48.0)(1.425)(3.578)(1.865)$

$= \underline{\underline{469 \text{ cfs}}}$ *

4) $Q_{500} = 60.5 \; A^{0.651} \; S^{0.366} \; If^{0.1[illegible]}$

$= (60.5)(1.71)^{0.651}(41.74)^{0.366}(37.5)^{[illegible]}$

$= (60.5)(1.418)(3.919)(1.691)$

$= \underline{\underline{569 \text{ cfs.}}}$

BY S.M.T DATE 10/28/85 PROJECT Lake Front Highway SHEET NO 2 OF 10

CHKD. BY ____ DATE ____ SUBJECT Pettibone Creek Tributary JOB NO ____

Drainage Area Estimation

1) Drainage Area Divide line was shown as in the U.S.G.S. Map.

Total Area was separated into 6 sub-area.

Area ① $\frac{1}{2}(1600' + 200') \times 5280' =$ 109 AC

Area ② $5280' \times 5280' =$ 640 AC

Area ③ $1100' \times 1320' =$ 33 AC

Area ④ $\frac{1}{2}(2000' + 1100') \times 2640' =$ 94 AC

Area ⑤ $\frac{1}{2}(6500' + 5500') \times 1300' =$ 178 AC

Area ⑥ $1700' \times 1000' =$ 39 AC

Total Area = **1093 AC** * ≃ **1.708 mi²**

2) Comp. with 3 7/8 in. structural plate pipe 150" ϕ / 1968 Bridge file

Drainage Area = 1350 ACres.

We will short 1350 − 1093 = 257 AC.

3) Drainage Area have been diverted into Waukegan Storm Sewer system per City Engineer.

(between Lewis Ave. & Green Bay Road & 14th St. & 9th St.)

$A = \frac{1}{2}(1800' + 2400') \times 700' + \frac{1}{2}(3300' + 4200') \times 3600'$

$= 34 + 224 = 258$ AC ≈ 257 AC ok

∴ the Drainage Area checked very close!

BY S.M.T DATE 10/29/85 PROJECT Lake Front Highway SHEET NO 3 OF 10

CHKD. BY ____ DATE ____ SUBJECT Pettibone Creek Tributary JOB NO ____

Slope of the main channel

1) Total length of the main channel from L.F. HWY ℄ to the watershed Divide was measured from U.S.G.S map.

$L_{Total} = 11300'$

2)

10% point = 1130' ⇒ Elev. = 631' (from Survey data)

85% point = 9605' ⇒ Elev. = 698' (U.S.G.S Map)

3) Slope of the main channel

$$S_o = \frac{698' - 631'}{9605' - 1130'}$$

$$= \frac{67'}{8475'}$$

$$= \frac{67'}{1.60 \text{ mile}}$$

$$= \underline{\underline{41.74 \text{ ft/mile}}} \ \ast$$

FA RTE 437
SEC. - - -
LAKE CO.
TRIB. PETTIBONE

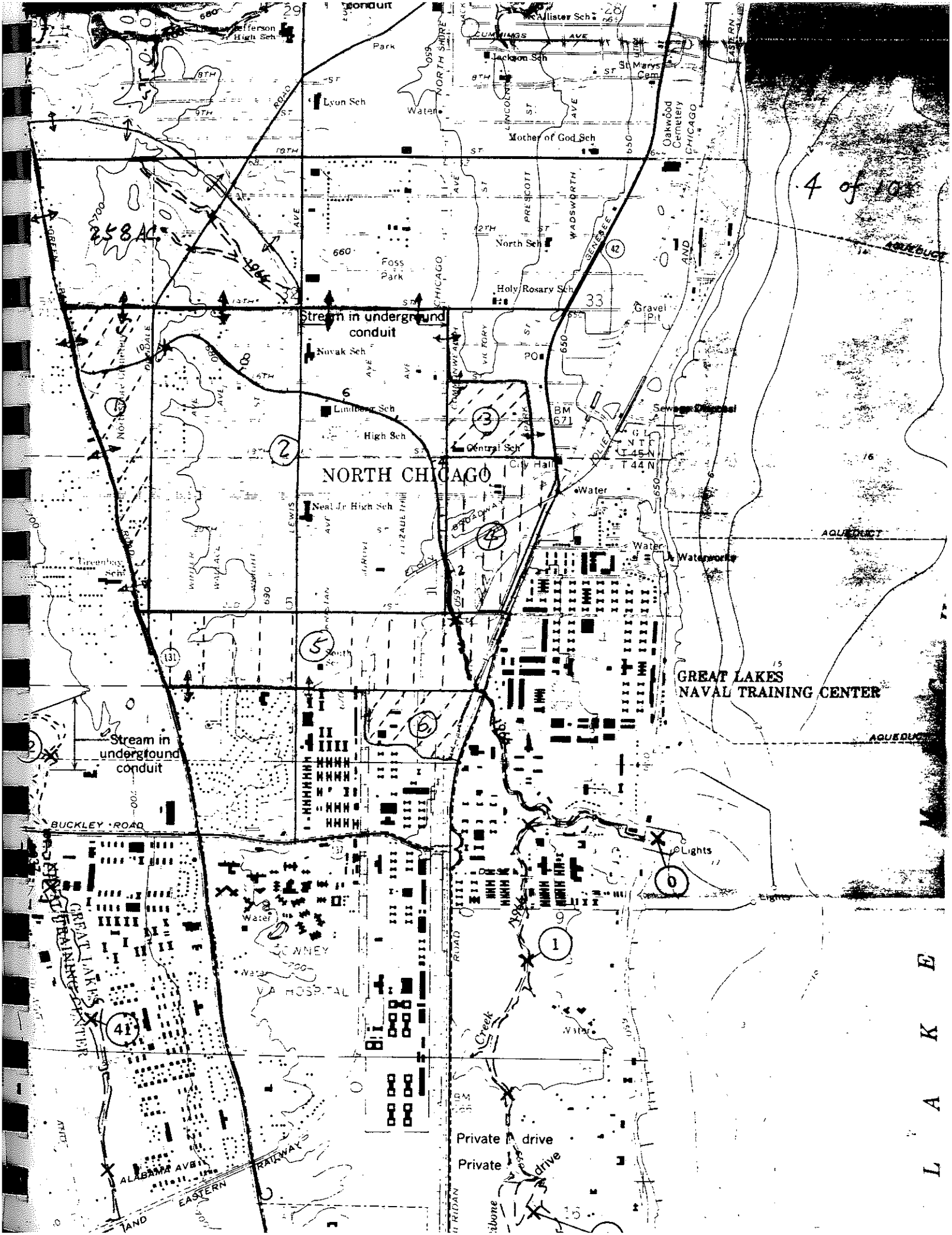
WATERWAY INFORMATION

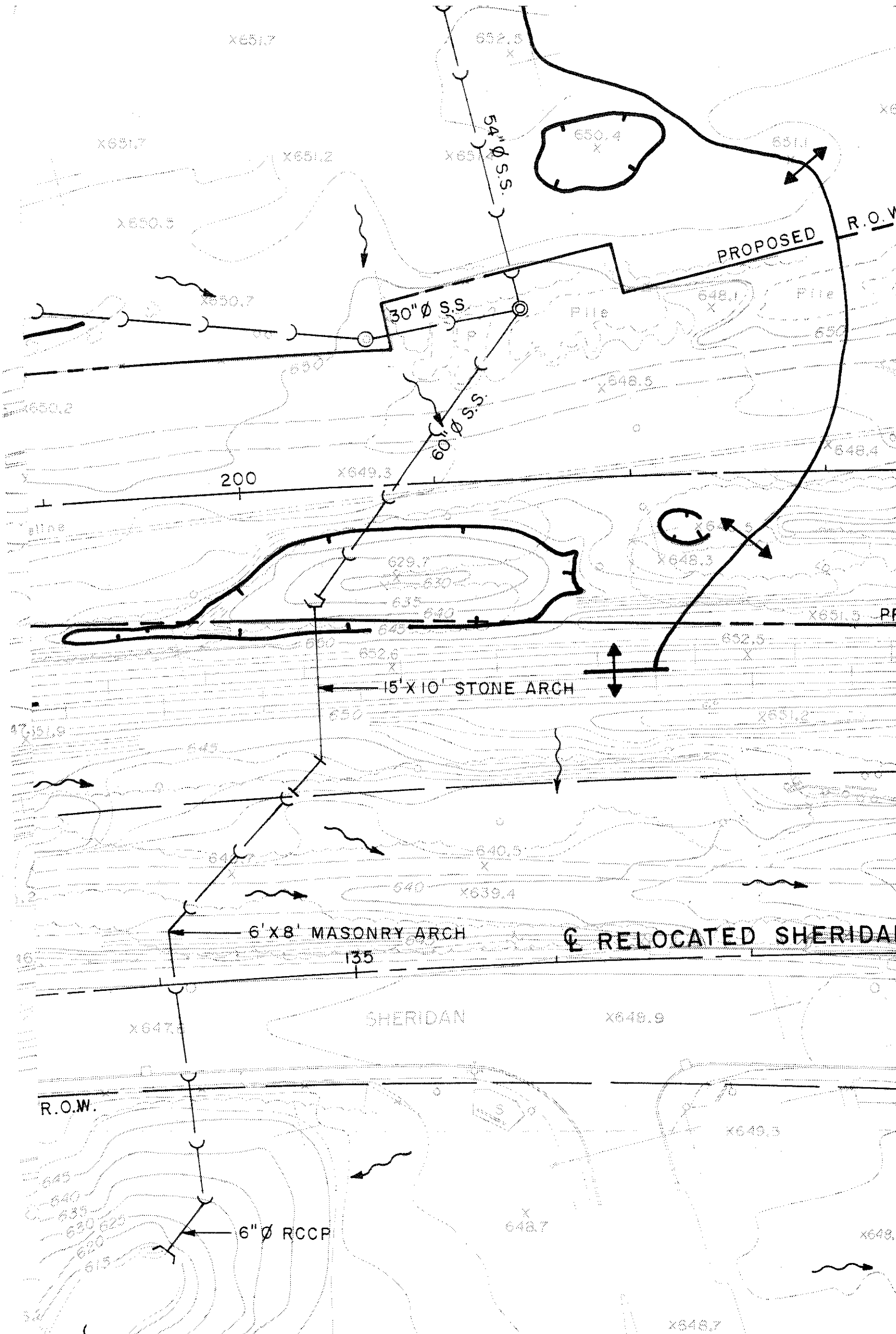
Drainage Area 1.71 sq. mi Low Grade Elev. 651.0 @ Sta. 204+00

Flood	Freq. Yr.	Q C.F.S.	Opening Sq. Ft. Exist.	Opening Sq. Ft. Prop.	Nat. H.W.E.	Head — Ft. Exist.	Head — Ft. Prop.	Headwater El. Exist.	Headwater El. Prop.
Design	50	422	24*	62**	624.3 / 626.4	10.2	1.0	634.5	627.4
Base	100	469	24*	64**	624.5 / 626.6	17.3	1.1	636.8	627.7
Overtopping									
Max. Calc.	500	569	24*	67**	624.9 / 627.0	17.4	1.4	642.3	628.4

* WATERWAY AREA AT MOST CONSTRICTED SECTION DOWNSTREAM (IN COVERED JUNCTION BOX STA. 3+30 ℄ ±). FOR THE PROPOSED CONDITION, THE 10×6 BOX BEGINNING AT STA. 3+50 ℄ ± WILL BE THE MOST CONSTRICTED SECTION.

** WATERWAY AREA FOR PROPOSED 10' DIAMETER PIPE BELOW NATURAL HIGH WATER AT UPSTREAM FACE.


4 of 10
258 AC
Stream in underground conduit
Stream in underground conduit
NORTH CHICAGO
GREAT LAKES NAVAL TRAINING CENTER
Private drive
Private drive
Jefferson High Sch
Lyon Sch
Mother of God Sch
Oakwood Cemetery
North Sch
Foss Park
Holy Rosary Sch
Gravel Pit
Novak Sch
Lindberg Sch
High Sch
Central Sch
City Hall
Sewage Disposal
Neal Jr High Sch
Waterworks
BUCKLEY ROAD
VA HOSPITAL
ALABAMA AVE
EASTERN RAILWAY
AQUEDUCT
LAKE


54" Ø S.S.
PROPOSED
R.O.W
30" Ø S.S.
60" Ø S.S.
200
15'X10' STONE ARCH
6'X8' MASONRY ARCH
135
℄ RELOCATED SHERIDAN
SHERIDAN
R.O.W.
6" Ø RCCP

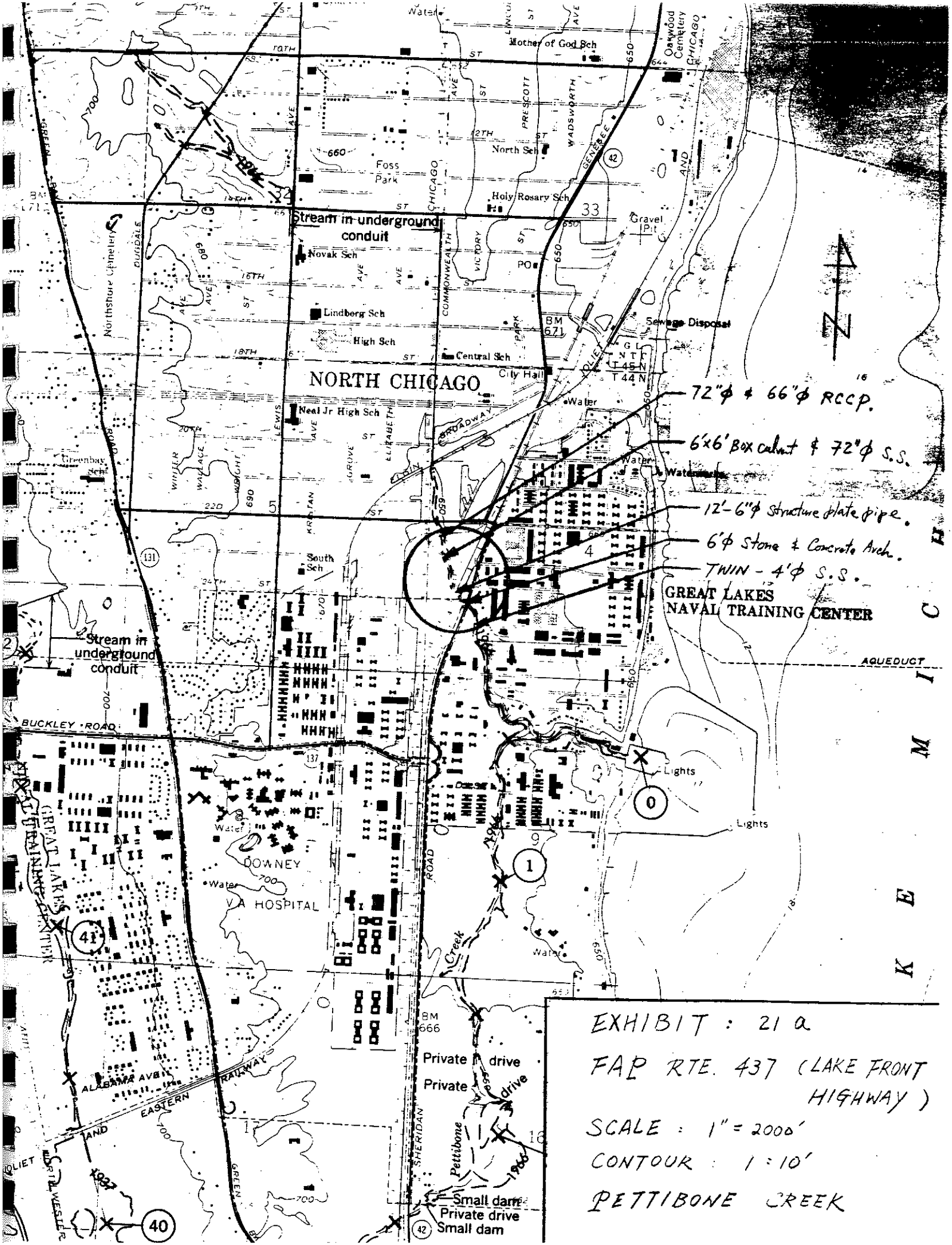


EXHIBIT : 21 a

FAP RTE. 437 (LAKE FRONT HIGHWAY)

SCALE : 1" = 2000'

CONTOUR : 1 : 10'

PETTIBONE CREEK

Rev. April, 1981

HYDRAULIC REPORT DATA SHEETS

FAP Route 437
Section
LAKE County

General Information

1. Name of stream PETTIBONE CREEK TRIBUTARY

2. Location of structure NW 1/4 of the SW 1/4, Section 4, Township 44 -- N, Range 12 -- E of the 3rd P.M.

Site Design Data

3. Drainage area upstream of bridge 1.71 (1) square miles.

4. Character of drainage area (for areas less than 10 sq. mi.): cultivated ____%, pasture ____%, timber 5 %, urbanized 95 %, other ____%.

5. Design frequency 50 years. Road design classification T-3.

6. Elevation of design frequency high water ____ feet.

7. Maximum known high water elevation 630 (2) feet. Date April 1966 (2).

8. Cause of maximum high water (headwater, backwater, etc.) Unknown.

9. Flow line elevation 617.2 (3) feet.

10. Approximate waterway area proposed below design high water ____ square feet.

11. Elevation of low point on proposed approach roadway 627.4 feet. Sta. 214+30. (Lake Front HWY N.B. Ramp)

12. Is any particularly valuable property located upstream within possible bridge backwater influence? NO Describe and list critical upstream flood elevation(s): ____

13. Will drift or ice permit pier in low flow channel? N.A.

14. Type of streambed soil Silty Gravel. Does it scour easily? None observed.

15. If bridge is proposed, supply abutment type: closed ____ open ____, skew ____. N.A.

16. If culvert is proposed, supply: type ____, length ____ feet, flow line slope ____%, entrance type ____, skew ____.

BD 1951

Figure 4-110.02a

17. Is necessity for separate overflow structure(s) indicated by field conditions? NO

18. Is reliable information available as to unconstricted water surface slope during some particular high water stage? NO . _____ Ft./1000 Ft.

Existing Structure Data

19. _____

Requested Data	Structure Upstream	Structure Near Site	Structure Downstream
Distance from proposed structure.....	740' u/s	32' D/s	110' D/s
Type of structure.....	6'x6' Box Culvert	12'-6"ϕ Structural plate pipe	6'ϕ Stone Arch
Low beam elevation (Top of Culvert).....	630.0 Ft.	629.7 Ft.	621.9 Ft.
Design Frequency.....	Yr.	Yr.	Yr.
Right angle waterway opening below design high water.....	Ft.^{2}	Ft.^{2}	Ft.^{2}
Maximum known high water elevation.....	632 (2) Ft.	630 (2) Ft.	630 (2) Ft.
Flow line elevation.....	624 (3) Ft.	617.2 (3) Ft.	615.9 (3) Ft.
Date of maximum high water.....	April 1966 (2)	April 1966 (2)	April 1966 (2)
Cause (backwater, headwater, etc.).....	Headwater	Backwater	Backwater
Does structure carry entire design flood flow?.....		yes	
If not, state kind and area of additional waterway.....			
	Ft.^{2}	Ft.^{2}	Ft.^{2}
Has detrimental scour occurred under or adjacent to the structure?.....	None observed	None Observed	None Observed
Apparent reason for scouring.....			

Required Additional Data

20. Information regarding high water from other streams, reservoirs, flood control projects, proposed channel changes, or other controls affecting proposed waterway area Navy Base Storm Sewer & Contour Map

5 channel checks Downstream (Navy Base)

BD 1951

Figure 4-110.02a - cont.

21. To be attached:

√a. Reproduction of applicable portion of USGS quadrangle sheet or map of equal detail showing locations of structures described in Item 19 and the proposed structure.

√b. Aerial photo of general site, showing alignment of proposed crossing.

√c. Sketch of waterway opening of existing structure(s) at site.

√d. Streambed profile extending 1,000 feet upstream and downstream from the proposed structure. Indicate profile plan location on map or photo.

√e. Existing and proposed roadway profile across floodplain.

√f. Three typical right angle channel cross sections including flood plain above elevation of design high water: (1) upstream, (2) at crossing, and (3) downstream, say 500 to 1,000-foot intervals. Manning's roughness coefficients, descriptions and boundaries are necessary within each section.

√g. A stream cross section immediately adjacent and parallel to the roadway taken across the full width of the floodplain.

h. If field conditions indicate that channel change is necessary, indicate location, cross section and gradient.

√i. If available, map showing 1 or 2-foot contour intervals, stream meanders, vegetation and manmade improvements.

22. Site inspection made by: S M Tony of H W Lochner, INC.

Report prepared by: S M Tony, H W Lochner, INC.

Remarks: (1) Interpolated from HA-234

(2) from HA-234 Estimation.

(3) Survey by H W Lochner, INC. Dated Oct. 1985

BD 1951

Figure 4-110.02a - cont.

APPENDIX L

HEC-RAS ANALYSIS - POST CONSTRUCTION FLOWS

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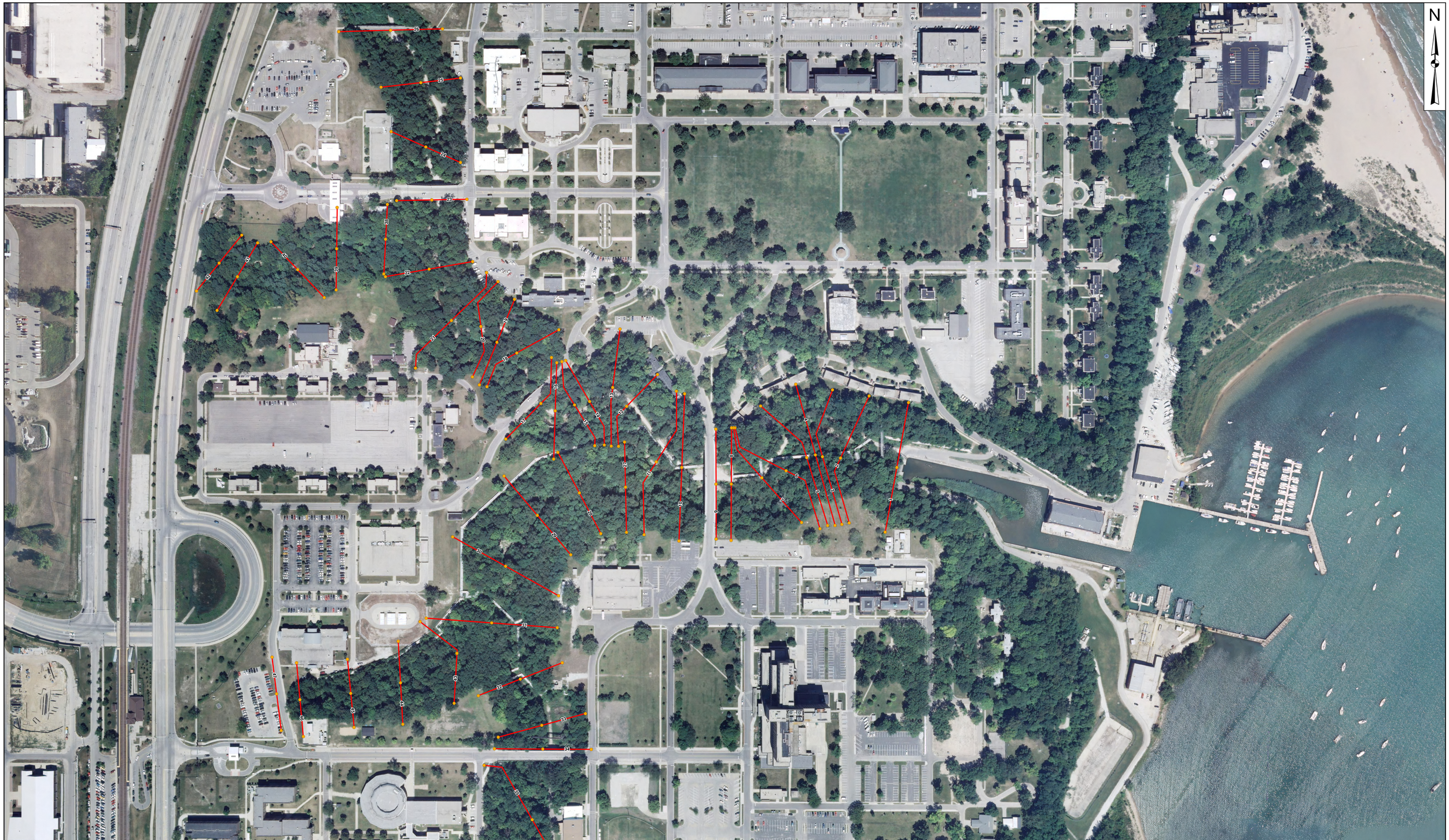


DRAWN BY	DATE
T. WHEATON	03/31/11
CHECKED BY	DATE
B. SMITH	03/31/11
REVISED BY	DATE

SCALE
AS NOTED

NAVFAC

CROSS SECTION LOCATIONS
NS GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. FIGURE 1	REV 0

PGH P:\GIS\GREATLAKES_NS\MAPDOCS\MXD\CROSS_SECTION_LOCATIONS_SOUTH.MXD 03/31/11 TW

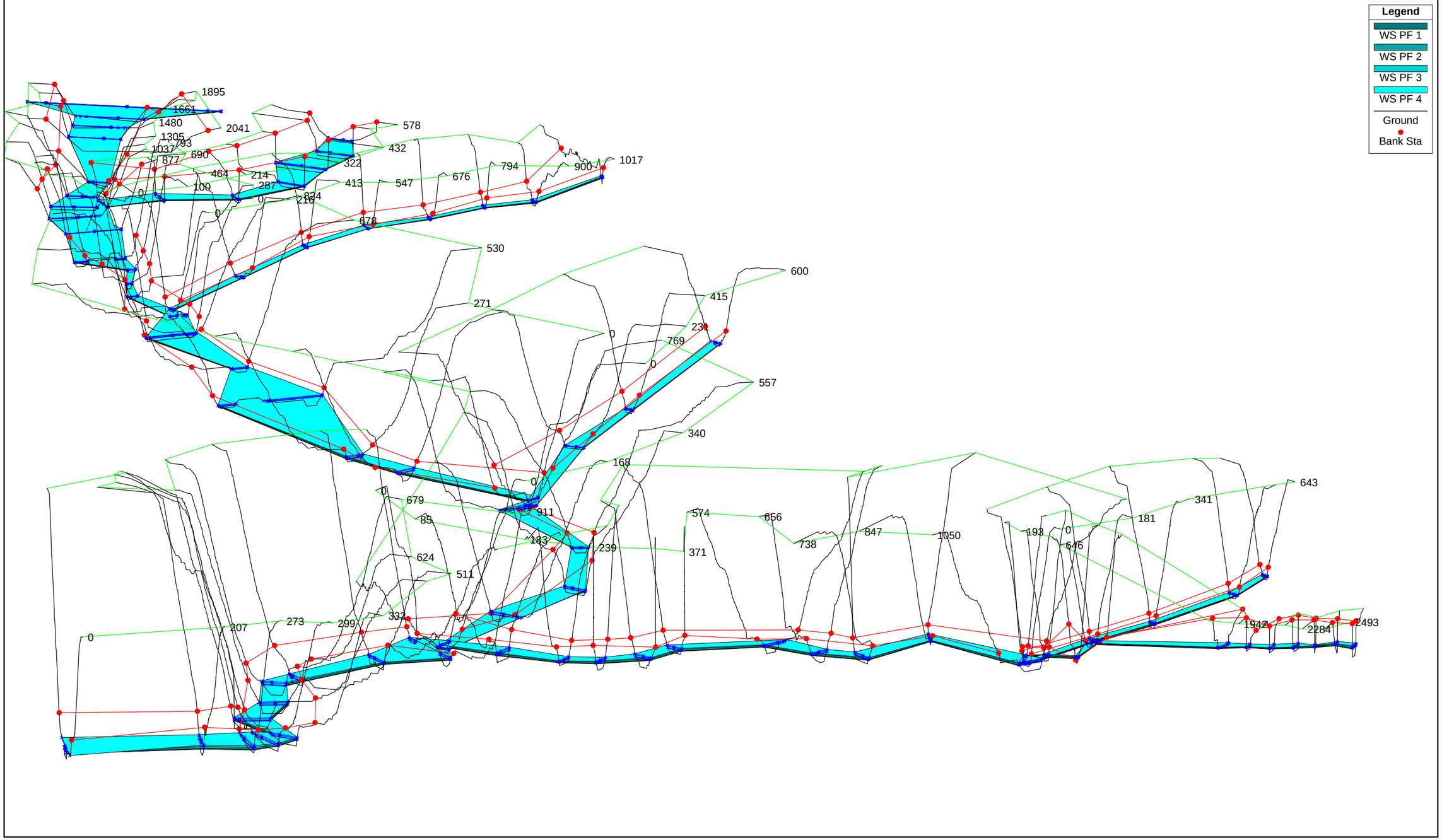
DRAWN BY	DATE
T. WHEATON	03/31/11
CHECKED BY	DATE
B. SMITH	03/31/11
REVISED BY	DATE
SCALE	
AS NOTED	

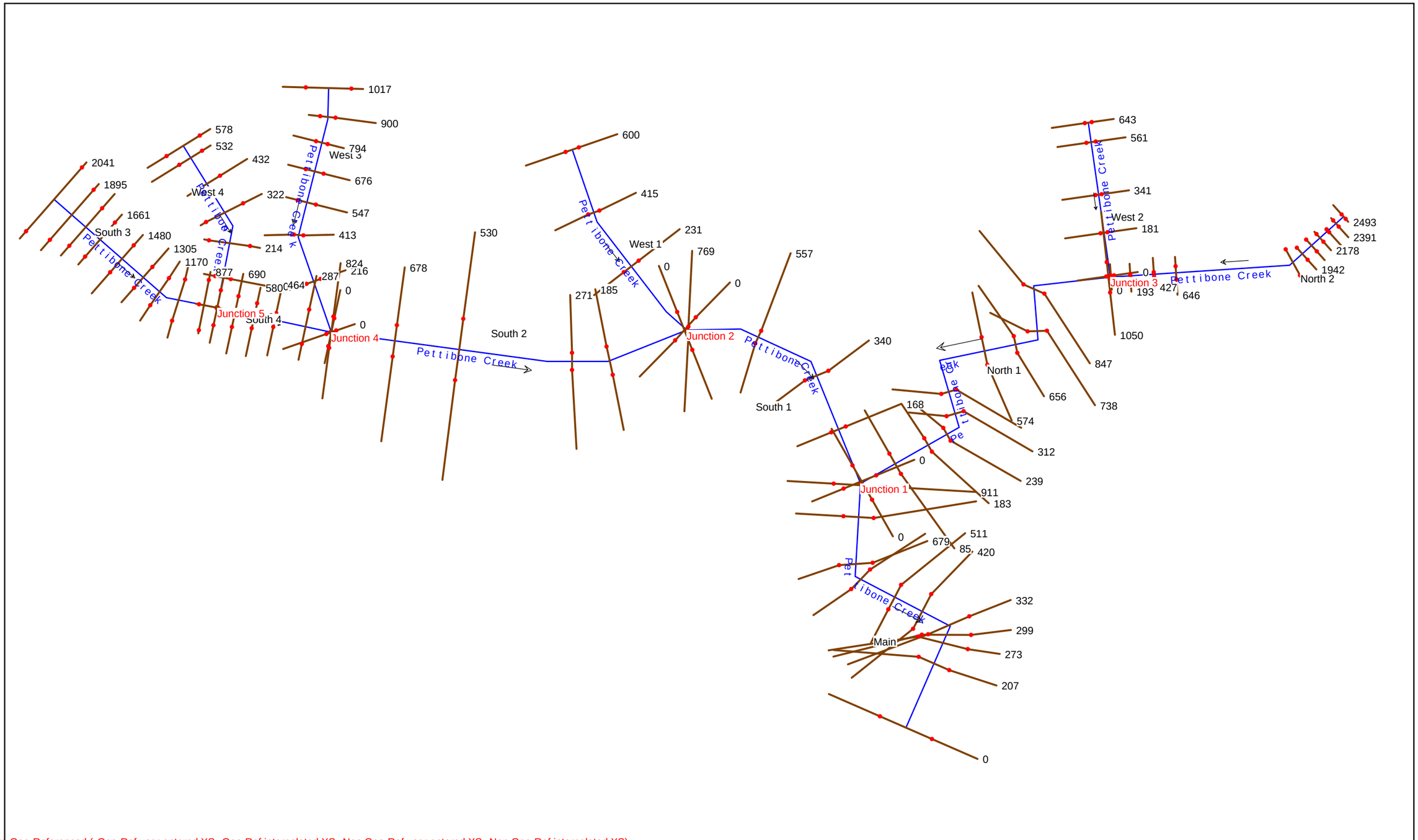
NAVFAC

CROSS SECTION LOCATIONS
SOUTHERN AREAS
NS GREAT LAKES
GREAT LAKES, ILLINOIS

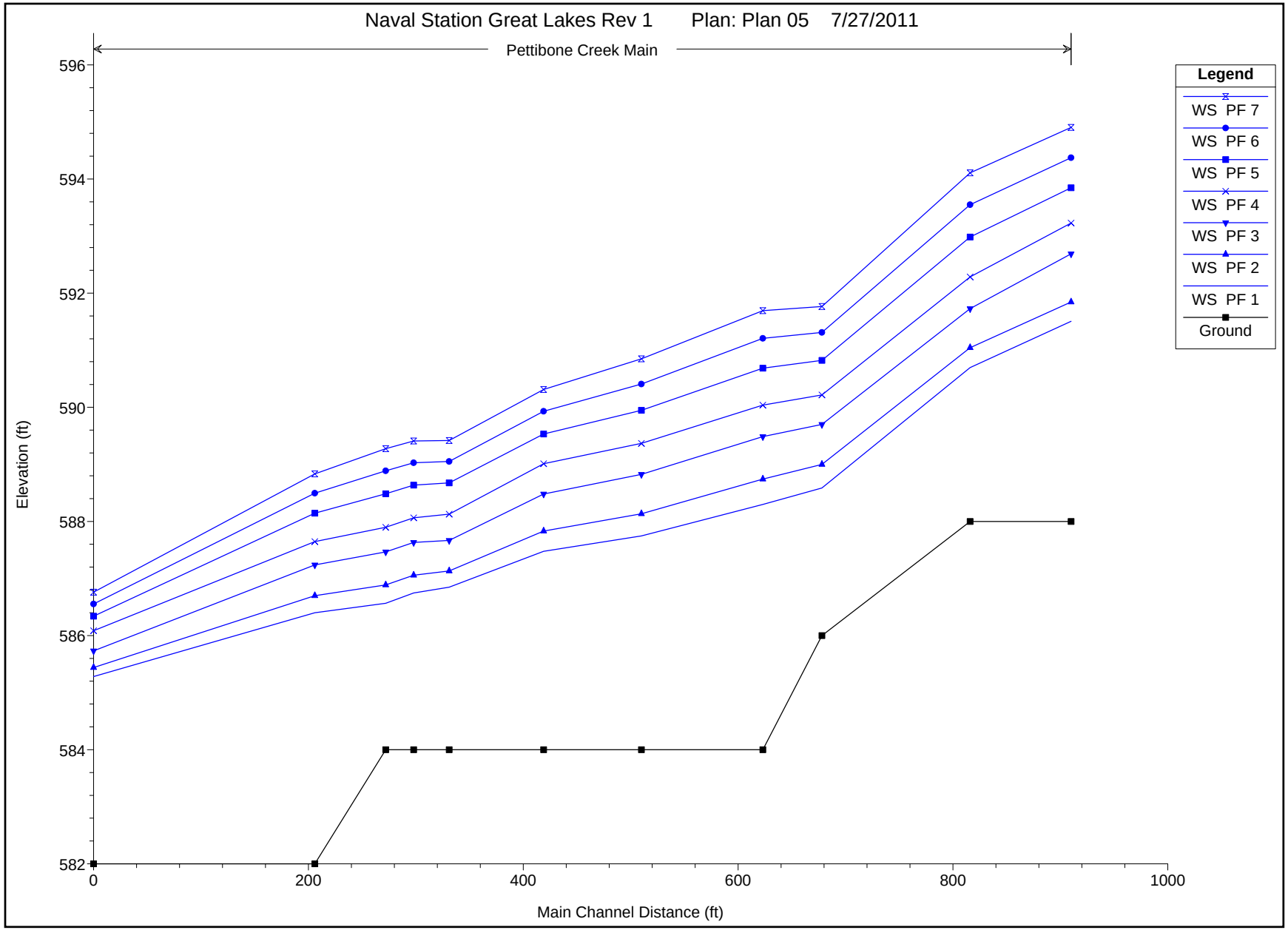
CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. FIGURE 2	REV 0

Naval Station Great Lakes Rev 2 Plan: Plan 06 3/30/2012





None of the XS's are Geo-Referenced (• Geo-Ref user entered XS • Geo-Ref interpolated XS • Non Geo-Ref user entered XS • Non Geo-Ref interpolated XS)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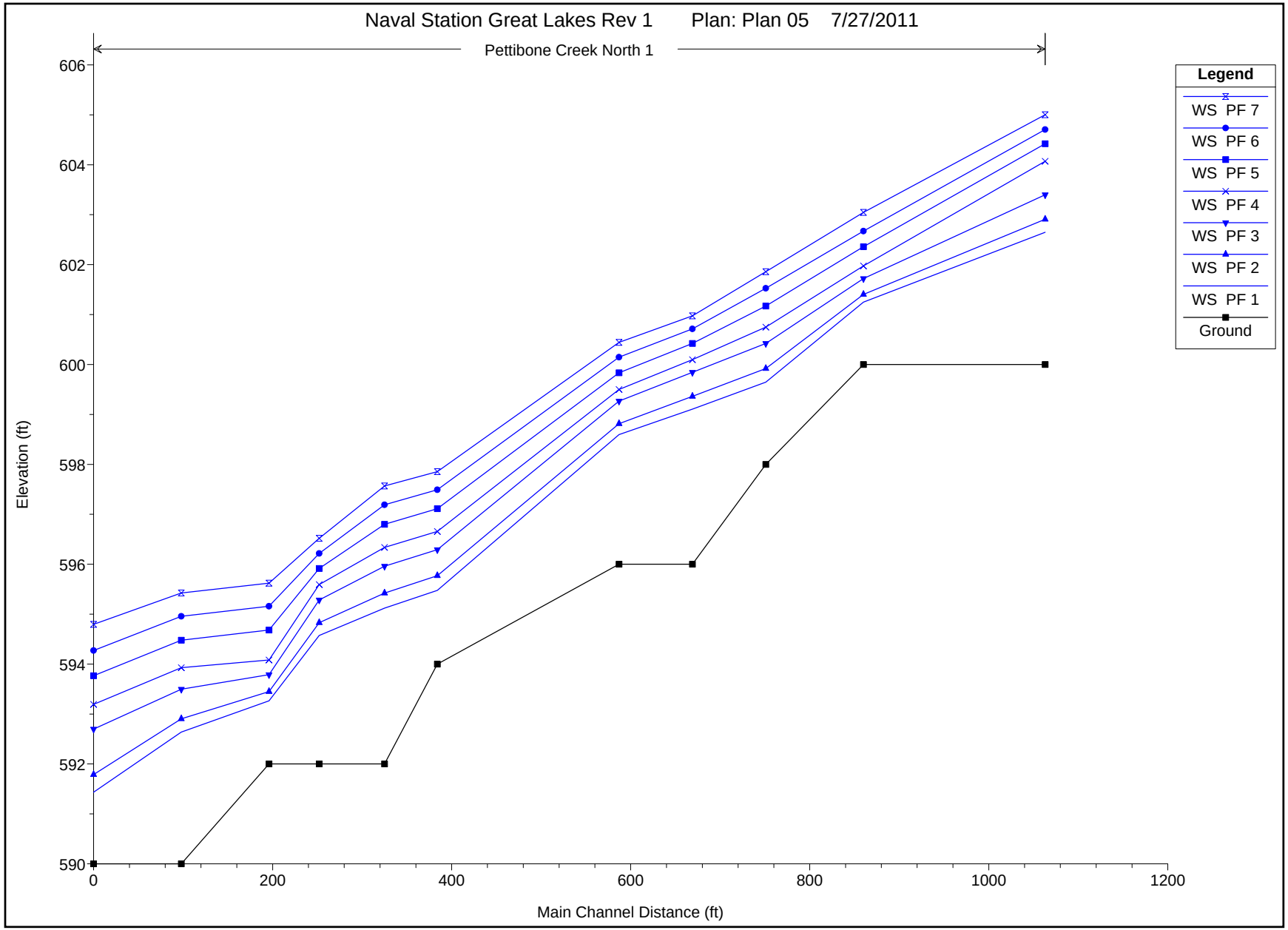
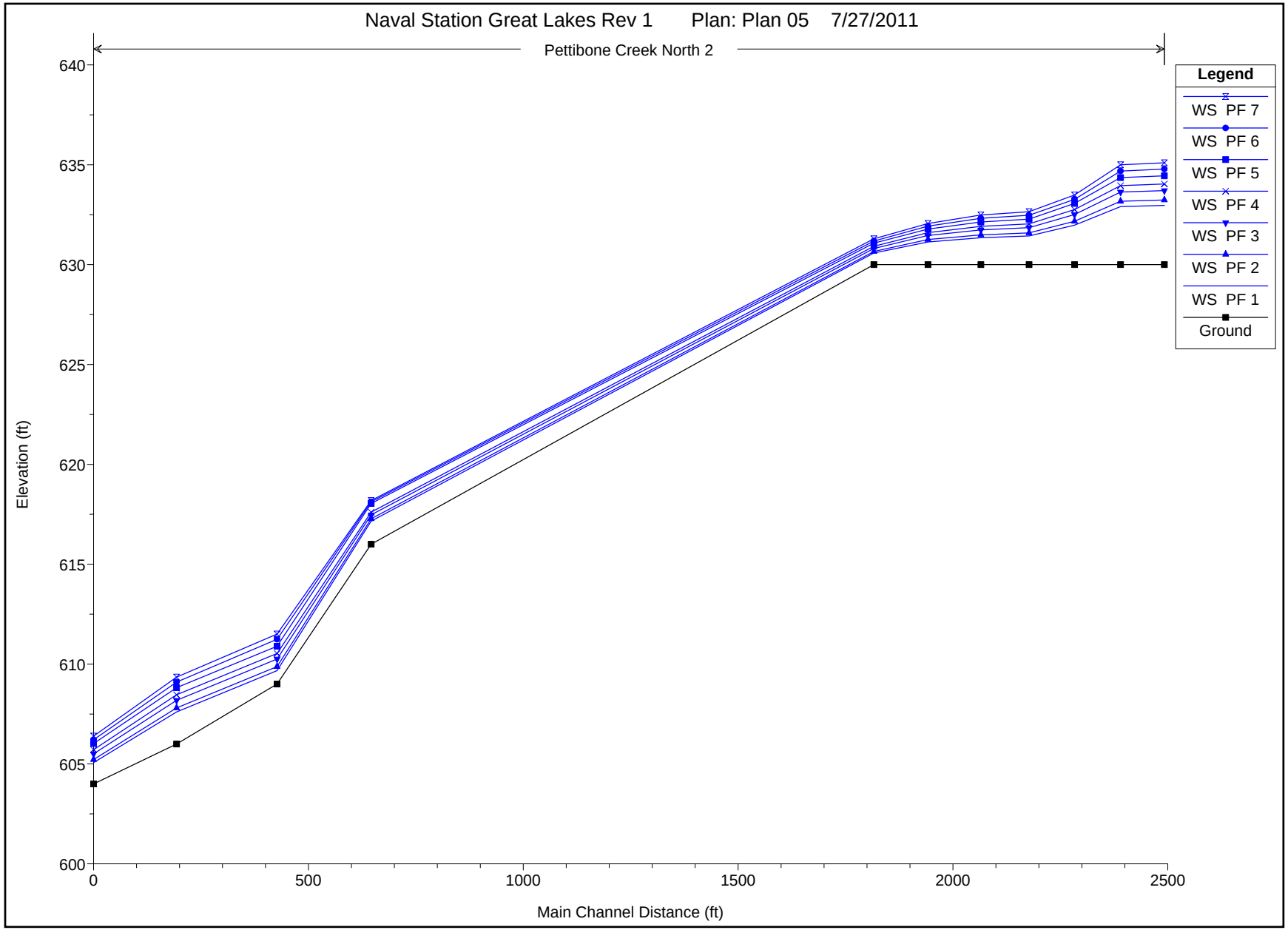
Pettibone Creek Main
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Elevation (ft)
596
594
592
590
588
586
584
582
0
200
400
600
800
1000
Main Channel Distance (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
Pettibone Creek North 1
Elevation (ft)
606
604
602
600
598
596
594
592
590
0
200
400
600
800
1000
1200
Main Channel Distance (ft)
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
Pettibone Creek North 2
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Elevation (ft)
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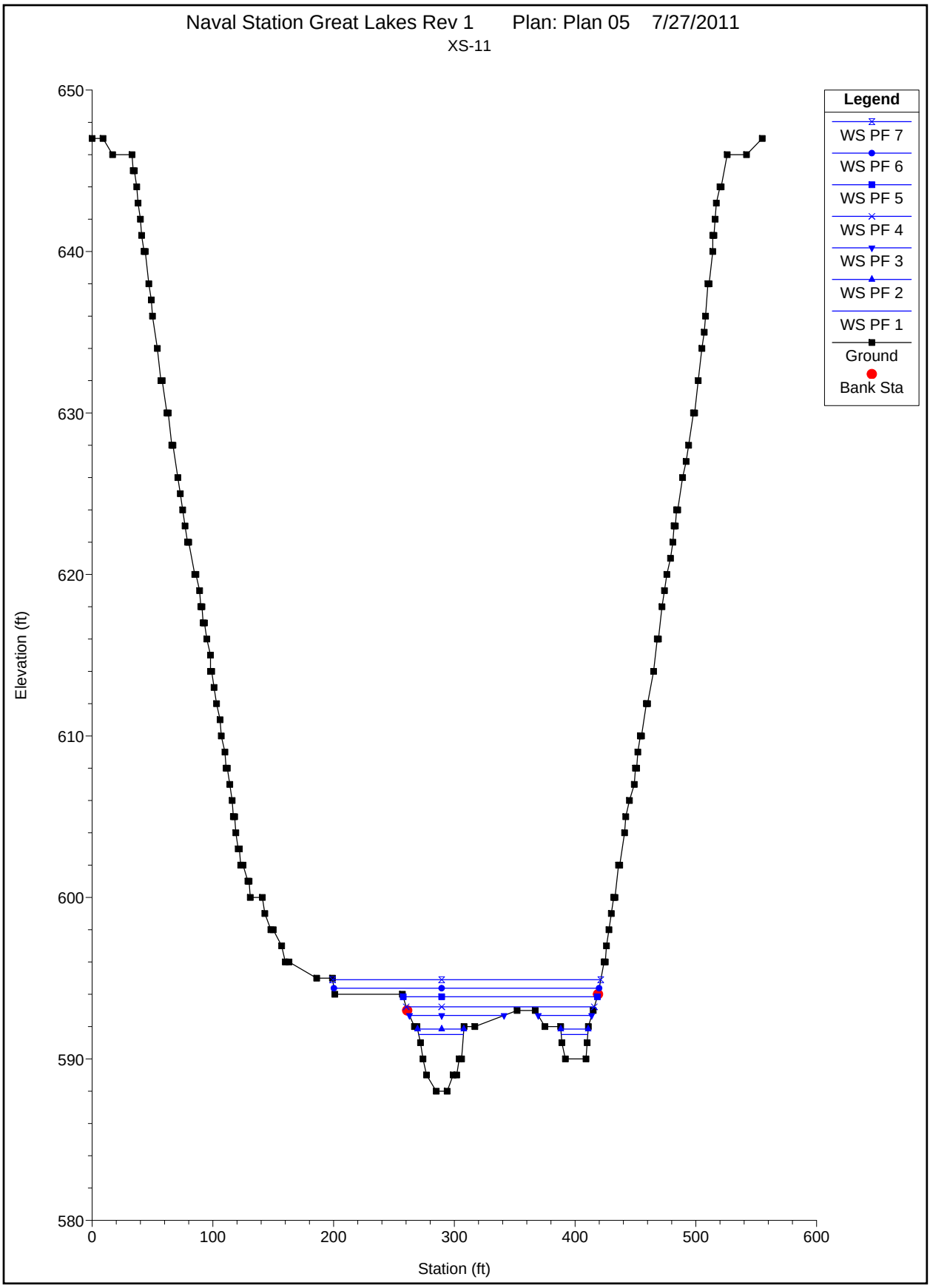
635
630
625
620
615
610
605
600
0
500
1000
1500
2000
2500
Main Channel Distance (ft)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XS-11
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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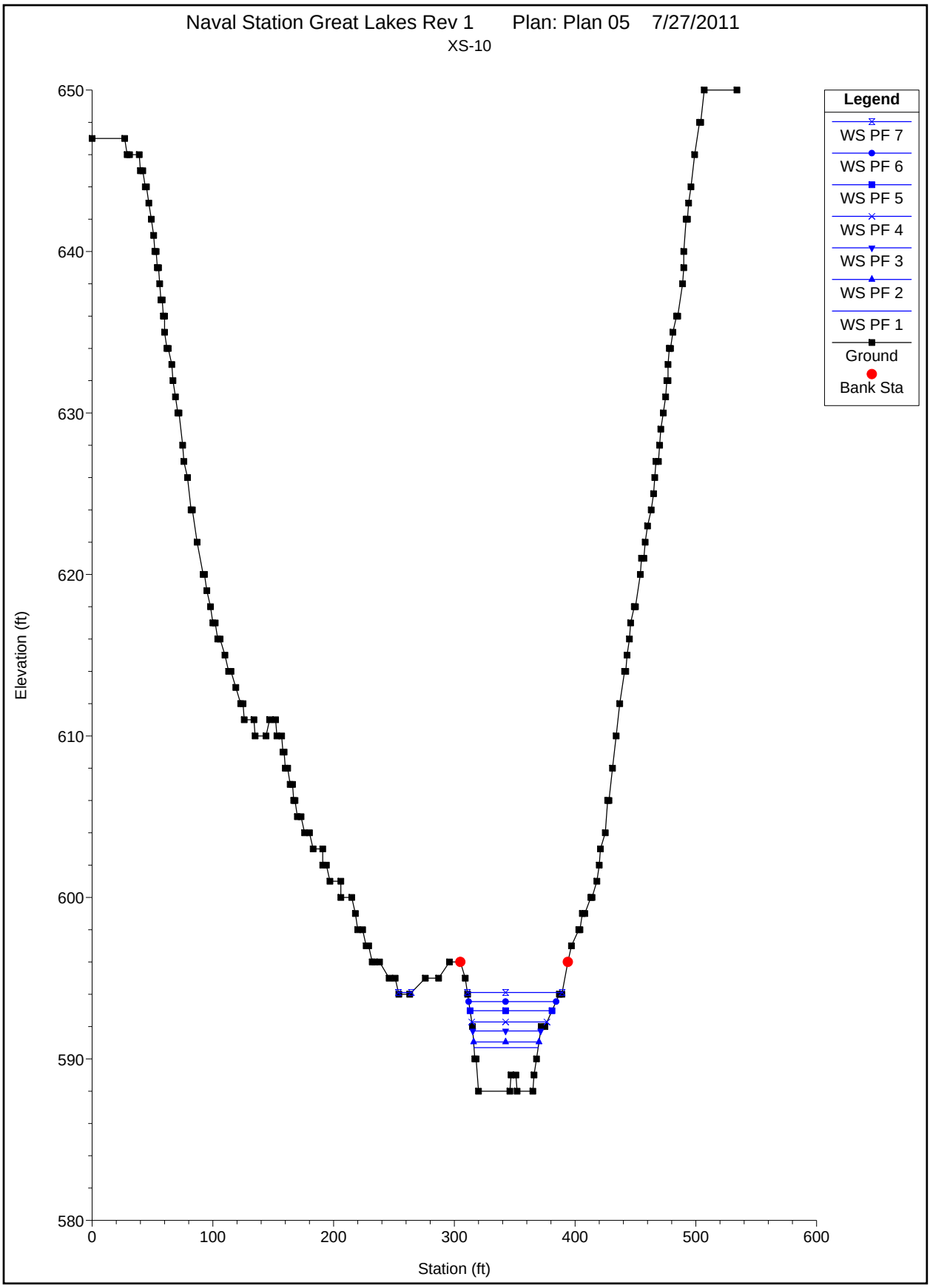
640
630
620
610
600
590
580
0
100
200
300
400
500
600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WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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640
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620
610
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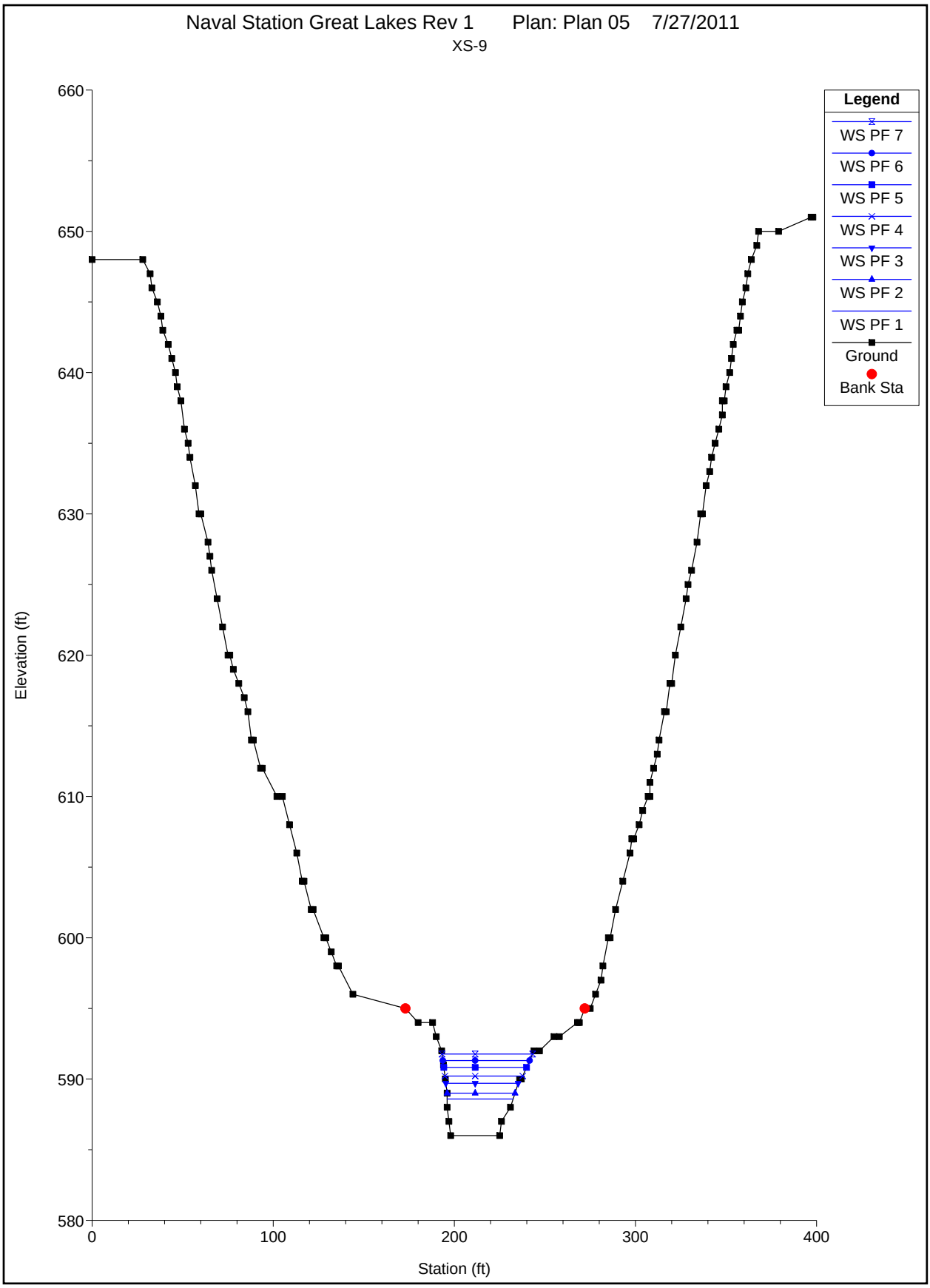
0
100
200
300
400
500
600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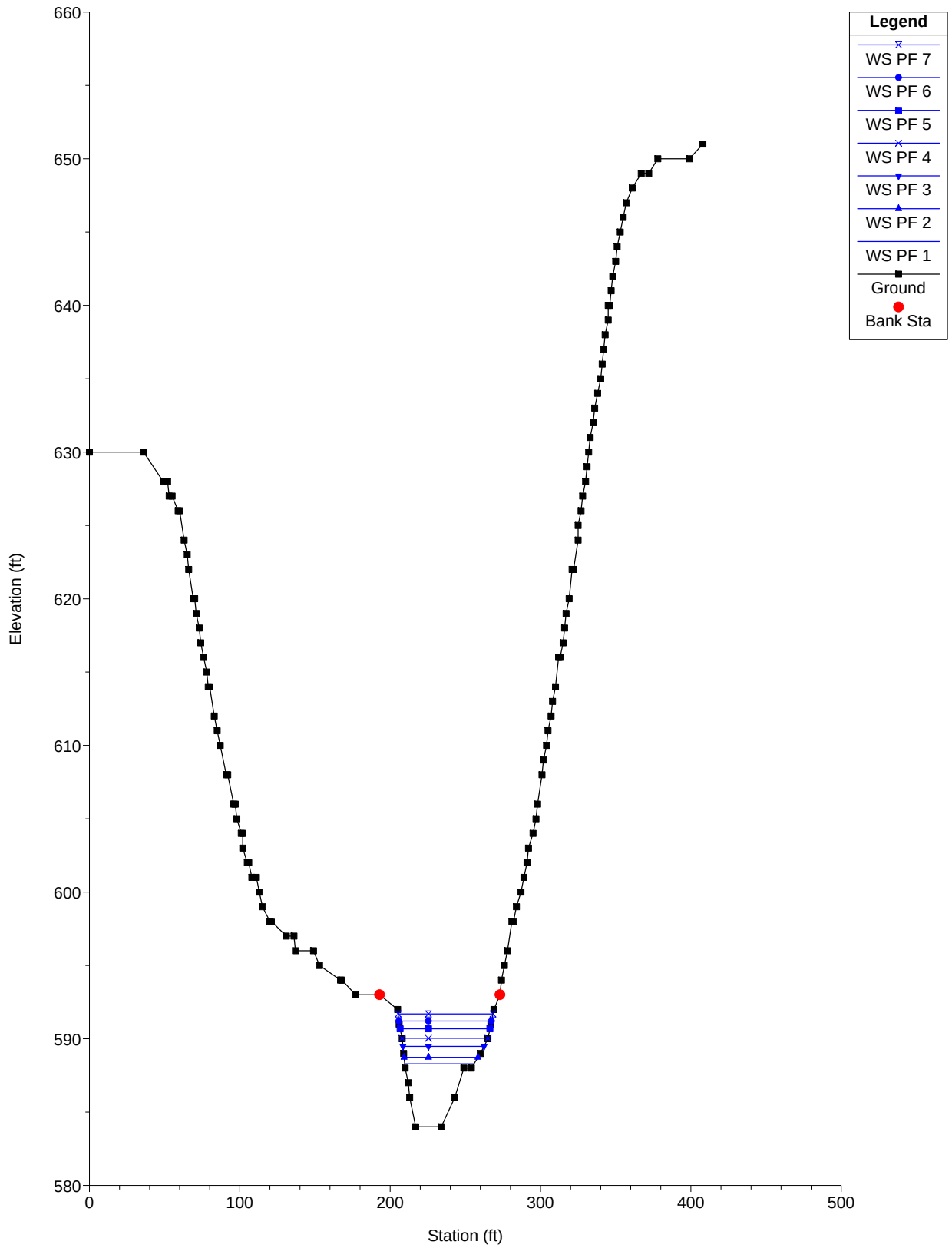
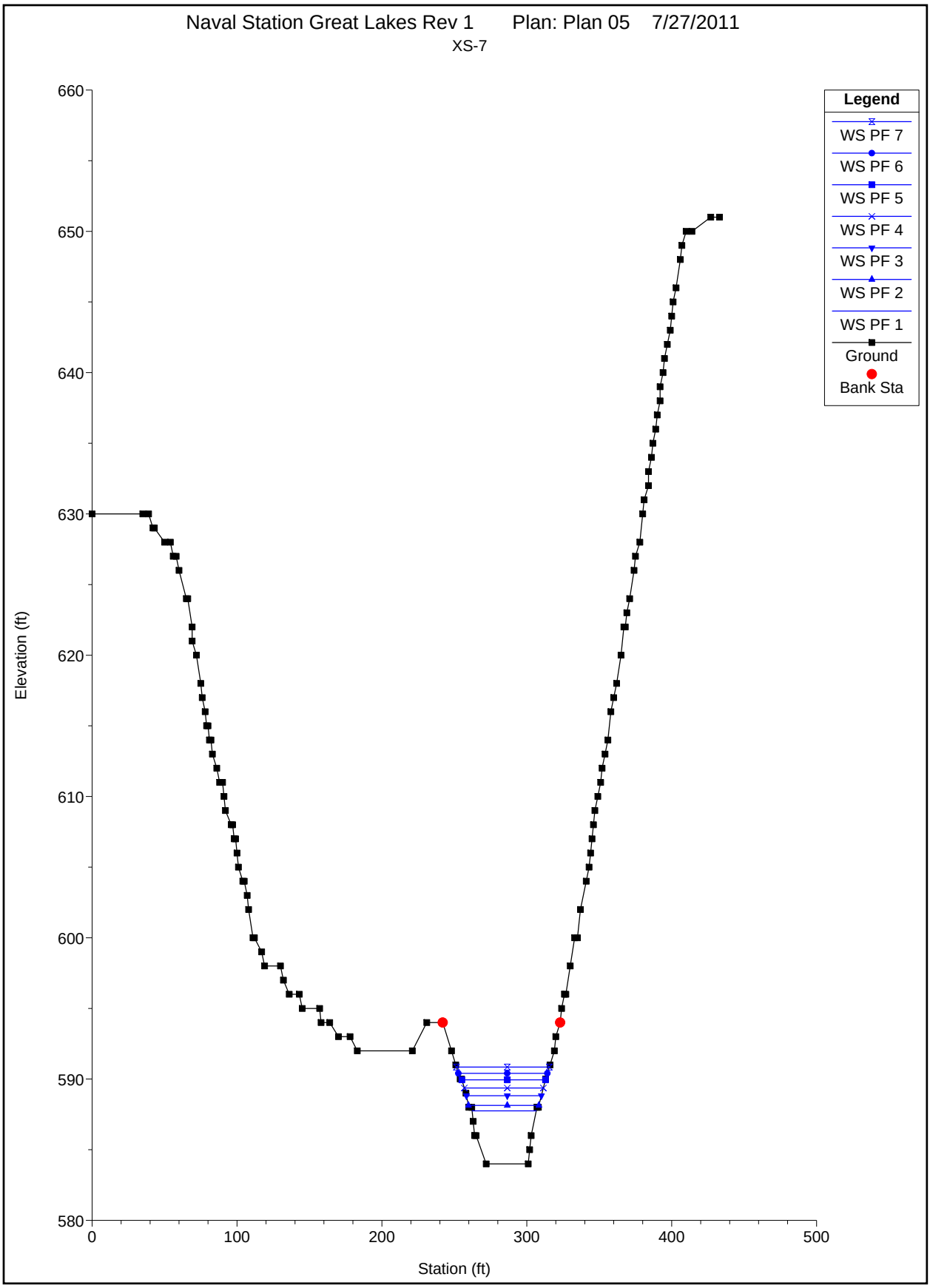
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
660
650
640
630
620
610
600
590
580
0
100
200
300
400

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

XS-8

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XS-7
Legend
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WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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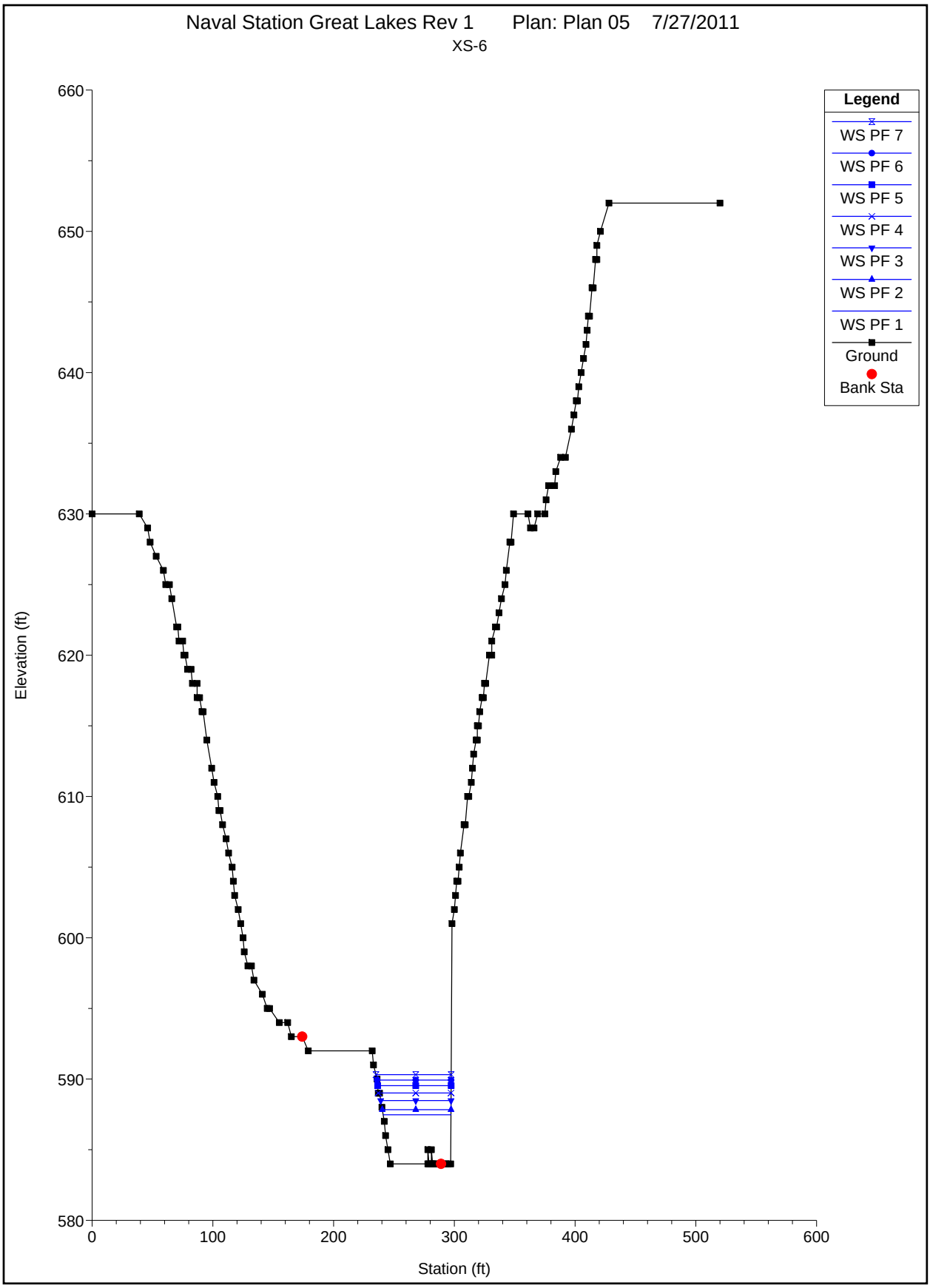
650
640
630
620
610
600
590
580
0
100
200
300
400
500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Legend
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WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
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Station (ft)
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650
640
630
620
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590
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100
200
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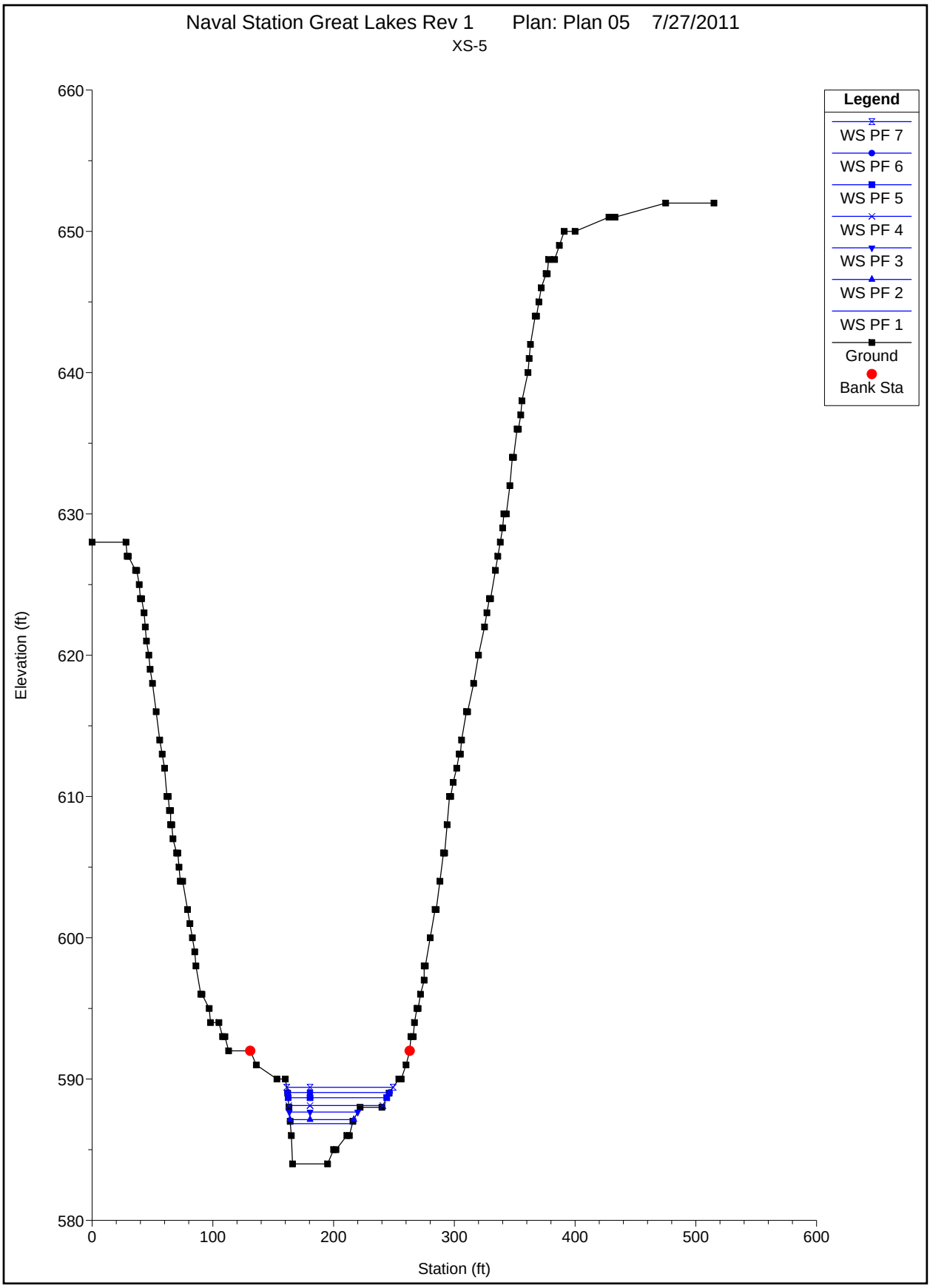
400
500
600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WS PF 2
WS PF 1
Ground
Bank Sta
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Station (ft)
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650
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100
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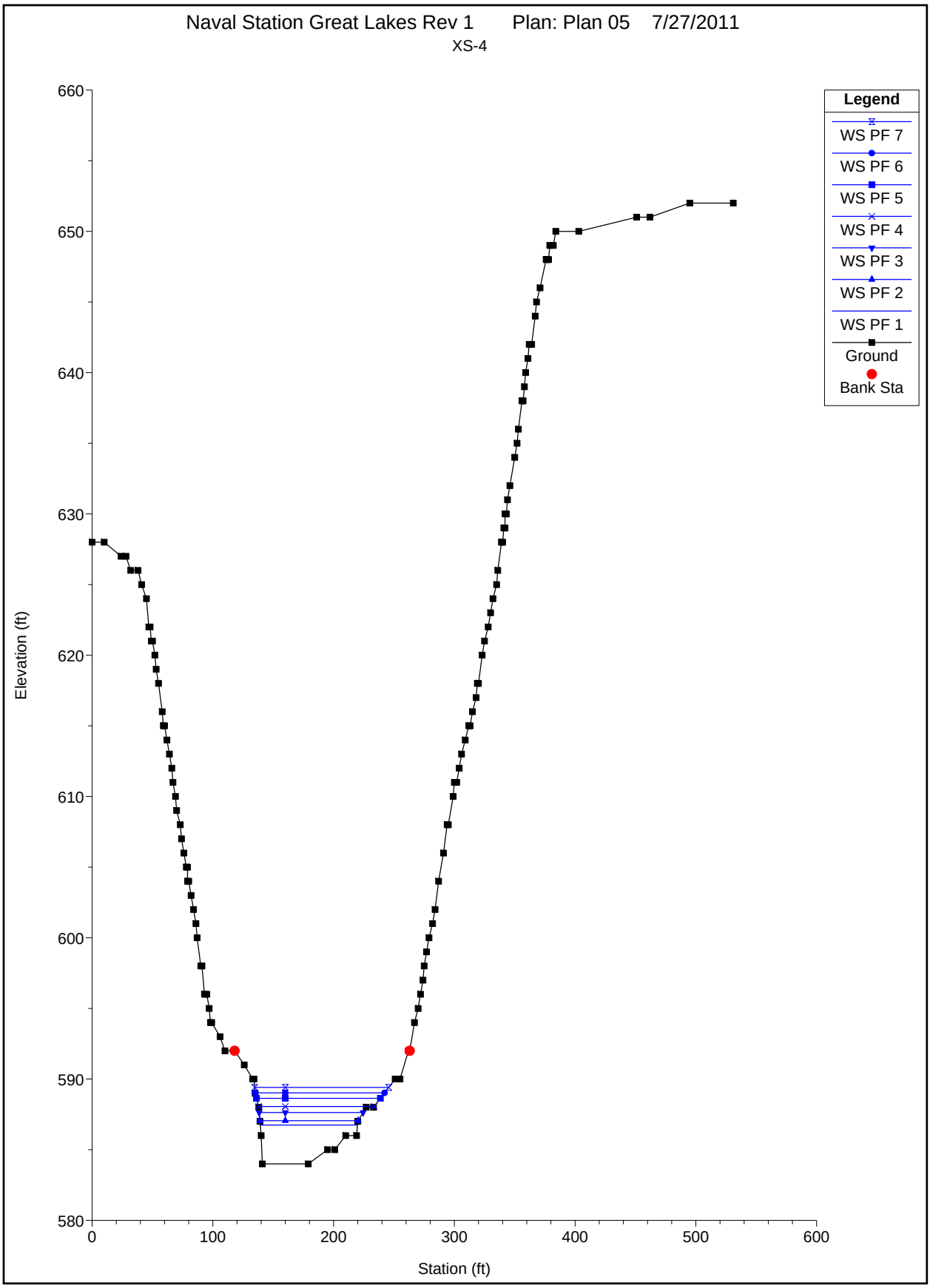
400
500
600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WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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650
640
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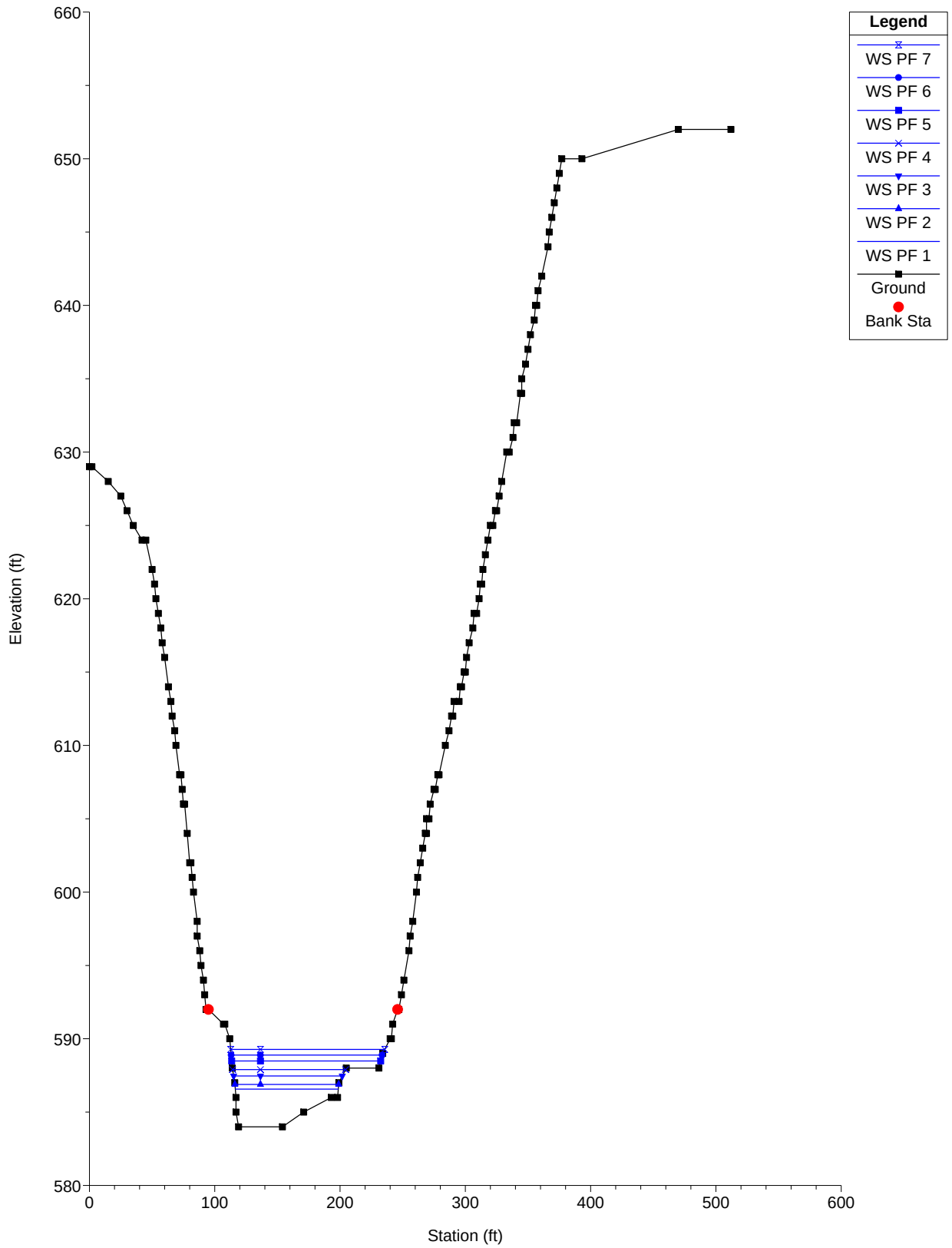
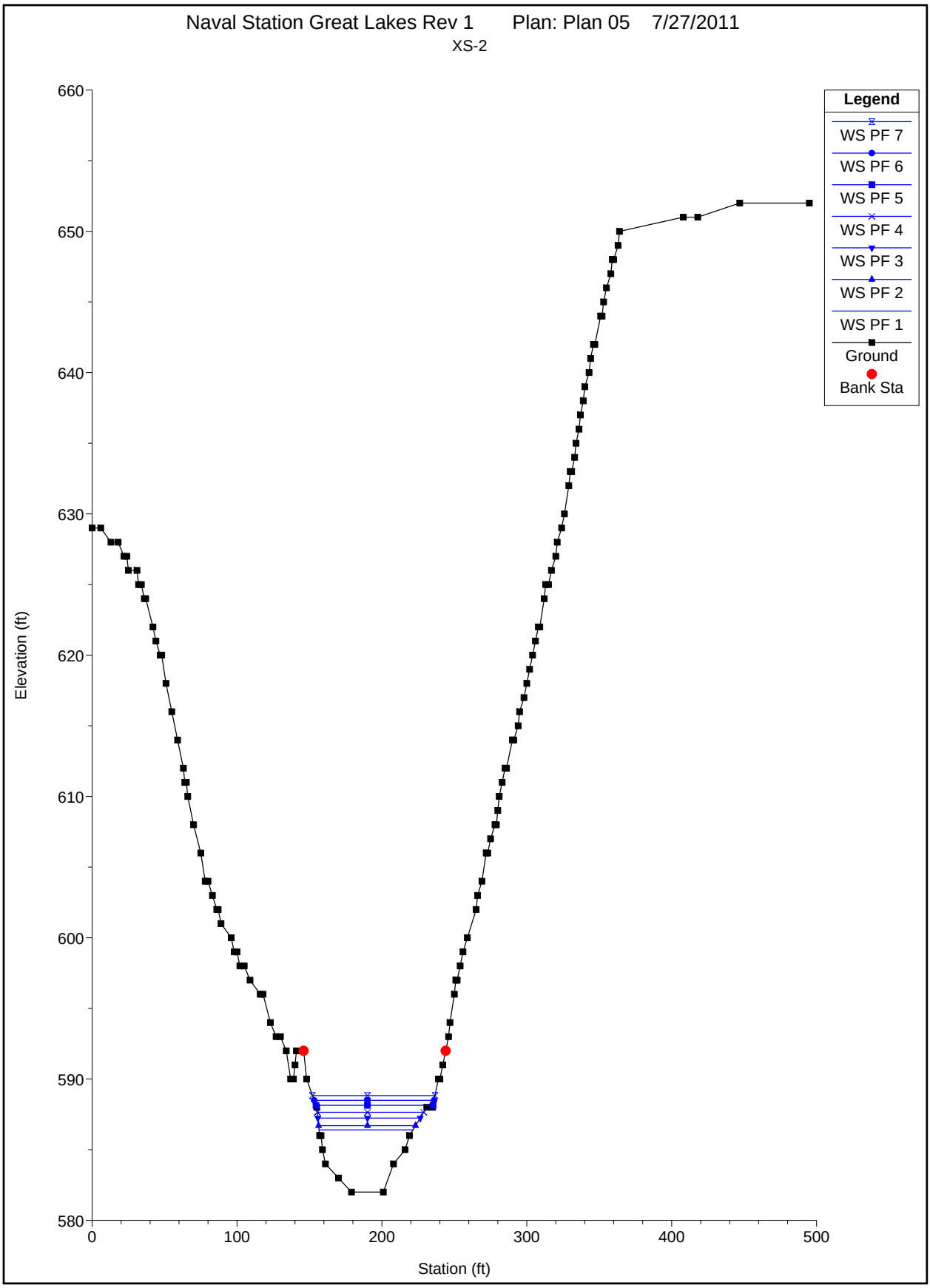
590
580
0
100
200
300
400
500
600

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

XS-3

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XS-2
Legend
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WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
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200
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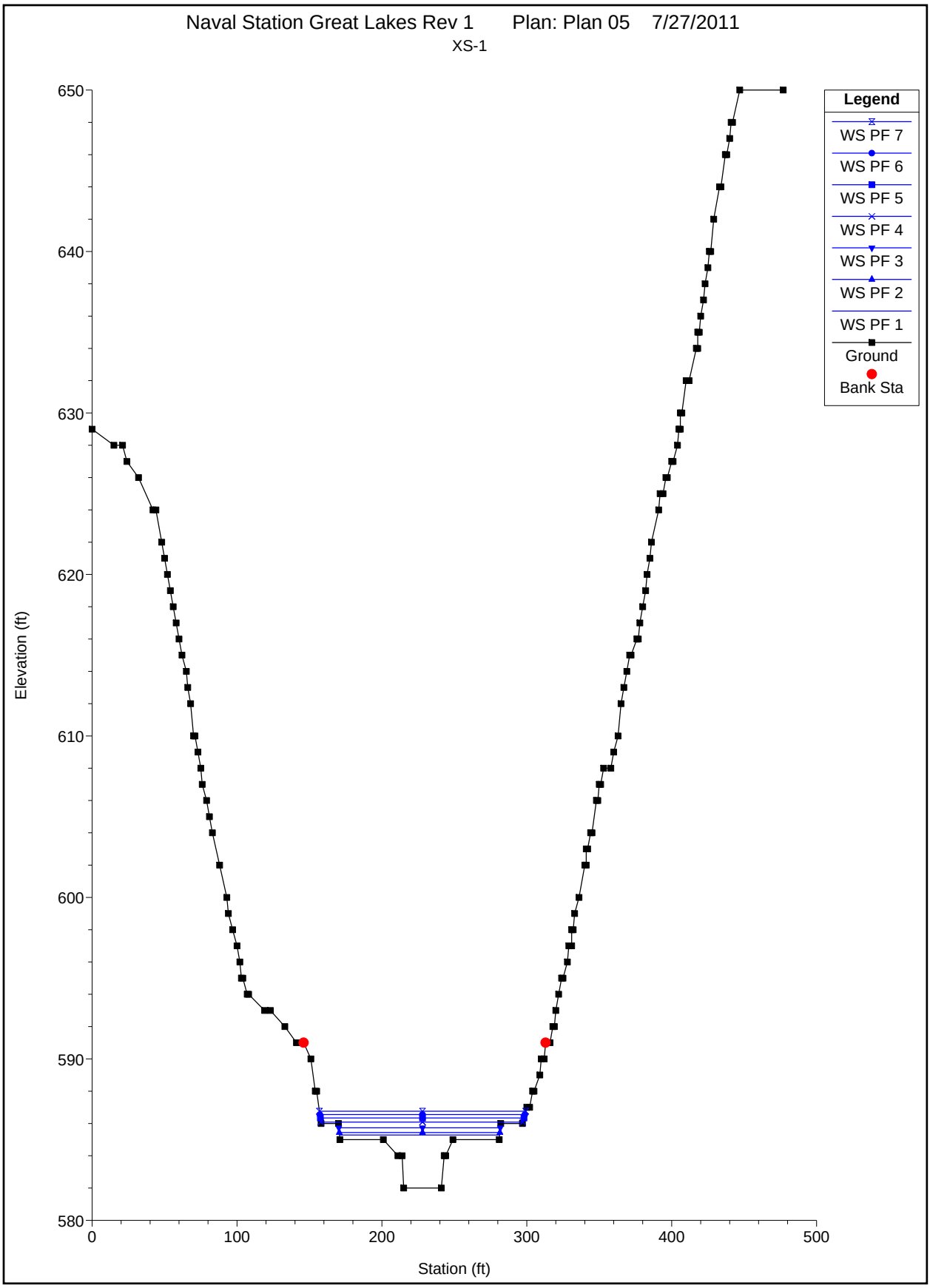
400
500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XS-1
Legend
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WS PF 2
WS PF 1
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Bank Sta
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Station (ft)
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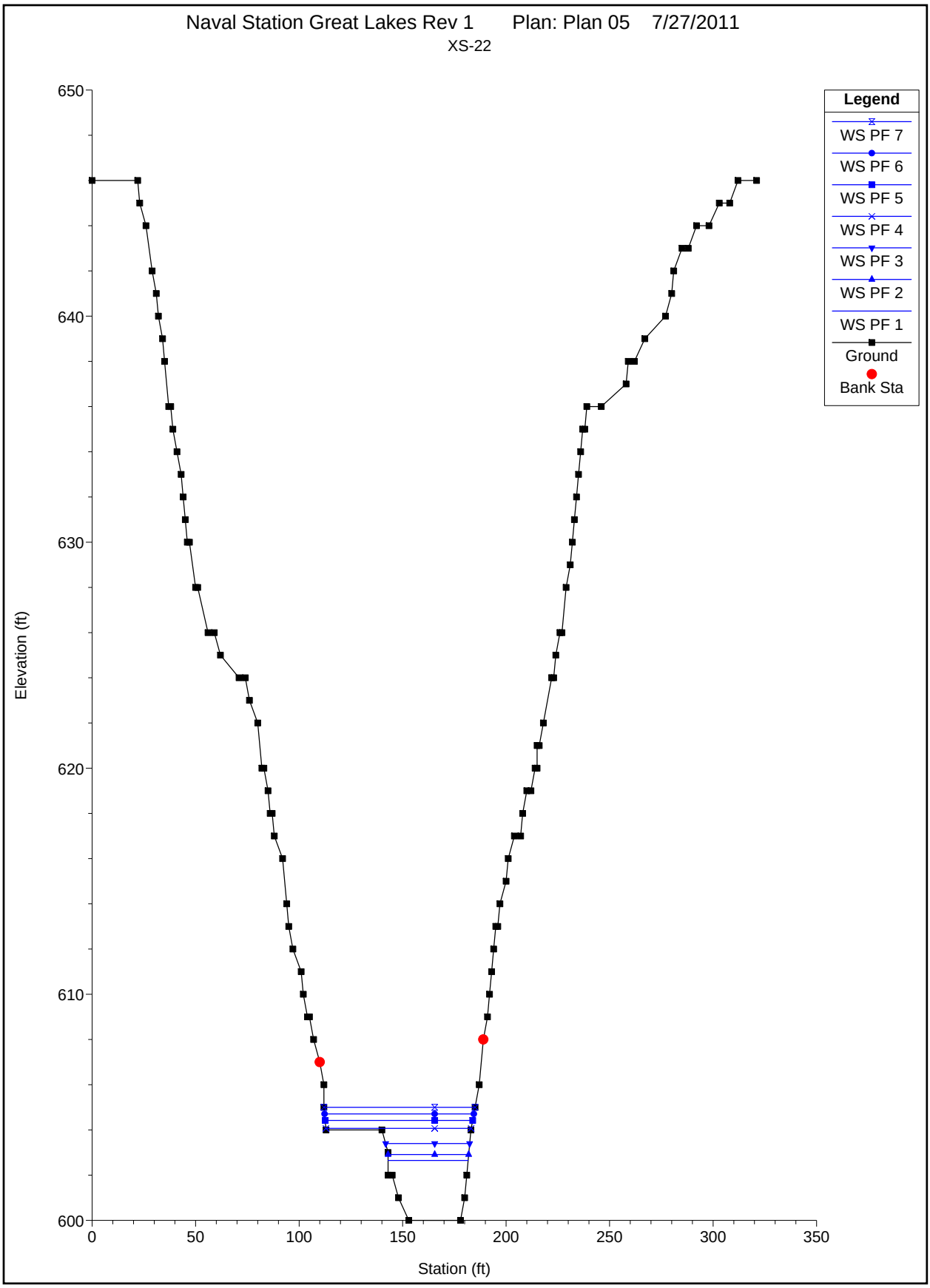
500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WS PF 4
WS PF 3
WS PF 2
WS PF 1
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Bank Sta
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610
600
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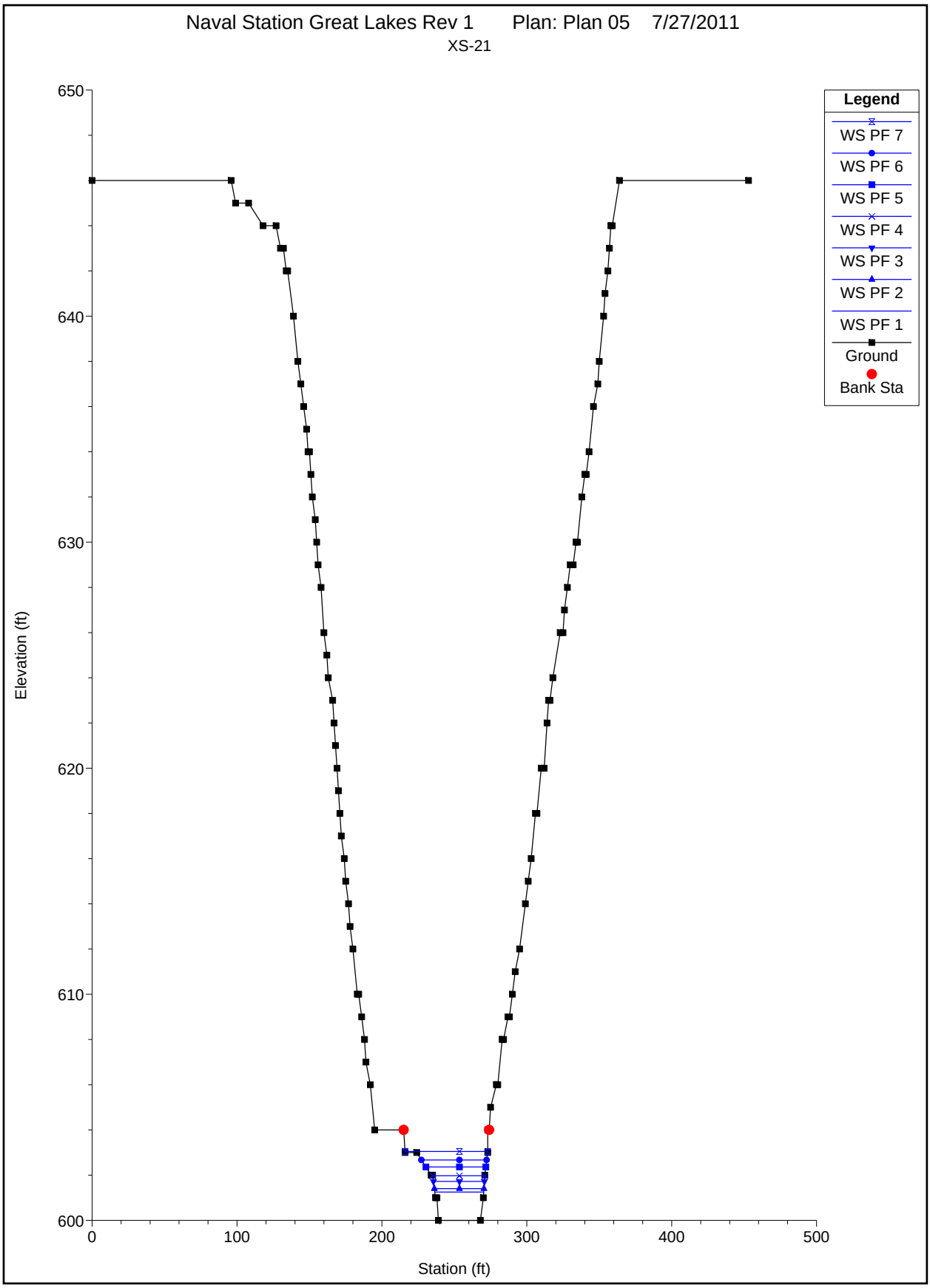
50
100
150
200
250
300
350
Station (ft)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XS-21
Legend
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WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
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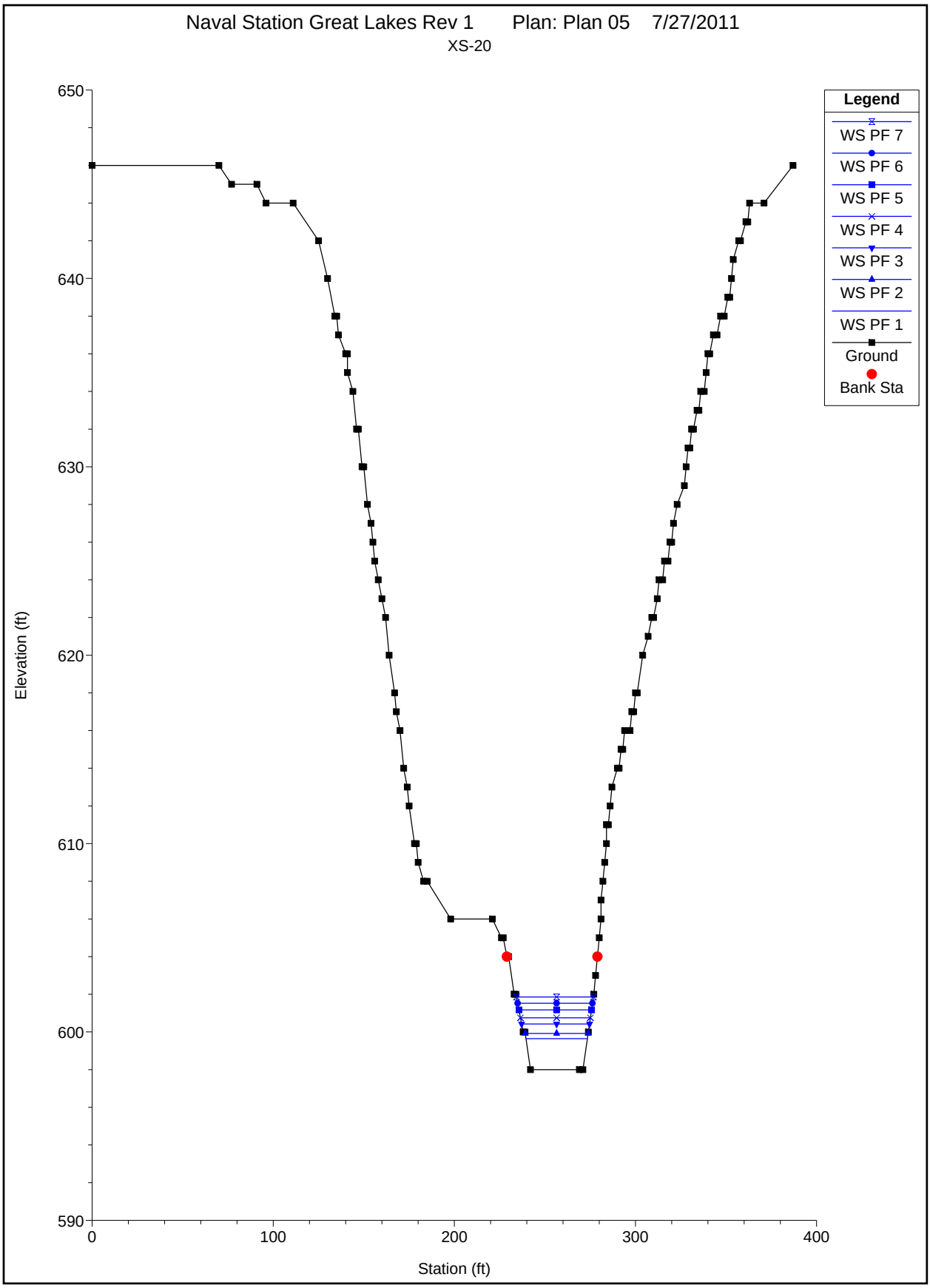
630
620
610
600
0
100
200
300
400
500
Station (ft)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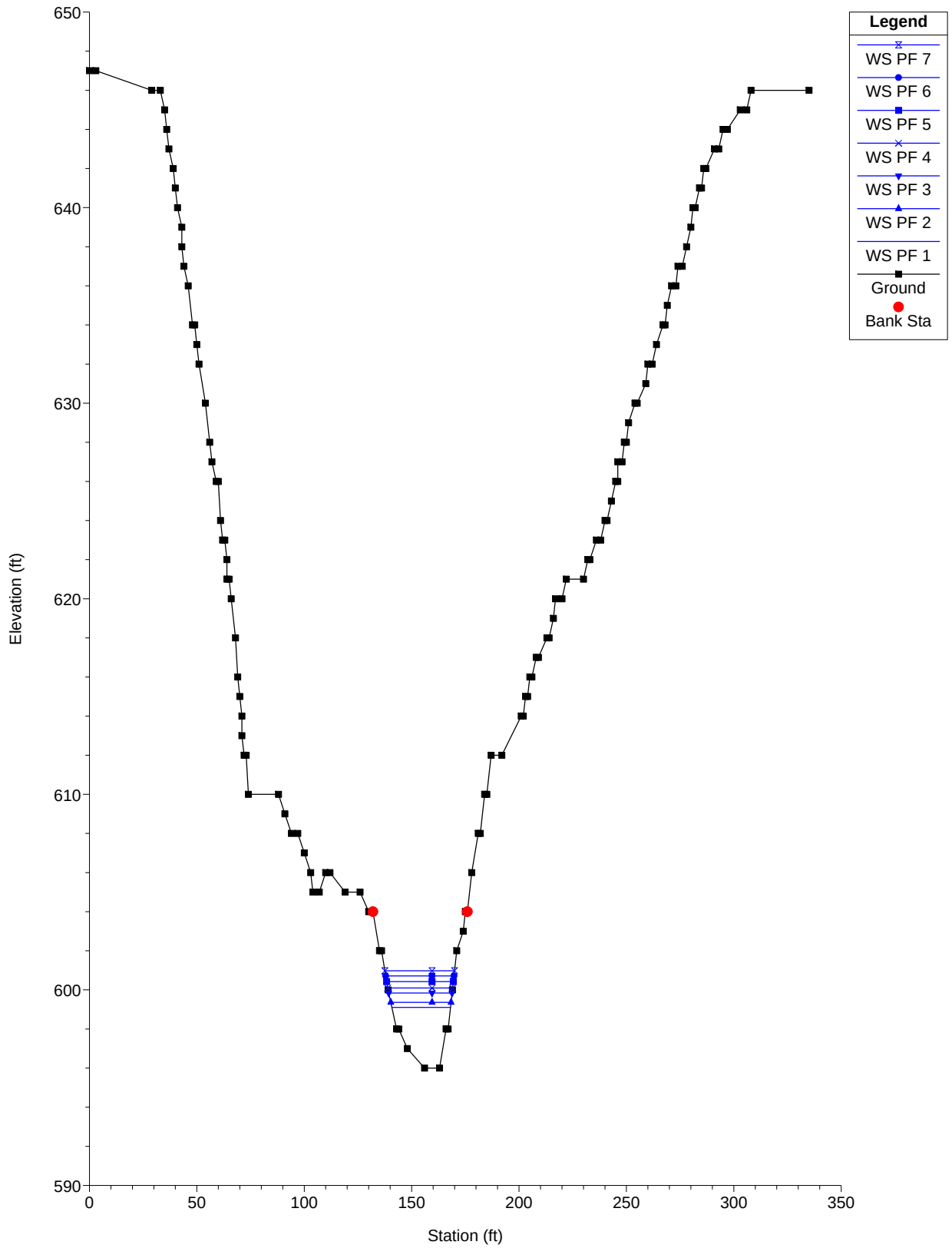
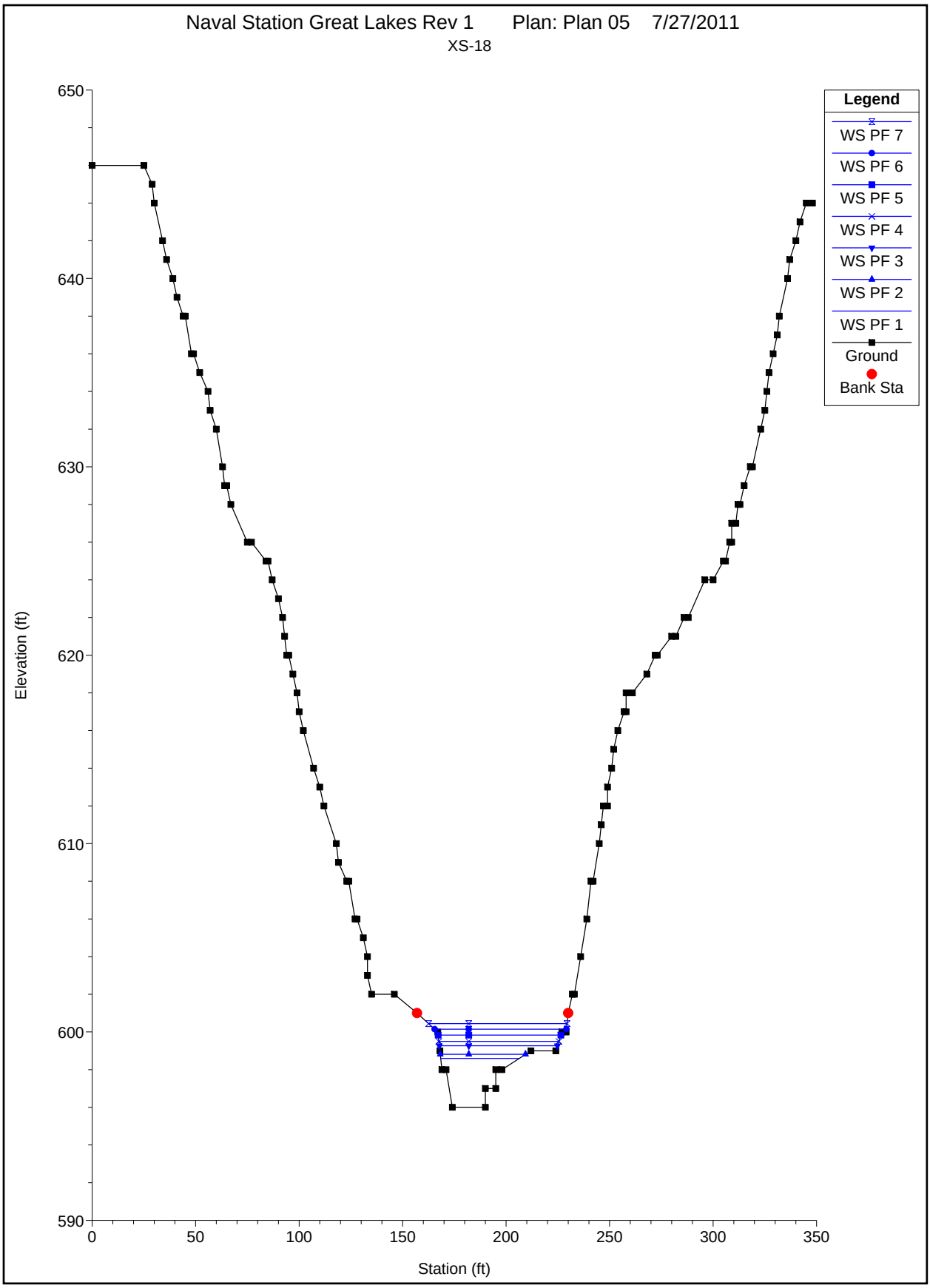
XS-20
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
590
0
100
200
300
400
Station (ft)

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

XS-19

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XS-18
Legend
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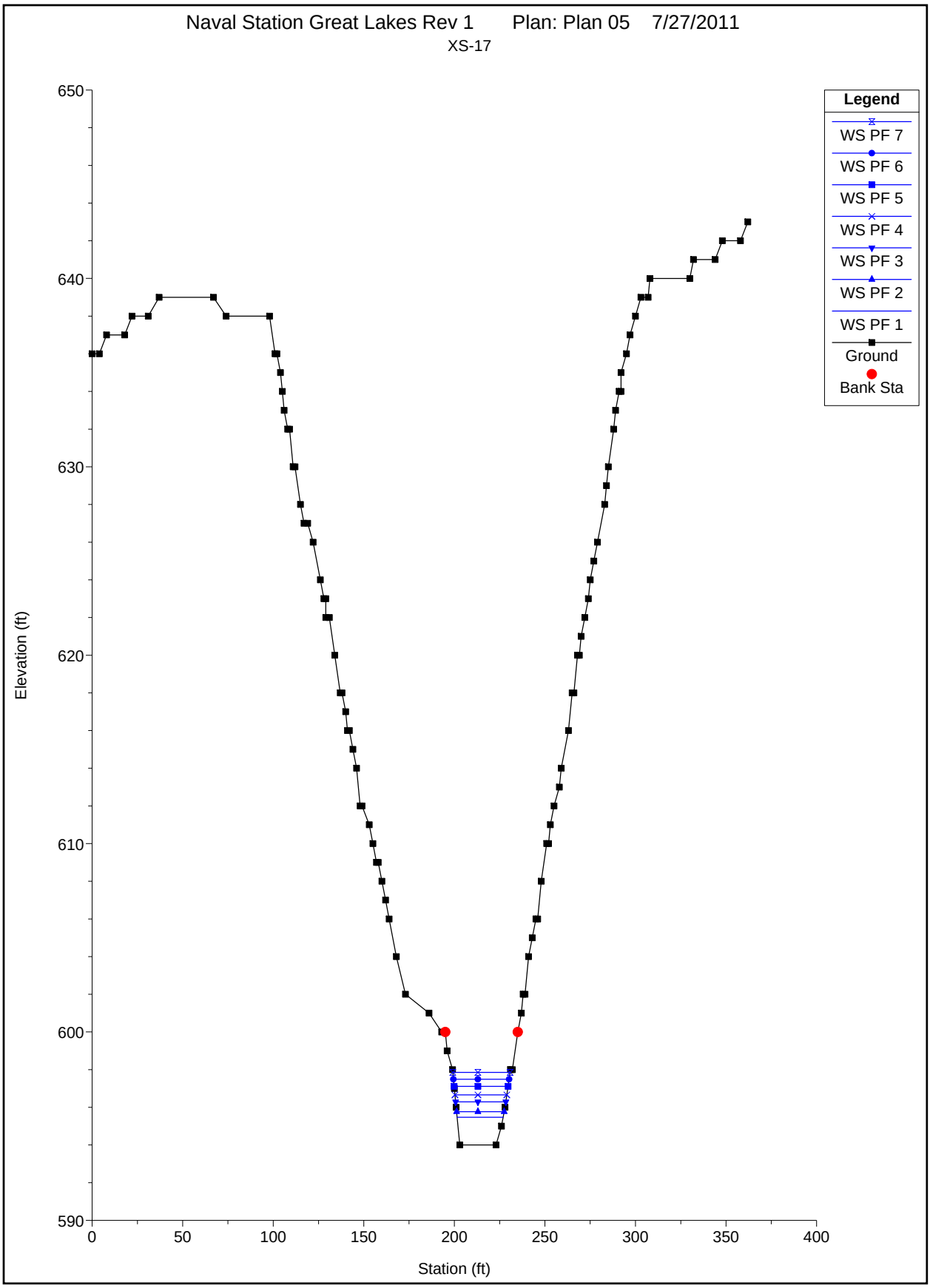
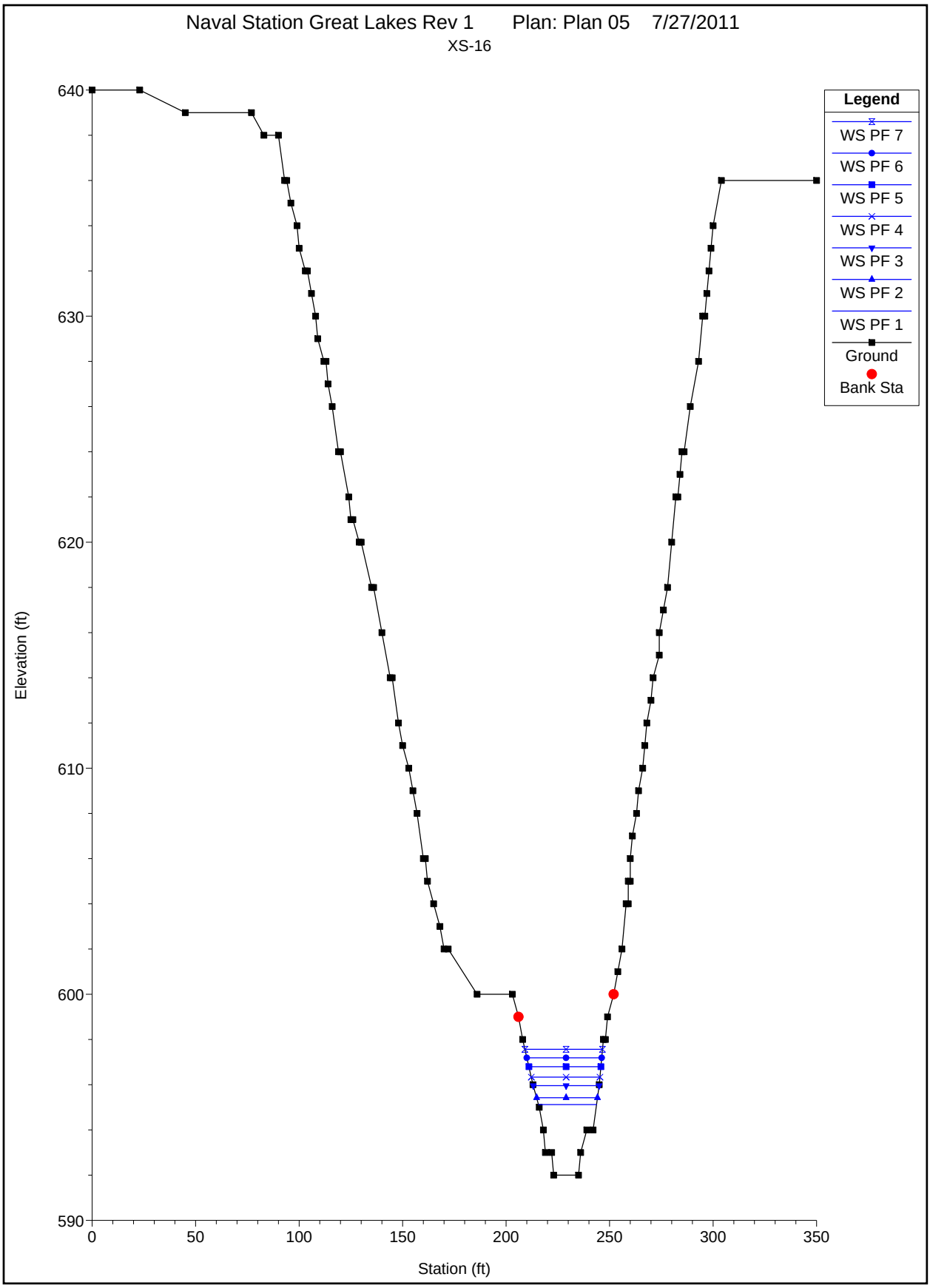
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
590
0
50
100
150
200
250
300
350
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-17
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
650
640
630
620
610
600
590
0
50
100
150
200
250
300
350
400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XS-16
Legend
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WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
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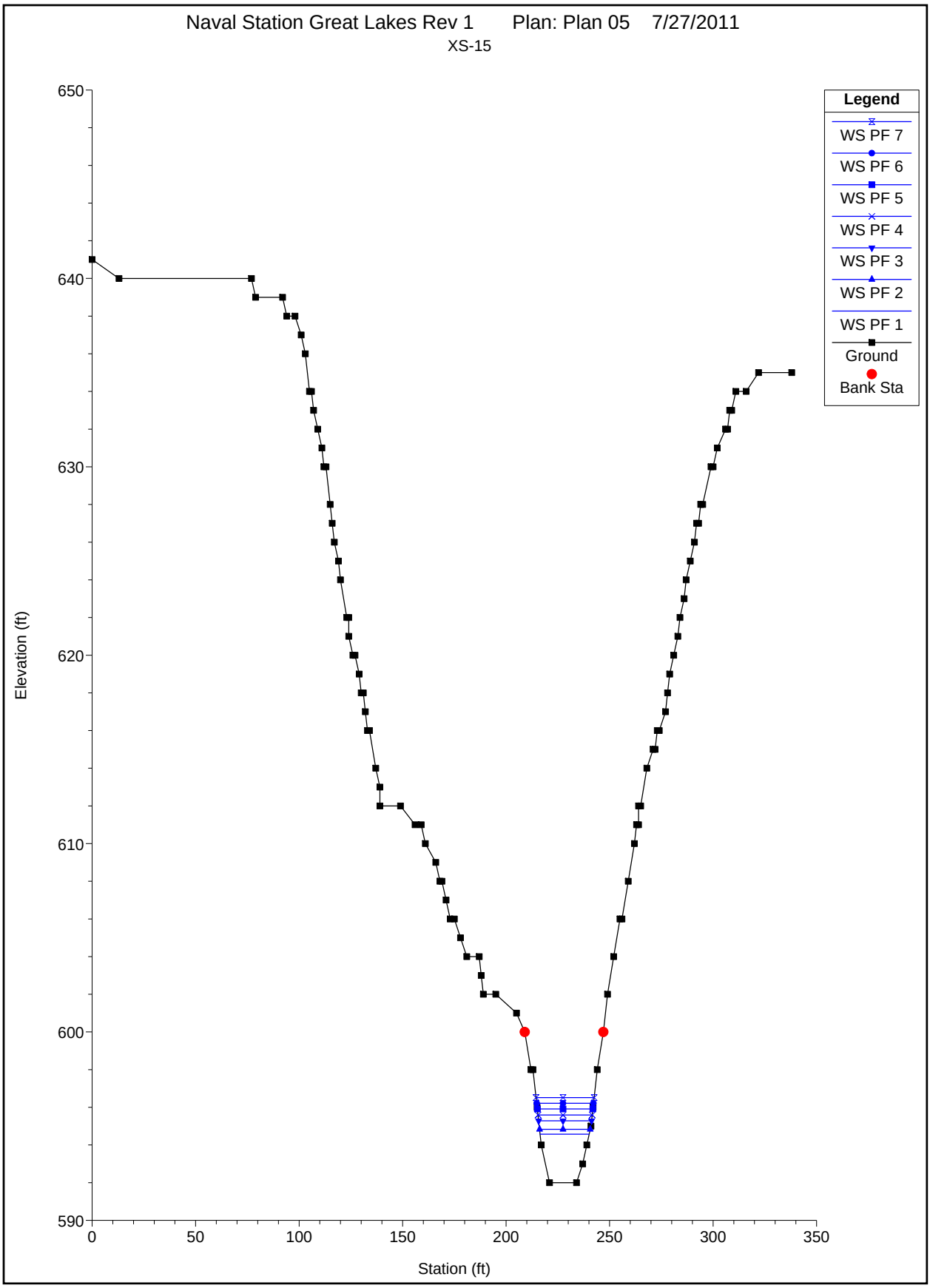
630
620
610
600
590
0
50
100
150
200
250
300
350
Station (ft)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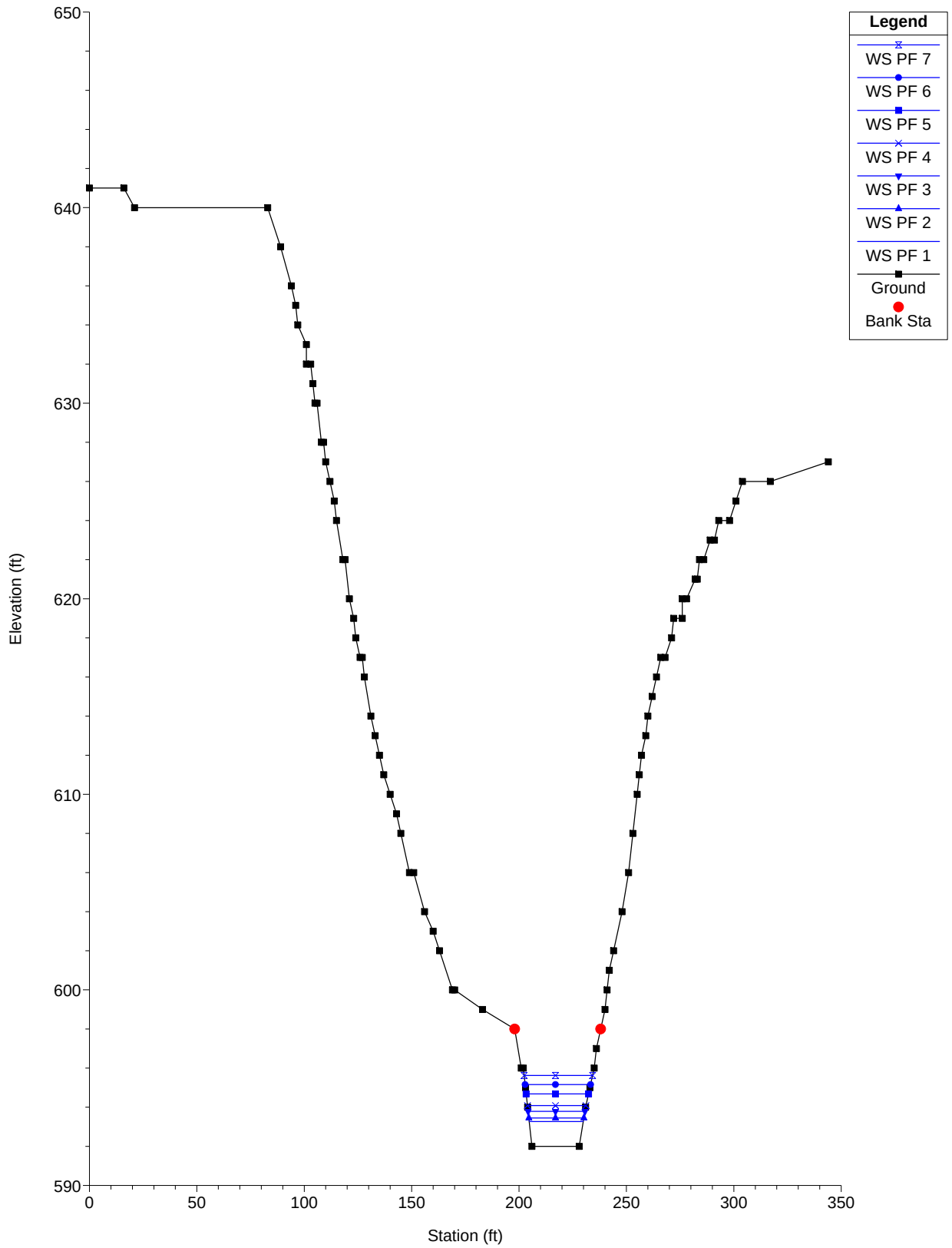
XS-15
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
590
0
50
100
150
200
250
300
350
Station (ft)

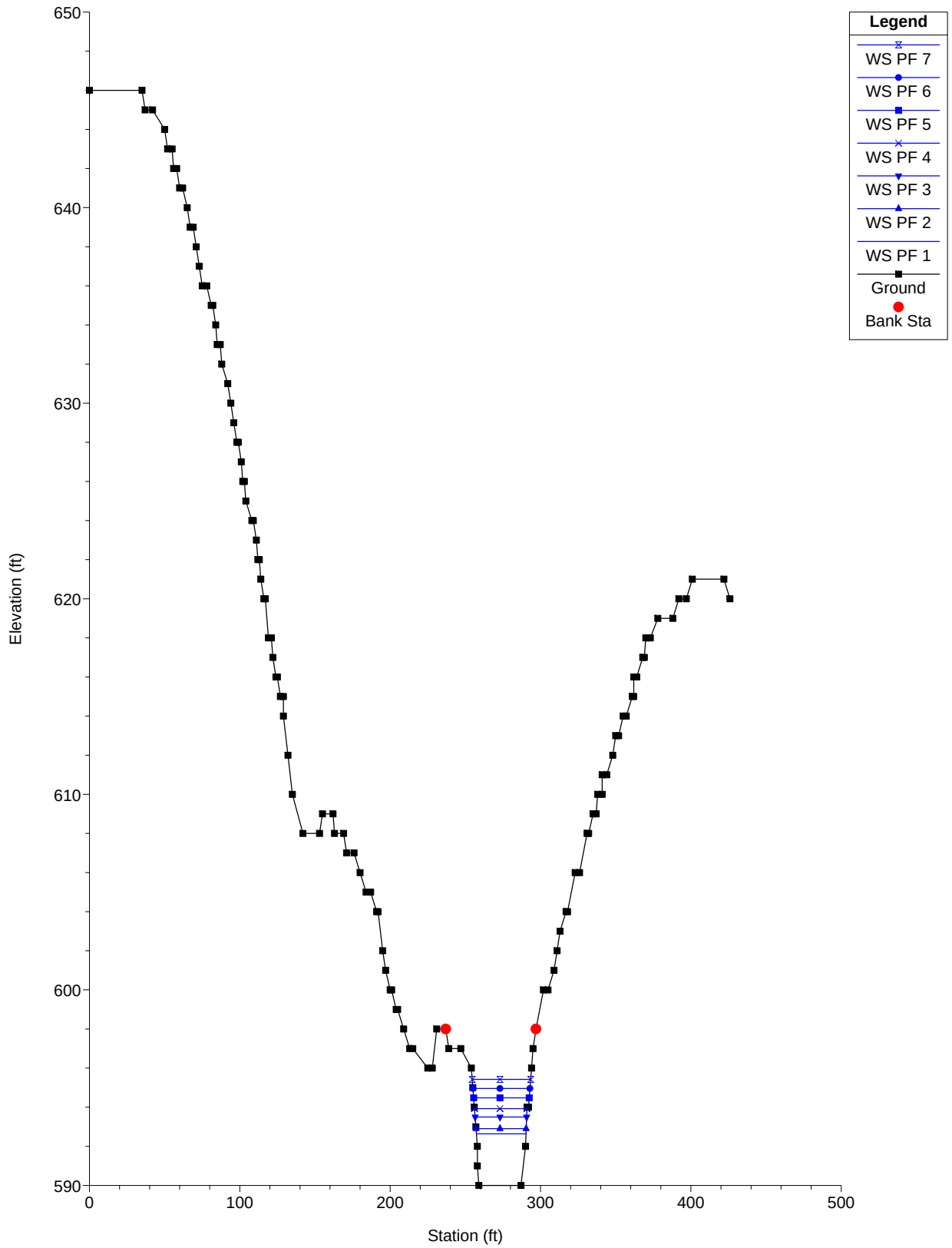
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

XS-14



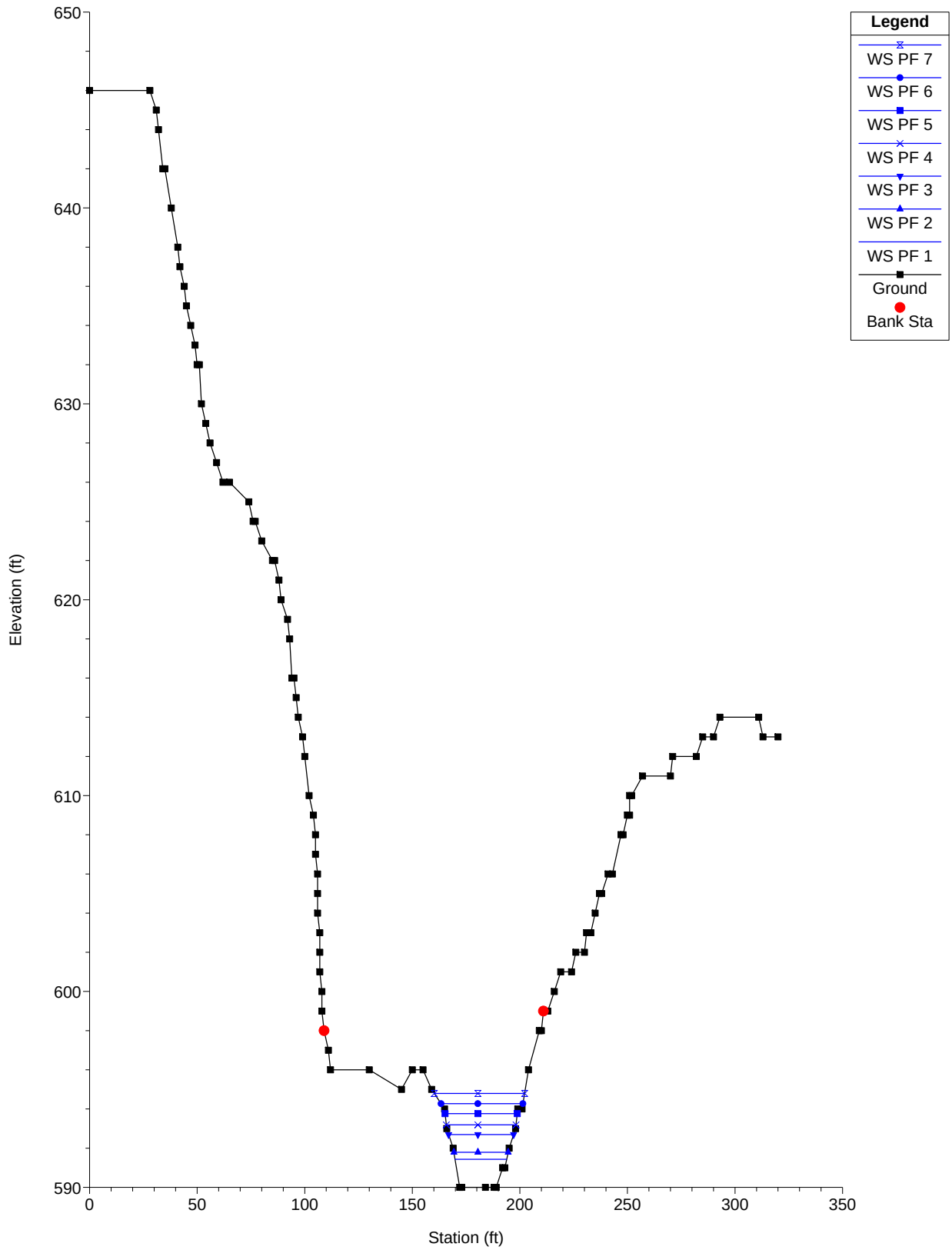
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

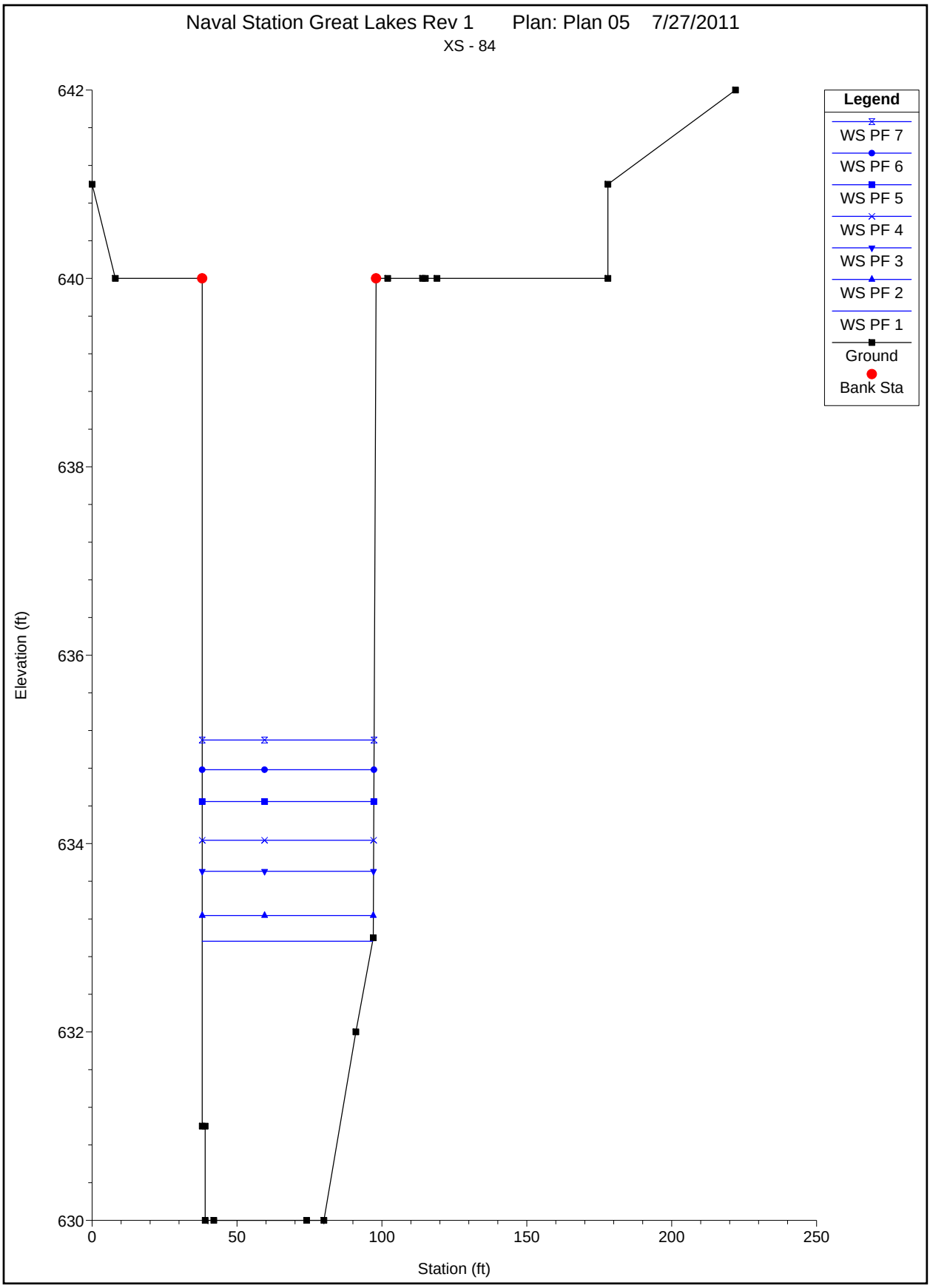
XS-13

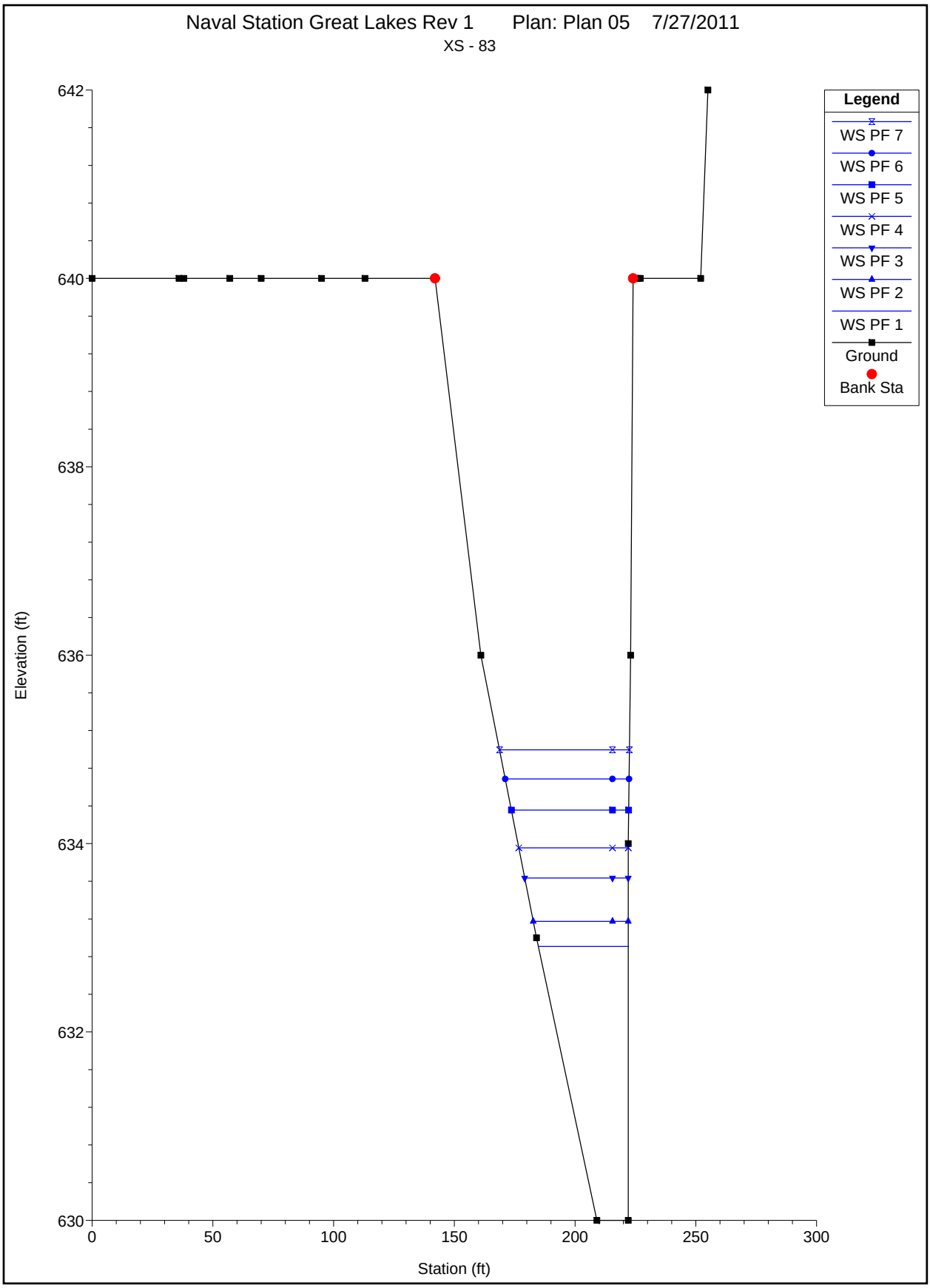


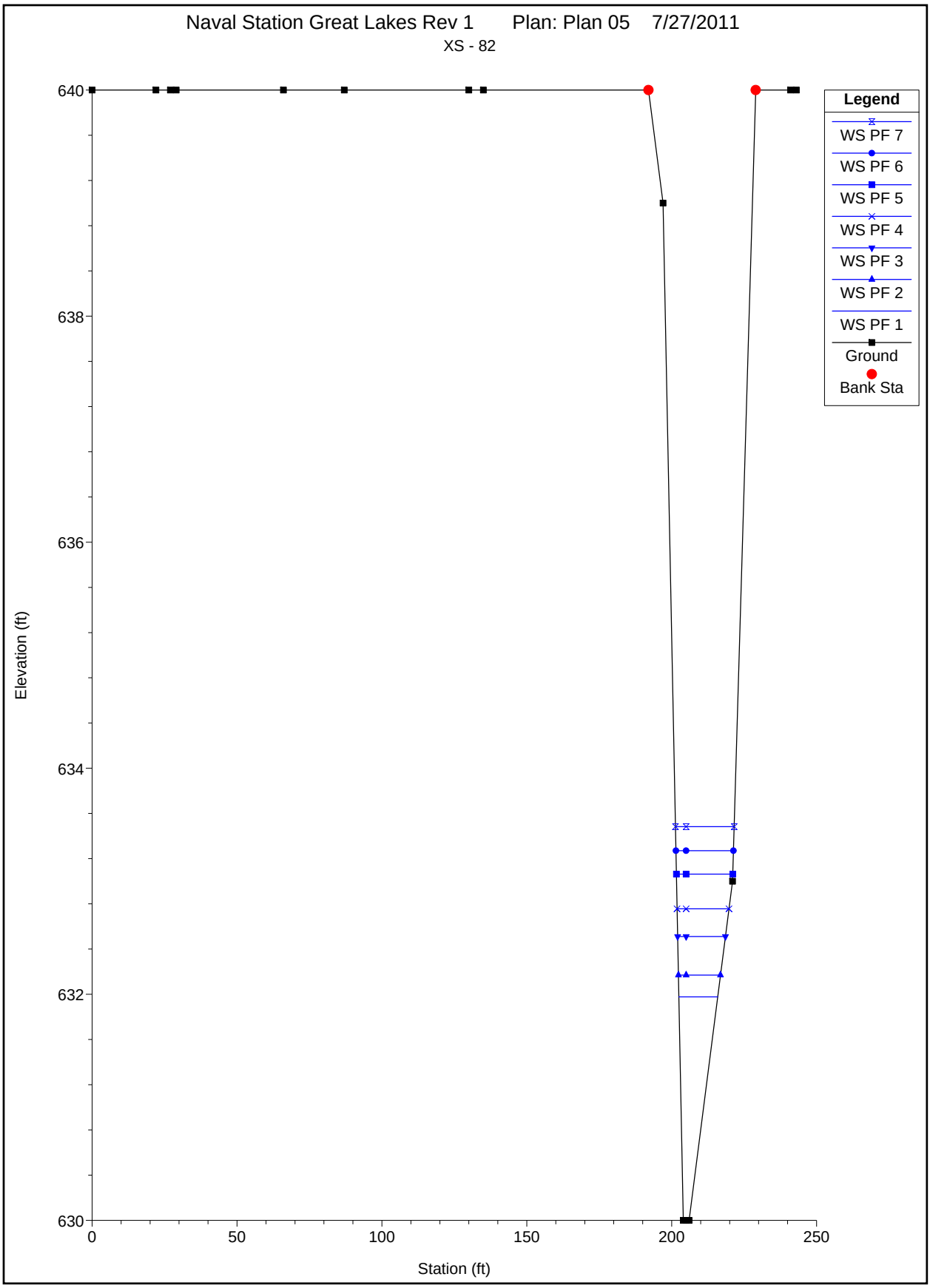
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

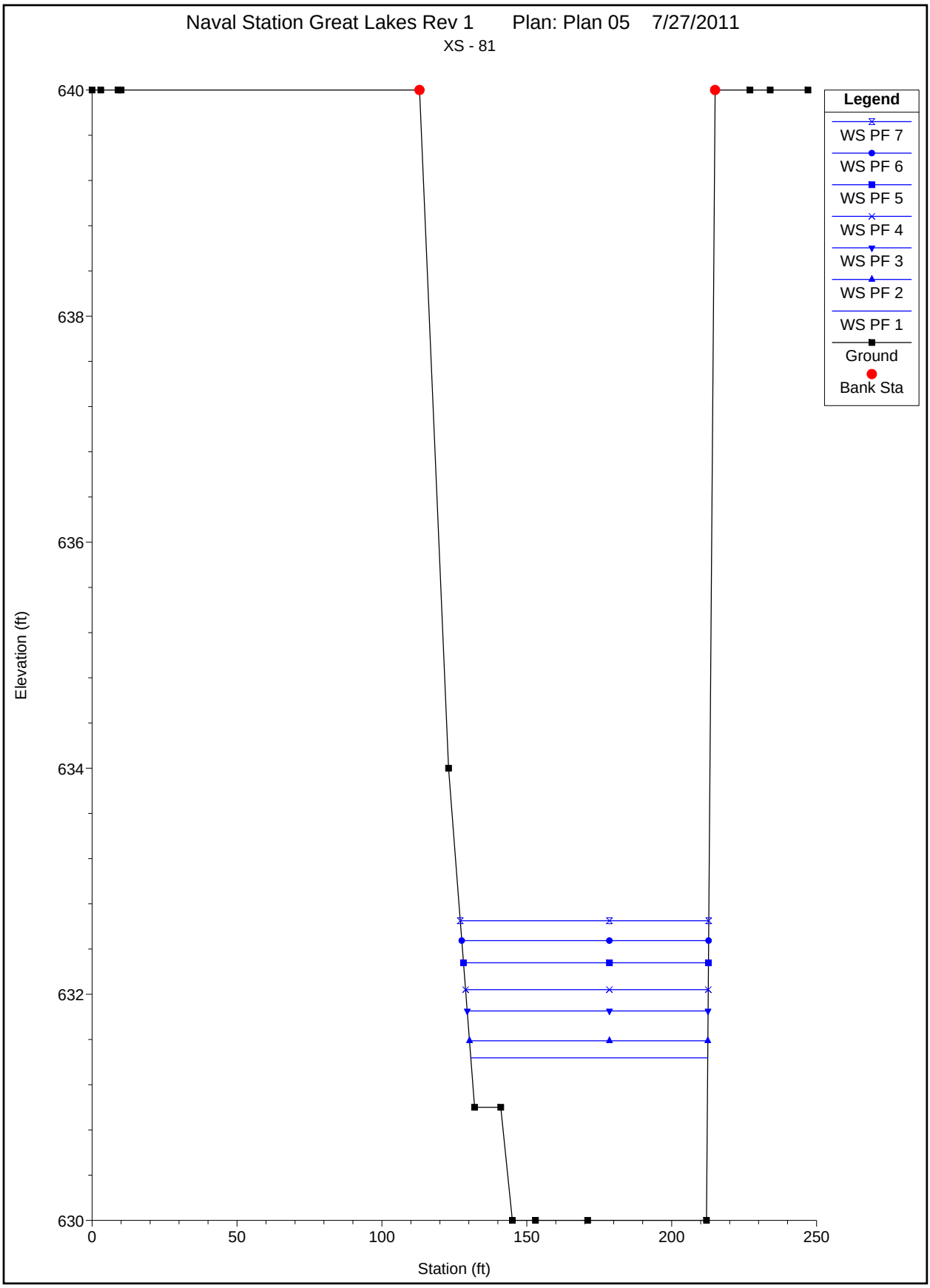
XS-12

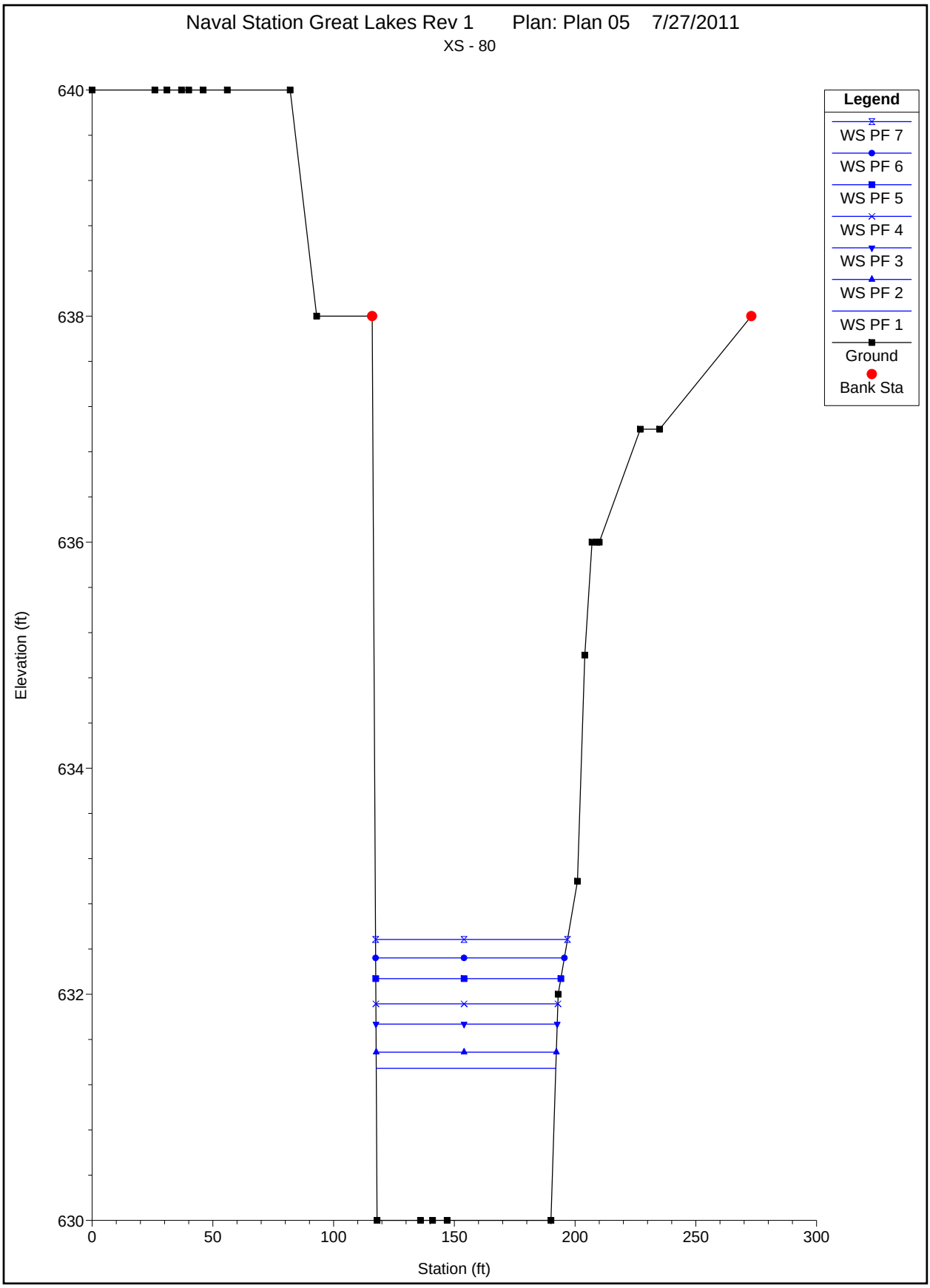



Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 84
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
642
640
638
636
634
632
630
0
50
100
150
200
250
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 83
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
642
640
638
636
634
632
630
0
50
100
150
200
250
300
Station (ft)

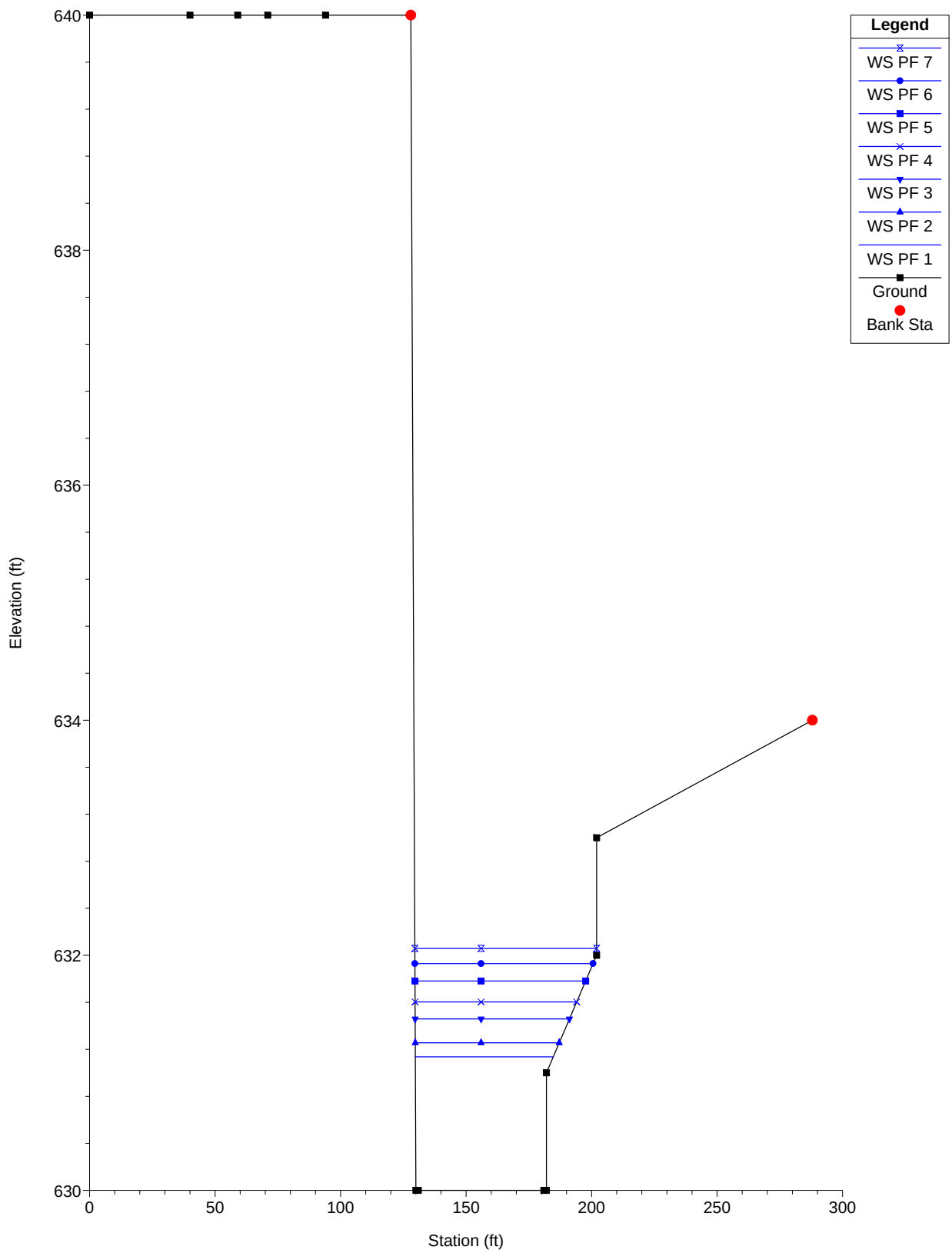

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 82
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
Station (ft)

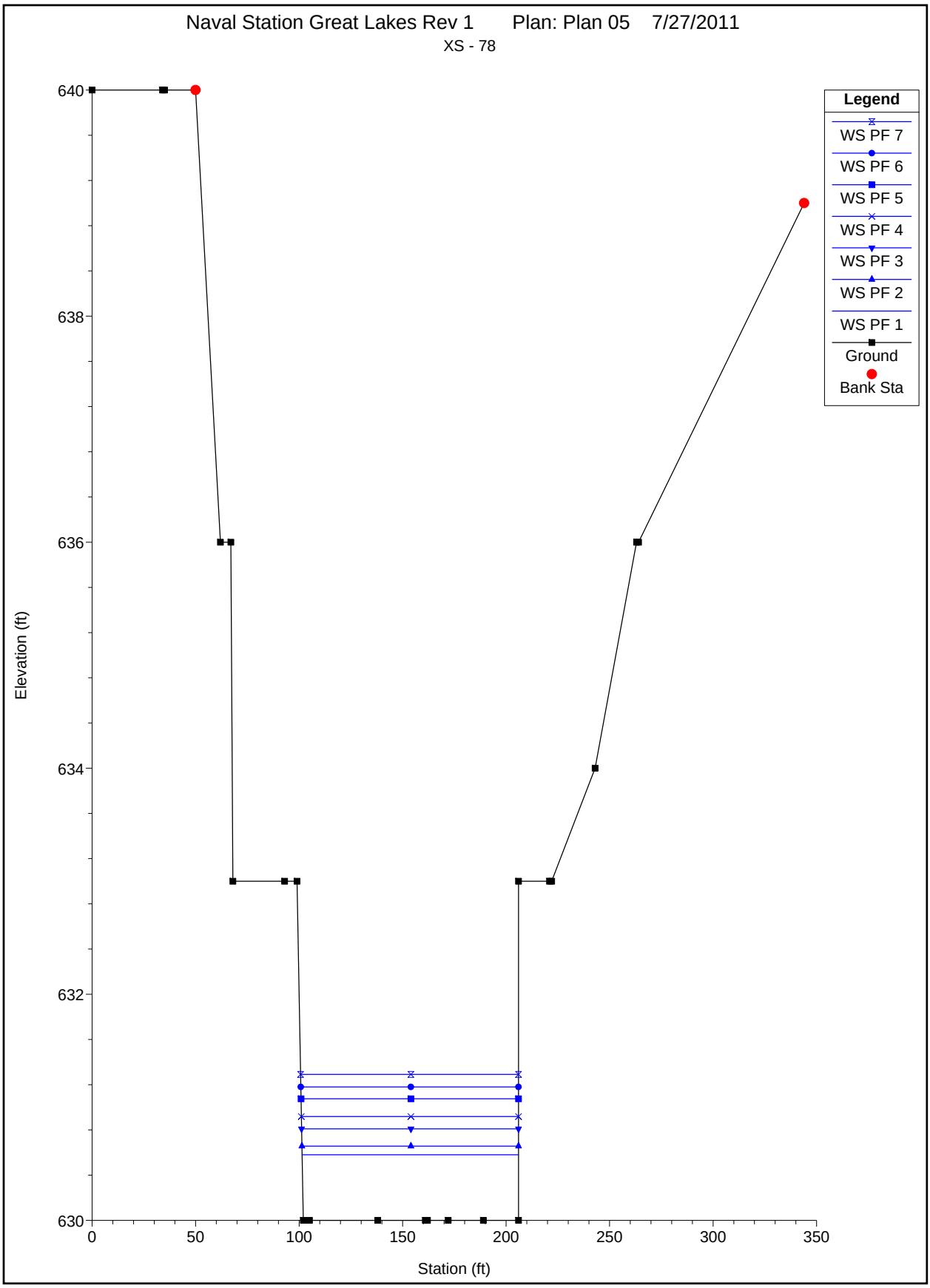

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 81
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
Station (ft)

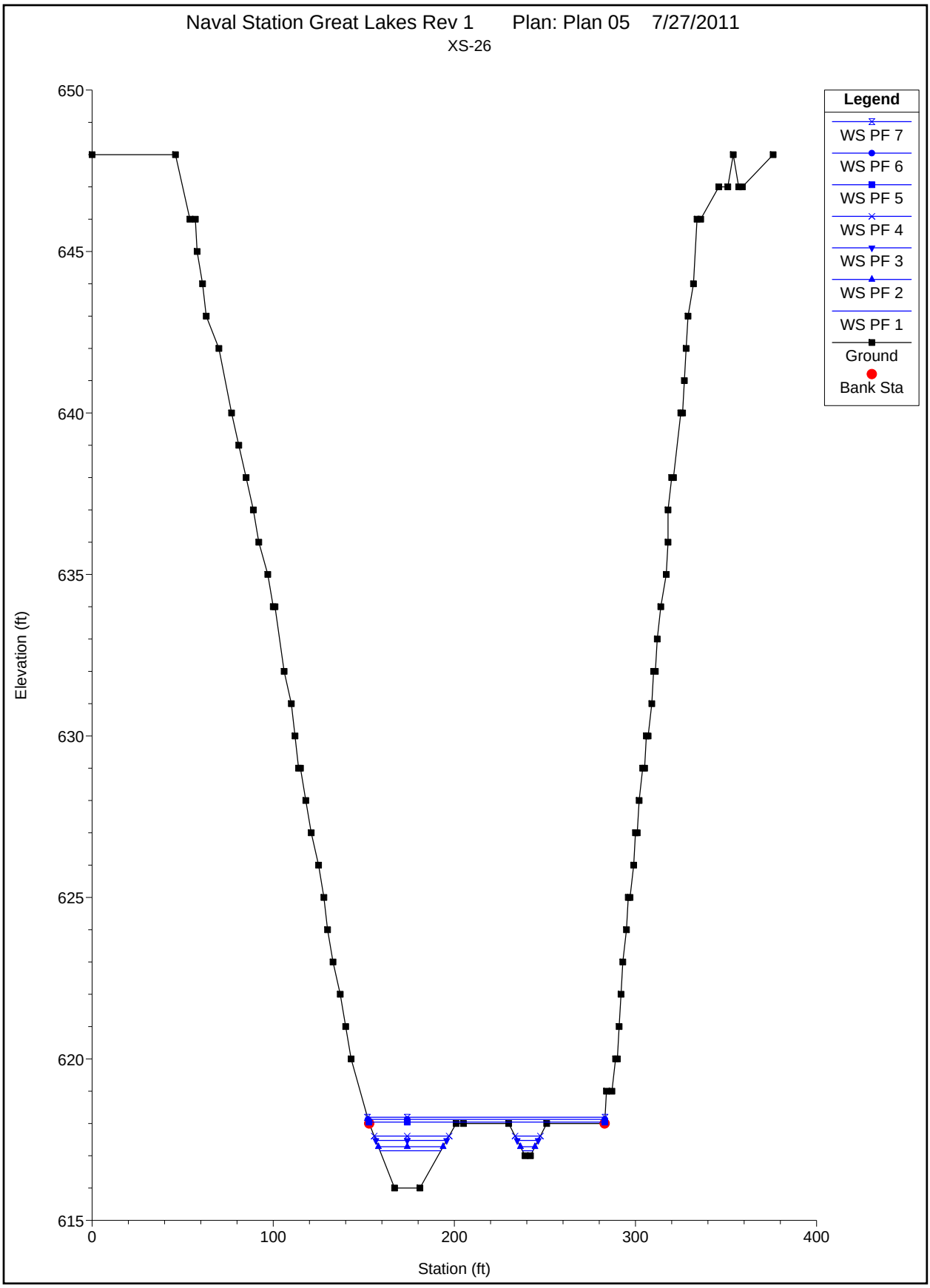

Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 80
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
300
Station (ft)

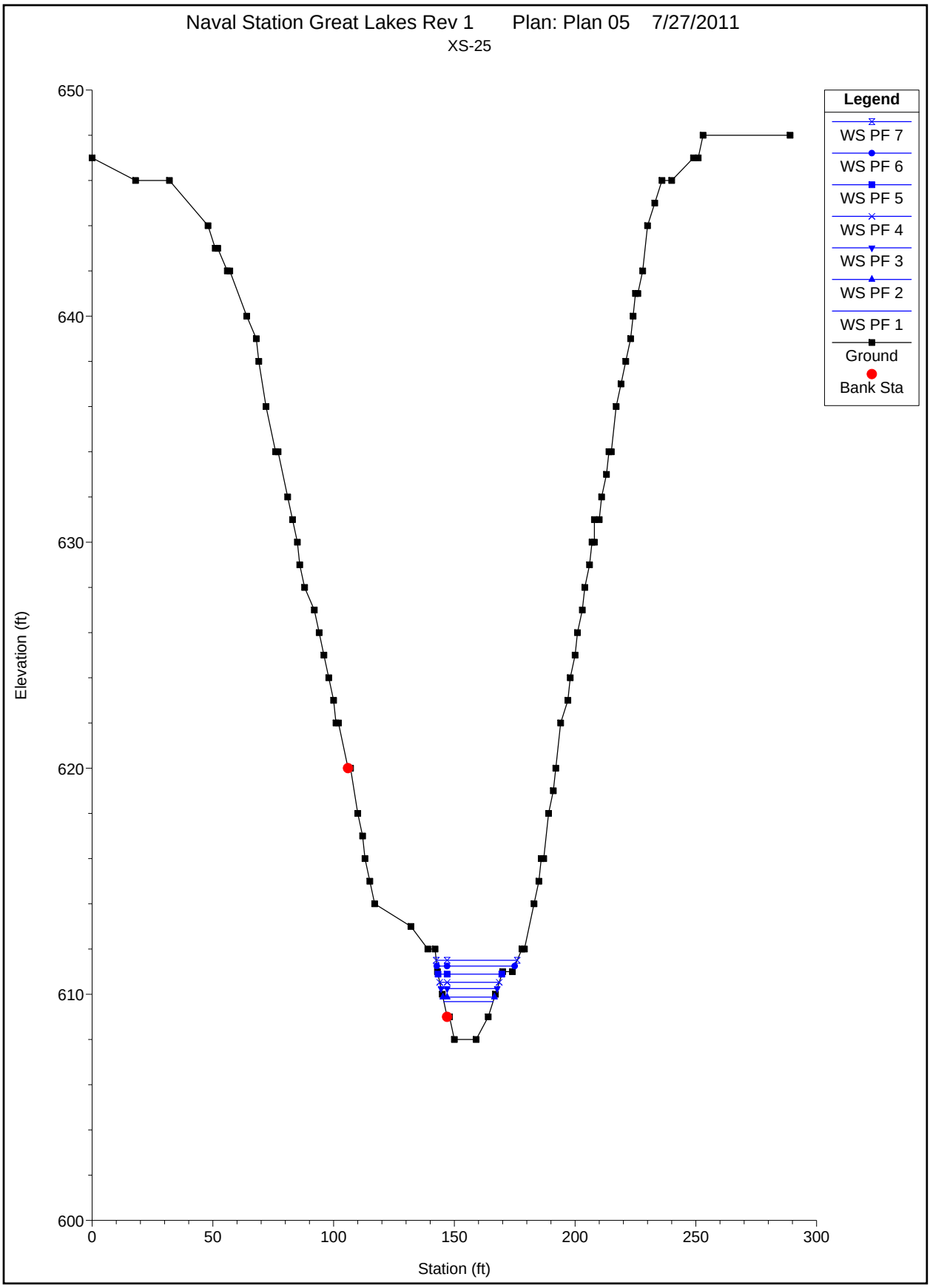
Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011

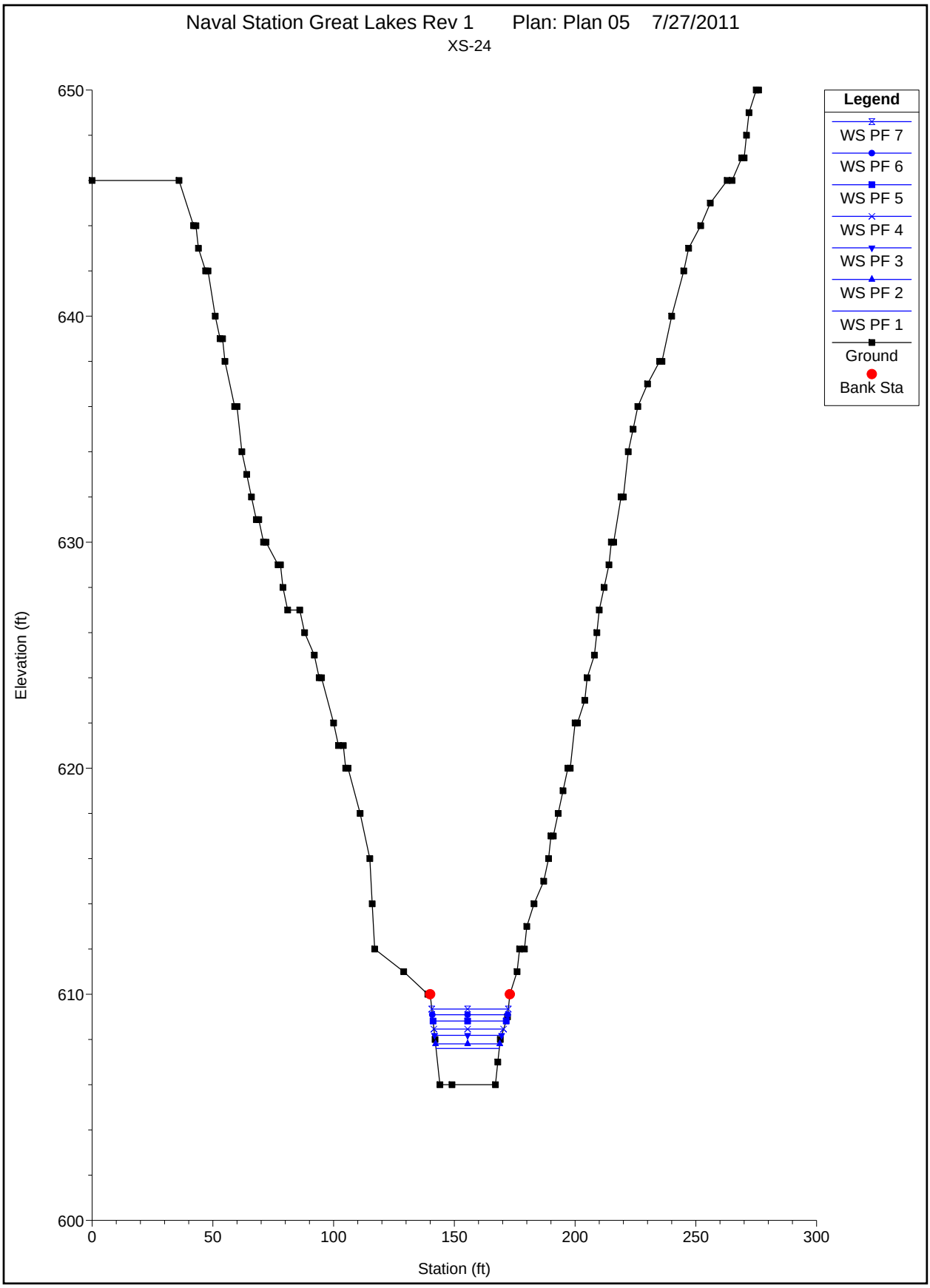
XS - 79

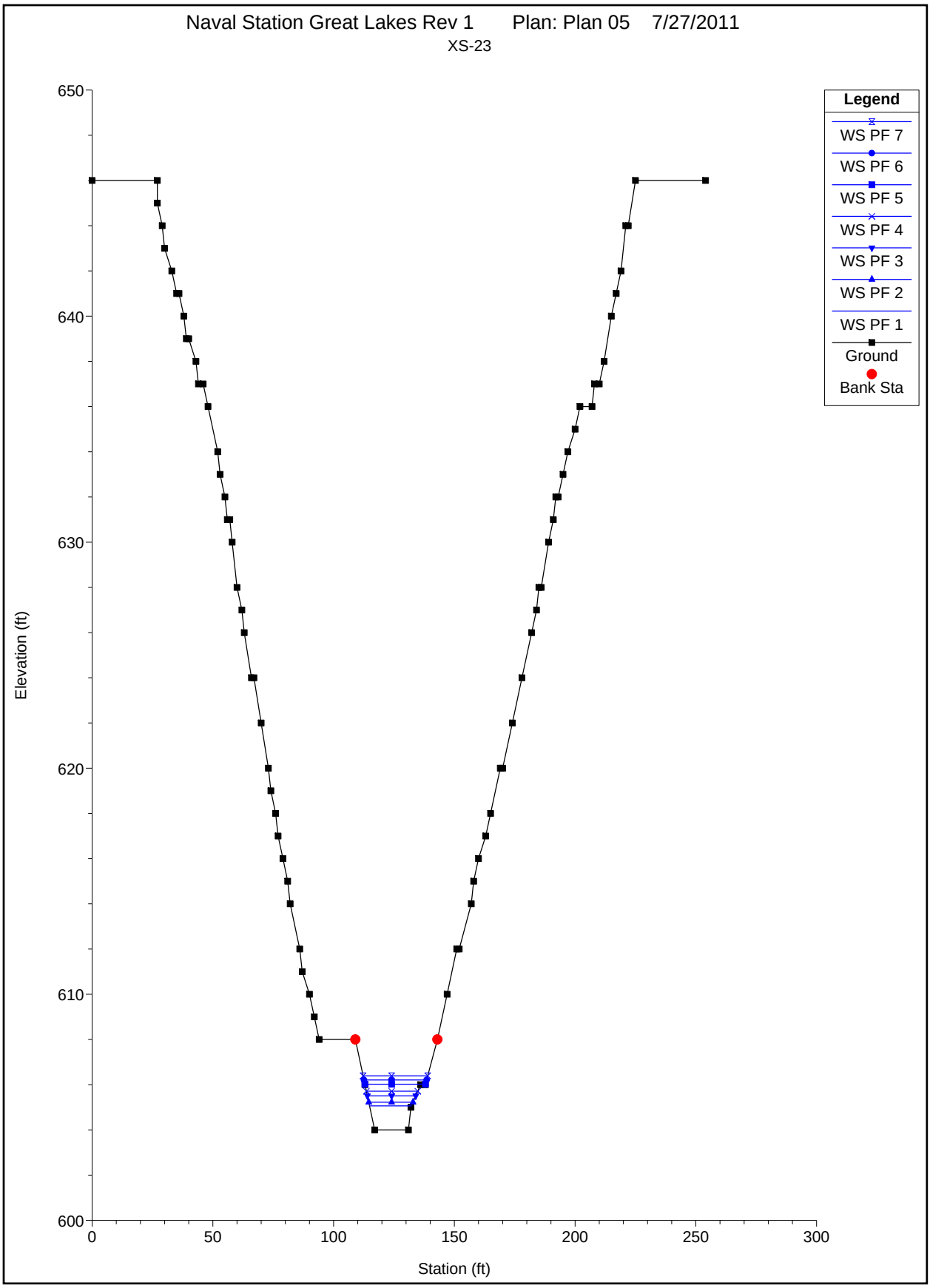



Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS - 78
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
640
638
636
634
632
630
0
50
100
150
200
250
300
350
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-26
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
Station (ft)
650
645
640
635
630
625
620
615
0
100
200
300
400


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-25
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
50
100
150
200
250
300
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-24
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
50
100
150
200
250
300
Station (ft)


Naval Station Great Lakes Rev 1 Plan: Plan 05 7/27/2011
XS-23
Legend
WS PF 7
WS PF 6
WS PF 5
WS PF 4
WS PF 3
WS PF 2
WS PF 1
Ground
Bank Sta
Elevation (ft)
650
640
630
620
610
600
0
50
100
150
200
250
300
Station (ft)

Plan: Plan 02 Pettibone Creek North 2 RS: 2493 Profile: PF 7

E.G. Elev (ft)	635.12	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.02	Wt. n-Val.		0.055	
W.S. Elev (ft)	635.10	Reach Len. (ft)	99.00	102.00	107.00
Crit W.S. (ft)		Flow Area (sq ft)		274.18	
E.G. Slope (ft/ft)	0.000322	Area (sq ft)		274.18	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	59.30	Top Width (ft)		59.30	
Vel Total (ft/s)	1.25	Avg. Vel. (ft/s)		1.25	
Max Chl Dpth (ft)	5.10	Hydr. Depth (ft)		4.62	
Conv. Total (cfs)	19049.6	Conv. (cfs)		19049.6	
Length Wtd. (ft)	102.00	Wetted Per. (ft)		66.48	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.08	
Alpha	1.00	Stream Power (lb/ft s)	222.00	0.00	0.00
Frctn Loss (ft)	0.06	Cum Volume (acre-ft)	0.00	6.37	0.32
C & E Loss (ft)	0.00	Cum SA (acres)	0.01	4.76	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2391 Profile: PF 7

E.G. Elev (ft)	635.06	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.06	Wt. n-Val.		0.055	
W.S. Elev (ft)	635.00	Reach Len. (ft)	104.00	107.00	110.00
Crit W.S. (ft)		Flow Area (sq ft)		167.82	
E.G. Slope (ft/ft)	0.001400	Area (sq ft)		167.82	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	53.79	Top Width (ft)		53.79	
Vel Total (ft/s)	2.04	Avg. Vel. (ft/s)		2.04	
Max Chl Dpth (ft)	5.00	Hydr. Depth (ft)		3.12	
Conv. Total (cfs)	9131.2	Conv. (cfs)		9131.2	
Length Wtd. (ft)	107.00	Wetted Per. (ft)		58.72	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.25	
Alpha	1.00	Stream Power (lb/ft s)	255.00	0.00	0.00
Frctn Loss (ft)	0.43	Cum Volume (acre-ft)	0.00	5.86	0.32
C & E Loss (ft)	0.10	Cum SA (acres)	0.01	4.63	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2284 Profile: PF 7

E.G. Elev (ft)	634.53	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.05	Wt. n-Val.		0.055	
W.S. Elev (ft)	633.48	Reach Len. (ft)	94.00	106.00	118.00
Crit W.S. (ft)	633.48	Flow Area (sq ft)		41.57	

Plan: Plan 02 Pettibone Creek North 2 RS: 2284 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.040686	Area (sq ft)		41.57	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	20.26	Top Width (ft)		20.26	
Vel Total (ft/s)	8.22	Avg. Vel. (ft/s)		8.22	
Max Chl Dpth (ft)	3.48	Hydr. Depth (ft)		2.05	
Conv. Total (cfs)	1694.0	Conv. (cfs)		1694.0	
Length Wtd. (ft)	106.00	Wetted Per. (ft)		22.44	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		4.70	
Alpha	1.00	Stream Power (lb/ft s)	243.00	0.00	0.00
Frctn Loss (ft)	0.37	Cum Volume (acre-ft)	0.00	5.60	0.32
C & E Loss (ft)	0.30	Cum SA (acres)	0.01	4.54	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2178 Profile: PF 7

E.G. Elev (ft)	632.69	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.04	Wt. n-Val.		0.055	
W.S. Elev (ft)	632.65	Reach Len. (ft)	117.00	112.00	109.00
Crit W.S. (ft)		Flow Area (sq ft)		206.20	
E.G. Slope (ft/ft)	0.001211	Area (sq ft)		206.20	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	85.75	Top Width (ft)		85.75	
Vel Total (ft/s)	1.66	Avg. Vel. (ft/s)		1.66	
Max Chl Dpth (ft)	2.65	Hydr. Depth (ft)		2.40	
Conv. Total (cfs)	9819.8	Conv. (cfs)		9819.8	
Length Wtd. (ft)	112.00	Wetted Per. (ft)		88.11	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.18	
Alpha	1.00	Stream Power (lb/ft s)	247.00	0.00	0.00
Frctn Loss (ft)	0.15	Cum Volume (acre-ft)	0.00	5.30	0.32
C & E Loss (ft)	0.00	Cum SA (acres)	0.01	4.41	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 2066 Profile: PF 7

E.G. Elev (ft)	632.54	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.05	Wt. n-Val.		0.055	
W.S. Elev (ft)	632.49	Reach Len. (ft)	121.00	123.00	127.00
Crit W.S. (ft)		Flow Area (sq ft)		185.11	
E.G. Slope (ft/ft)	0.001578	Area (sq ft)		185.11	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	79.50	Top Width (ft)		79.50	
Vel Total (ft/s)	1.85	Avg. Vel. (ft/s)		1.85	

Plan: Plan 02 Pettibone Creek North 2 RS: 2066 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	2.49	Hydr. Depth (ft)		2.33	
Conv. Total (cfs)	8600.6	Conv. (cfs)		8600.6	
Length Wtd. (ft)	123.00	Wetted Per. (ft)		82.08	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.22	
Alpha	1.00	Stream Power (lb/ft s)	273.00	0.00	0.00
Frctn Loss (ft)	0.34	Cum Volume (acre-ft)	0.00	4.79	0.32
C & E Loss (ft)	0.01	Cum SA (acres)	0.01	4.20	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 1942 Profile: PF 7

E.G. Elev (ft)	632.19	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.13	Wt. n-Val.		0.055	
W.S. Elev (ft)	632.06	Reach Len. (ft)	116.00	126.00	142.00
Crit W.S. (ft)		Flow Area (sq ft)		118.64	
E.G. Slope (ft/ft)	0.006186	Area (sq ft)		118.64	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	72.41	Top Width (ft)		72.41	
Vel Total (ft/s)	2.88	Avg. Vel. (ft/s)		2.88	
Max Chl Dpth (ft)	2.06	Hydr. Depth (ft)		1.64	
Conv. Total (cfs)	4344.4	Conv. (cfs)		4344.4	
Length Wtd. (ft)	126.00	Wetted Per. (ft)		75.18	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.61	
Alpha	1.00	Stream Power (lb/ft s)	288.00	0.00	0.00
Frctn Loss (ft)	0.79	Cum Volume (acre-ft)	0.00	4.36	0.32
C & E Loss (ft)	0.01	Cum SA (acres)	0.01	3.98	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 1816 Profile: PF 7

E.G. Elev (ft)	631.39	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.10	Wt. n-Val.		0.055	
W.S. Elev (ft)	631.29	Reach Len. (ft)	1170.00	1170.00	1170.00
Crit W.S. (ft)	630.69	Flow Area (sq ft)		135.09	
E.G. Slope (ft/ft)	0.006433	Area (sq ft)		135.09	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	105.29	Top Width (ft)		105.29	
Vel Total (ft/s)	2.53	Avg. Vel. (ft/s)		2.53	
Max Chl Dpth (ft)	1.29	Hydr. Depth (ft)		1.28	
Conv. Total (cfs)	4260.4	Conv. (cfs)		4260.4	
Length Wtd. (ft)	1170.00	Wetted Per. (ft)		107.12	
Min Ch El (ft)	630.00	Shear (lb/sq ft)		0.51	

Plan: Plan 02 Pettibone Creek North 2 RS: 1816 Profile: PF 7 (Continued)

Alpha	1.00	Stream Power (lb/ft s)	344.00	0.00	0.00
Frctn Loss (ft)	13.00	Cum Volume (acre-ft)	0.00	4.00	0.32
C & E Loss (ft)	0.01	Cum SA (acres)	0.01	3.72	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 646 Profile: PF 7

E.G. Elev (ft)	618.38	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.19	Wt. n-Val.	0.100	0.055	0.100
W.S. Elev (ft)	618.19	Reach Len. (ft)	190.00	219.00	253.00
Crit W.S. (ft)	617.79	Flow Area (sq ft)	0.09	98.88	0.02
E.G. Slope (ft/ft)	0.023640	Area (sq ft)	0.09	98.88	0.02
Q Total (cfs)	341.70	Flow (cfs)	0.04	341.65	0.01
Top Width (ft)	131.15	Top Width (ft)	0.96	130.00	0.19
Vel Total (ft/s)	3.45	Avg. Vel. (ft/s)	0.47	3.46	0.38
Max Chl Dpth (ft)	2.19	Hydr. Depth (ft)	0.10	0.76	0.10
Conv. Total (cfs)	2222.4	Conv. (cfs)	0.3	2222.1	0.0
Length Wtd. (ft)	234.32	Wetted Per. (ft)	0.98	130.35	0.27
Min Ch El (ft)	616.00	Shear (lb/sq ft)	0.14	1.12	0.10
Alpha	1.00	Stream Power (lb/ft s)	376.00	0.00	0.00
Frctn Loss (ft)	6.51	Cum Volume (acre-ft)	0.00	0.86	0.32
C & E Loss (ft)	0.02	Cum SA (acres)	0.00	0.56	0.14

Plan: Plan 02 Pettibone Creek North 2 RS: 427 Profile: PF 7

E.G. Elev (ft)	611.85	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.35	Wt. n-Val.		0.055	0.100
W.S. Elev (ft)	611.50	Reach Len. (ft)	306.00	234.00	165.00
Crit W.S. (ft)		Flow Area (sq ft)		6.14	66.57
E.G. Slope (ft/ft)	0.033087	Area (sq ft)		6.14	66.57
Q Total (cfs)	341.70	Flow (cfs)		33.75	307.95
Top Width (ft)	33.51	Top Width (ft)		4.50	29.01
Vel Total (ft/s)	4.70	Avg. Vel. (ft/s)		5.50	4.63
Max Chl Dpth (ft)	3.50	Hydr. Depth (ft)		1.36	2.29
Conv. Total (cfs)	1878.5	Conv. (cfs)		185.5	1693.0
Length Wtd. (ft)	202.91	Wetted Per. (ft)		5.18	29.73
Min Ch El (ft)	609.00	Shear (lb/sq ft)		2.45	4.63
Alpha	1.01	Stream Power (lb/ft s)	289.00	0.00	0.00
Frctn Loss (ft)	2.24	Cum Volume (acre-ft)		0.59	0.13
C & E Loss (ft)	0.04	Cum SA (acres)		0.23	0.05

Plan: Plan 02 Pettibone Creek North 2 RS: 193 Profile: PF 7

E.G. Elev (ft)	609.57	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.22	Wt. n-Val.		0.055	
W.S. Elev (ft)	609.35	Reach Len. (ft)	135.00	193.00	251.00
Crit W.S. (ft)		Flow Area (sq ft)		89.94	
E.G. Slope (ft/ft)	0.005452	Area (sq ft)		89.94	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	31.70	Top Width (ft)		31.70	
Vel Total (ft/s)	3.80	Avg. Vel. (ft/s)		3.80	
Max Chl Dpth (ft)	3.35	Hydr. Depth (ft)		2.84	
Conv. Total (cfs)	4627.7	Conv. (cfs)		4627.7	
Length Wtd. (ft)	193.00	Wetted Per. (ft)		34.22	
Min Ch El (ft)	606.00	Shear (lb/sq ft)		0.89	
Alpha	1.00	Stream Power (lb/ft s)	276.00	0.00	0.00
Frctn Loss (ft)	2.24	Cum Volume (acre-ft)		0.33	
C & E Loss (ft)	0.06	Cum SA (acres)		0.13	

Plan: Plan 02 Pettibone Creek North 2 RS: 0 Profile: PF 7

E.G. Elev (ft)	607.26	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.87	Wt. n-Val.		0.055	
W.S. Elev (ft)	606.39	Reach Len. (ft)	10.00	10.00	10.00
Crit W.S. (ft)	606.39	Flow Area (sq ft)		45.67	
E.G. Slope (ft/ft)	0.039832	Area (sq ft)		45.67	
Q Total (cfs)	341.70	Flow (cfs)		341.70	
Top Width (ft)	26.77	Top Width (ft)		26.77	
Vel Total (ft/s)	7.48	Avg. Vel. (ft/s)		7.48	
Max Chl Dpth (ft)	2.39	Hydr. Depth (ft)		1.71	
Conv. Total (cfs)	1712.1	Conv. (cfs)		1712.1	
Length Wtd. (ft)	10.00	Wetted Per. (ft)		27.95	
Min Ch El (ft)	604.00	Shear (lb/sq ft)		4.06	
Alpha	1.00	Stream Power (lb/ft s)	254.00	0.00	0.00
Frctn Loss (ft)	0.04	Cum Volume (acre-ft)		0.03	
C & E Loss (ft)	0.22	Cum SA (acres)			

Plan: Plan 02 Pettibone Creek North 1 RS: 1050 Profile: PF 7

E.G. Elev (ft)	604.75	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.12	Wt. n-Val.		0.055	
W.S. Elev (ft)	604.63	Reach Len. (ft)	65.00	203.00	349.00
Crit W.S. (ft)		Flow Area (sq ft)		244.55	

Plan: Plan 02 Pettibone Creek North 1 RS: 1050 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.002294	Area (sq ft)		244.55	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	72.13	Top Width (ft)		72.13	
Vel Total (ft/s)	2.79	Avg. Vel. (ft/s)		2.79	
Max Chl Dpth (ft)	4.63	Hydr. Depth (ft)		3.39	
Conv. Total (cfs)	14265.9	Conv. (cfs)		14265.9	
Length Wtd. (ft)	203.00	Wetted Per. (ft)		77.08	
Min Ch El (ft)	600.00	Shear (lb/sq ft)		0.45	
Alpha	1.00	Stream Power (lb/ft s)	321.00	0.00	0.00
Frctn Loss (ft)	1.07	Cum Volume (acre-ft)	0.02	3.48	0.00
C & E Loss (ft)	0.05	Cum SA (acres)		1.13	

Plan: Plan 02 Pettibone Creek North 1 RS: 847 Profile: PF 7

E.G. Elev (ft)	603.64	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.59	Wt. n-Val.		0.055	
W.S. Elev (ft)	603.05	Reach Len. (ft)	53.00	109.00	208.00
Crit W.S. (ft)		Flow Area (sq ft)		110.62	
E.G. Slope (ft/ft)	0.022449	Area (sq ft)		110.62	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	57.05	Top Width (ft)		57.05	
Vel Total (ft/s)	6.18	Avg. Vel. (ft/s)		6.18	
Max Chl Dpth (ft)	3.05	Hydr. Depth (ft)		1.94	
Conv. Total (cfs)	4559.8	Conv. (cfs)		4559.8	
Length Wtd. (ft)	109.00	Wetted Per. (ft)		58.70	
Min Ch El (ft)	600.00	Shear (lb/sq ft)		2.64	
Alpha	1.00	Stream Power (lb/ft s)	453.00	0.00	0.00
Frctn Loss (ft)	1.33	Cum Volume (acre-ft)	0.02	2.65	0.00
C & E Loss (ft)	0.06	Cum SA (acres)		0.83	

Plan: Plan 02 Pettibone Creek North 1 RS: 738 Profile: PF 7

E.G. Elev (ft)	602.24	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.39	Wt. n-Val.		0.055	
W.S. Elev (ft)	601.86	Reach Len. (ft)	88.00	82.00	38.00
Crit W.S. (ft)		Flow Area (sq ft)		136.91	
E.G. Slope (ft/ft)	0.007673	Area (sq ft)		136.91	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	42.50	Top Width (ft)		42.50	
Vel Total (ft/s)	4.99	Avg. Vel. (ft/s)		4.99	

Plan: Plan 02 Pettibone Creek North 1 RS: 738 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	3.86	Hydr. Depth (ft)		3.22	
Conv. Total (cfs)	7799.5	Conv. (cfs)		7799.5	
Length Wtd. (ft)	82.00	Wetted Per. (ft)		44.71	
Min Ch El (ft)	598.00	Shear (lb/sq ft)		1.47	
Alpha	1.00	Stream Power (lb/ft s)	387.00	0.00	0.00
Frctn Loss (ft)	0.71	Cum Volume (acre-ft)	0.02	2.34	0.00
C & E Loss (ft)	0.02	Cum SA (acres)		0.70	

Plan: Plan 02 Pettibone Creek North 1 RS: 656 Profile: PF 7

E.G. Elev (ft)	601.52	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.54	Wt. n-Val.		0.055	
W.S. Elev (ft)	600.97	Reach Len. (ft)	195.00	82.00	28.00
Crit W.S. (ft)		Flow Area (sq ft)		115.43	
E.G. Slope (ft/ft)	0.009861	Area (sq ft)		115.43	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	32.44	Top Width (ft)		32.44	
Vel Total (ft/s)	5.92	Avg. Vel. (ft/s)		5.92	
Max Chl Dpth (ft)	4.97	Hydr. Depth (ft)		3.56	
Conv. Total (cfs)	6880.1	Conv. (cfs)		6880.1	
Length Wtd. (ft)	82.00	Wetted Per. (ft)		35.23	
Min Ch El (ft)	596.00	Shear (lb/sq ft)		2.02	
Alpha	1.00	Stream Power (lb/ft s)	335.00	0.00	0.00
Frctn Loss (ft)	0.72	Cum Volume (acre-ft)	0.02	2.11	0.00
C & E Loss (ft)	0.08	Cum SA (acres)		0.63	

Plan: Plan 02 Pettibone Creek North 1 RS: 574 Profile: PF 7

E.G. Elev (ft)	600.72	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.27	Wt. n-Val.		0.055	
W.S. Elev (ft)	600.44	Reach Len. (ft)	104.00	203.00	201.00
Crit W.S. (ft)		Flow Area (sq ft)		163.11	
E.G. Slope (ft/ft)	0.007888	Area (sq ft)		163.11	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	66.88	Top Width (ft)		66.88	
Vel Total (ft/s)	4.19	Avg. Vel. (ft/s)		4.19	
Max Chl Dpth (ft)	4.44	Hydr. Depth (ft)		2.44	
Conv. Total (cfs)	7692.2	Conv. (cfs)		7692.2	
Length Wtd. (ft)	203.00	Wetted Per. (ft)		70.72	
Min Ch El (ft)	596.00	Shear (lb/sq ft)		1.14	

Plan: Plan 02 Pettibone Creek North 1 RS: 574 Profile: PF 7 (Continued)

Alpha	1.00	Stream Power (lb/ft s)	348.00	0.00	0.00
Frctn Loss (ft)	2.11	Cum Volume (acre-ft)	0.02	1.84	0.00
C & E Loss (ft)	0.04	Cum SA (acres)		0.54	

Plan: Plan 02 Pettibone Creek North 1 RS: 371 Profile: PF 7

E.G. Elev (ft)	598.55	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.70	Wt. n-Val.		0.055	
W.S. Elev (ft)	597.85	Reach Len. (ft)	27.00	59.00	188.00
Crit W.S. (ft)		Flow Area (sq ft)		101.85	
E.G. Slope (ft/ft)	0.014381	Area (sq ft)		101.85	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	31.64	Top Width (ft)		31.64	
Vel Total (ft/s)	6.71	Avg. Vel. (ft/s)		6.71	
Max Chl Dpth (ft)	3.85	Hydr. Depth (ft)		3.22	
Conv. Total (cfs)	5697.2	Conv. (cfs)		5697.2	
Length Wtd. (ft)	59.00	Wetted Per. (ft)		34.19	
Min Ch El (ft)	594.00	Shear (lb/sq ft)		2.67	
Alpha	1.00	Stream Power (lb/ft s)	362.00	0.00	0.00
Frctn Loss (ft)	0.52	Cum Volume (acre-ft)	0.02	1.23	0.00
C & E Loss (ft)	0.10	Cum SA (acres)		0.31	

Plan: Plan 02 Pettibone Creek North 1 RS: 312 Profile: PF 7

E.G. Elev (ft)	597.93	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.36	Wt. n-Val.		0.055	
W.S. Elev (ft)	597.57	Reach Len. (ft)	19.00	73.00	156.00
Crit W.S. (ft)		Flow Area (sq ft)		141.93	
E.G. Slope (ft/ft)	0.006031	Area (sq ft)		141.93	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	37.48	Top Width (ft)		37.48	
Vel Total (ft/s)	4.81	Avg. Vel. (ft/s)		4.81	
Max Chl Dpth (ft)	5.57	Hydr. Depth (ft)		3.79	
Conv. Total (cfs)	8797.2	Conv. (cfs)		8797.2	
Length Wtd. (ft)	73.00	Wetted Per. (ft)		40.84	
Min Ch El (ft)	592.00	Shear (lb/sq ft)		1.31	
Alpha	1.00	Stream Power (lb/ft s)	350.00	0.00	0.00
Frctn Loss (ft)	0.64	Cum Volume (acre-ft)	0.02	1.06	0.00
C & E Loss (ft)	0.04	Cum SA (acres)		0.26	

Plan: Plan 02 Pettibone Creek North 1 RS: 239 Profile: PF 7

E.G. Elev (ft)	597.25	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.74	Wt. n-Val.		0.055	
W.S. Elev (ft)	596.52	Reach Len. (ft)	14.00	56.00	35.00
Crit W.S. (ft)		Flow Area (sq ft)		99.24	
E.G. Slope (ft/ft)	0.013653	Area (sq ft)		99.24	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	28.03	Top Width (ft)		28.03	
Vel Total (ft/s)	6.88	Avg. Vel. (ft/s)		6.88	
Max Chl Dpth (ft)	4.52	Hydr. Depth (ft)		3.54	
Conv. Total (cfs)	5846.9	Conv. (cfs)		5846.9	
Length Wtd. (ft)	56.00	Wetted Per. (ft)		30.81	
Min Ch El (ft)	592.00	Shear (lb/sq ft)		2.75	
Alpha	1.00	Stream Power (lb/ft s)	338.00	0.00	0.00
Frctn Loss (ft)	0.88	Cum Volume (acre-ft)	0.02	0.86	0.00
C & E Loss (ft)	0.01	Cum SA (acres)		0.21	

Plan: Plan 02 Pettibone Creek North 1 RS: 183 Profile: PF 7

E.G. Elev (ft)	596.37	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.80	Wt. n-Val.		0.055	
W.S. Elev (ft)	595.57	Reach Len. (ft)	227.00	98.00	25.00
Crit W.S. (ft)		Flow Area (sq ft)		94.94	
E.G. Slope (ft/ft)	0.018145	Area (sq ft)		94.94	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	31.70	Top Width (ft)		31.70	
Vel Total (ft/s)	7.20	Avg. Vel. (ft/s)		7.20	
Max Chl Dpth (ft)	3.57	Hydr. Depth (ft)		3.00	
Conv. Total (cfs)	5071.9	Conv. (cfs)		5071.9	
Length Wtd. (ft)	98.00	Wetted Per. (ft)		34.15	
Min Ch El (ft)	592.00	Shear (lb/sq ft)		3.15	
Alpha	1.00	Stream Power (lb/ft s)	344.00	0.00	0.00
Frctn Loss (ft)	0.61	Cum Volume (acre-ft)	0.02	0.73	0.00
C & E Loss (ft)	0.17	Cum SA (acres)		0.17	

Plan: Plan 02 Pettibone Creek North 1 RS: 85 Profile: PF 7

E.G. Elev (ft)	595.58	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.23	Wt. n-Val.		0.055	
W.S. Elev (ft)	595.36	Reach Len. (ft)	213.00	98.00	26.00
Crit W.S. (ft)		Flow Area (sq ft)		178.18	

Plan: Plan 02 Pettibone Creek North 1 RS: 85 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.003113	Area (sq ft)		178.18	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	38.71	Top Width (ft)		38.71	
Vel Total (ft/s)	3.83	Avg. Vel. (ft/s)		3.83	
Max Chl Dpth (ft)	5.36	Hydr. Depth (ft)		4.60	
Conv. Total (cfs)	12244.3	Conv. (cfs)		12244.3	
Length Wtd. (ft)	98.00	Wetted Per. (ft)		43.92	
Min Ch El (ft)	590.00	Shear (lb/sq ft)		0.79	
Alpha	1.00	Stream Power (lb/ft s)	426.00	0.00	0.00
Frctn Loss (ft)	0.47	Cum Volume (acre-ft)	0.02	0.43	0.00
C & E Loss (ft)	0.02	Cum SA (acres)		0.09	

Plan: Plan 02 Pettibone Creek North 1 RS: 0 Profile: PF 7

E.G. Elev (ft)	595.09	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.42	Wt. n-Val.		0.055	
W.S. Elev (ft)	594.67	Reach Len. (ft)	10.00	10.00	10.00
Crit W.S. (ft)		Flow Area (sq ft)		131.44	
E.G. Slope (ft/ft)	0.008465	Area (sq ft)		131.44	
Q Total (cfs)	683.20	Flow (cfs)		683.20	
Top Width (ft)	41.05	Top Width (ft)		41.05	
Vel Total (ft/s)	5.20	Avg. Vel. (ft/s)		5.20	
Max Chl Dpth (ft)	4.67	Hydr. Depth (ft)		3.20	
Conv. Total (cfs)	7425.6	Conv. (cfs)		7425.6	
Length Wtd. (ft)	10.00	Wetted Per. (ft)		43.47	
Min Ch El (ft)	590.00	Shear (lb/sq ft)		1.60	
Alpha	1.00	Stream Power (lb/ft s)	320.00	0.00	0.00
Frctn Loss (ft)	0.03	Cum Volume (acre-ft)	0.02	0.08	0.00
C & E Loss (ft)	0.08	Cum SA (acres)			

Plan: Plan 02 Pettibone Creek Main RS: 911 Profile: PF 7

E.G. Elev (ft)	594.97	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.14	Wt. n-Val.	0.100	0.055	0.100
W.S. Elev (ft)	594.84	Reach Len. (ft)	31.00	94.00	128.00
Crit W.S. (ft)		Flow Area (sq ft)	170.88	555.18	0.87
E.G. Slope (ft/ft)	0.002608	Area (sq ft)	170.88	555.18	0.87
Q Total (cfs)	1995.20	Flow (cfs)	250.78	1744.06	0.35
Top Width (ft)	221.98	Top Width (ft)	61.89	158.00	2.09
Vel Total (ft/s)	2.74	Avg. Vel. (ft/s)	1.47	3.14	0.40

Plan: Plan 02 Pettibone Creek Main RS: 911 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	6.84	Hydr. Depth (ft)	2.76	3.51	0.42
Conv. Total (cfs)	39068.8	Conv. (cfs)	4910.7	34151.2	6.9
Length Wtd. (ft)	88.58	Wetted Per. (ft)	63.53	161.60	2.25
Min Ch El (ft)	588.00	Shear (lb/sq ft)	0.44	0.56	0.06
Alpha	1.18	Stream Power (lb/ft s)	555.00	0.00	0.00
Frctn Loss (ft)	0.34	Cum Volume (acre-ft)	0.21	7.36	0.00
C & E Loss (ft)	0.03	Cum SA (acres)	0.13	1.82	0.00

Plan: Plan 02 Pettibone Creek Main RS: 817 Profile: PF 7

E.G. Elev (ft)	594.60	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.45	Wt. n-Val.	0.100	0.055	
W.S. Elev (ft)	594.15	Reach Len. (ft)	171.00	138.00	135.00
Crit W.S. (ft)		Flow Area (sq ft)	64.64	345.44	
E.G. Slope (ft/ft)	0.006209	Area (sq ft)	64.64	345.44	
Q Total (cfs)	1995.20	Flow (cfs)	92.39	1902.81	
Top Width (ft)	125.99	Top Width (ft)	47.30	78.69	
Vel Total (ft/s)	4.87	Avg. Vel. (ft/s)	1.43	5.51	
Max Chl Dpth (ft)	6.15	Hydr. Depth (ft)	1.37	4.39	
Conv. Total (cfs)	25320.0	Conv. (cfs)	1172.5	24147.4	
Length Wtd. (ft)	138.76	Wetted Per. (ft)	47.93	83.00	
Min Ch El (ft)	588.00	Shear (lb/sq ft)	0.52	1.61	
Alpha	1.23	Stream Power (lb/ft s)	534.00	0.00	0.00
Frctn Loss (ft)	1.32	Cum Volume (acre-ft)	0.13	6.39	
C & E Loss (ft)	0.07	Cum SA (acres)	0.09	1.57	

Plan: Plan 02 Pettibone Creek Main RS: 679 Profile: PF 7

E.G. Elev (ft)	593.21	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.15	Wt. n-Val.		0.055	
W.S. Elev (ft)	592.06	Reach Len. (ft)	57.00	55.00	54.00
Crit W.S. (ft)		Flow Area (sq ft)		231.90	
E.G. Slope (ft/ft)	0.016332	Area (sq ft)		231.90	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	54.69	Top Width (ft)		54.69	
Vel Total (ft/s)	8.60	Avg. Vel. (ft/s)		8.60	
Max Chl Dpth (ft)	6.06	Hydr. Depth (ft)		4.24	
Conv. Total (cfs)	15612.1	Conv. (cfs)		15612.1	
Length Wtd. (ft)	55.00	Wetted Per. (ft)		58.95	
Min Ch El (ft)	586.00	Shear (lb/sq ft)		4.01	

Plan: Plan 02 Pettibone Creek Main RS: 679 Profile: PF 7 (Continued)

Alpha	1.00	Stream Power (lb/ft s)	398.00	0.00	0.00
Frctn Loss (ft)	0.49	Cum Volume (acre-ft)		5.47	
C & E Loss (ft)	0.18	Cum SA (acres)		1.35	

Plan: Plan 02 Pettibone Creek Main RS: 624 Profile: PF 7

E.G. Elev (ft)	592.54	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.54	Wt. n-Val.		0.055	
W.S. Elev (ft)	592.00	Reach Len. (ft)	7.00	113.00	264.00
Crit W.S. (ft)		Flow Area (sq ft)		338.44	
E.G. Slope (ft/ft)	0.005581	Area (sq ft)		338.44	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	64.00	Top Width (ft)		64.00	
Vel Total (ft/s)	5.90	Avg. Vel. (ft/s)		5.90	
Max Chl Dpth (ft)	8.00	Hydr. Depth (ft)		5.29	
Conv. Total (cfs)	26707.7	Conv. (cfs)		26707.7	
Length Wtd. (ft)	113.00	Wetted Per. (ft)		67.80	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		1.74	
Alpha	1.00	Stream Power (lb/ft s)	408.00	0.00	0.00
Frctn Loss (ft)	0.63	Cum Volume (acre-ft)		5.11	
C & E Loss (ft)	0.00	Cum SA (acres)		1.28	

Plan: Plan 02 Pettibone Creek Main RS: 511 Profile: PF 7

E.G. Elev (ft)	591.90	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.52	Wt. n-Val.		0.055	
W.S. Elev (ft)	591.38	Reach Len. (ft)	5.00	91.00	70.00
Crit W.S. (ft)		Flow Area (sq ft)		343.32	
E.G. Slope (ft/ft)	0.005647	Area (sq ft)		343.32	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	67.25	Top Width (ft)		67.25	
Vel Total (ft/s)	5.81	Avg. Vel. (ft/s)		5.81	
Max Chl Dpth (ft)	7.38	Hydr. Depth (ft)		5.10	
Conv. Total (cfs)	26550.1	Conv. (cfs)		26550.1	
Length Wtd. (ft)	91.00	Wetted Per. (ft)		70.89	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		1.71	
Alpha	1.00	Stream Power (lb/ft s)	433.00	0.00	0.00
Frctn Loss (ft)	0.83	Cum Volume (acre-ft)		4.23	
C & E Loss (ft)	0.08	Cum SA (acres)		1.11	

Plan: Plan 02 Pettibone Creek Main RS: 420 Profile: PF 7

E.G. Elev (ft)	590.99	Element	Left OB	Channel	Right OB
Vel Head (ft)	1.33	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.66	Reach Len. (ft)	122.00	88.00	30.00
Crit W.S. (ft)		Flow Area (sq ft)		215.19	
E.G. Slope (ft/ft)	0.017091	Area (sq ft)		215.19	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	45.66	Top Width (ft)		45.66	
Vel Total (ft/s)	9.27	Avg. Vel. (ft/s)		9.27	
Max Chl Dpth (ft)	5.66	Hydr. Depth (ft)		4.71	
Conv. Total (cfs)	15261.6	Conv. (cfs)		15261.6	
Length Wtd. (ft)	88.00	Wetted Per. (ft)		50.60	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		4.54	
Alpha	1.00	Stream Power (lb/ft s)	520.00	0.00	0.00
Frctn Loss (ft)	0.94	Cum Volume (acre-ft)		3.65	
C & E Loss (ft)	0.25	Cum SA (acres)		0.99	

Plan: Plan 02 Pettibone Creek Main RS: 332 Profile: PF 7

E.G. Elev (ft)	589.80	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.50	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.29	Reach Len. (ft)	149.00	33.00	26.00
Crit W.S. (ft)		Flow Area (sq ft)		350.67	
E.G. Slope (ft/ft)	0.007343	Area (sq ft)		350.67	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	86.94	Top Width (ft)		86.94	
Vel Total (ft/s)	5.69	Avg. Vel. (ft/s)		5.69	
Max Chl Dpth (ft)	5.29	Hydr. Depth (ft)		4.03	
Conv. Total (cfs)	23283.3	Conv. (cfs)		23283.3	
Length Wtd. (ft)	33.00	Wetted Per. (ft)		91.02	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		1.77	
Alpha	1.00	Stream Power (lb/ft s)	515.00	0.00	0.00
Frctn Loss (ft)	0.15	Cum Volume (acre-ft)		3.07	
C & E Loss (ft)	0.08	Cum SA (acres)		0.86	

Plan: Plan 02 Pettibone Creek Main RS: 299 Profile: PF 7

E.G. Elev (ft)	589.56	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.22	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.34	Reach Len. (ft)	135.00	26.00	25.00
Crit W.S. (ft)		Flow Area (sq ft)		526.48	

Plan: Plan 02 Pettibone Creek Main RS: 299 Profile: PF 7 (Continued)

E.G. Slope (ft/ft)	0.003240	Area (sq ft)		526.48	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	128.00	Top Width (ft)		128.00	
Vel Total (ft/s)	3.79	Avg. Vel. (ft/s)		3.79	
Max Chl Dpth (ft)	5.34	Hydr. Depth (ft)		4.11	
Conv. Total (cfs)	35052.1	Conv. (cfs)		35052.1	
Length Wtd. (ft)	26.00	Wetted Per. (ft)		136.09	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		0.78	
Alpha	1.00	Stream Power (lb/ft s)	531.00	0.00	0.00
Frctn Loss (ft)	0.07	Cum Volume (acre-ft)		2.74	
C & E Loss (ft)	0.02	Cum SA (acres)		0.78	

Plan: Plan 02 Pettibone Creek Main RS: 273 Profile: PF 7

E.G. Elev (ft)	589.48	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.17	Wt. n-Val.		0.055	
W.S. Elev (ft)	589.31	Reach Len. (ft)	134.00	66.00	27.00
Crit W.S. (ft)		Flow Area (sq ft)		602.16	
E.G. Slope (ft/ft)	0.002102	Area (sq ft)		602.16	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	129.06	Top Width (ft)		129.06	
Vel Total (ft/s)	3.31	Avg. Vel. (ft/s)		3.31	
Max Chl Dpth (ft)	5.31	Hydr. Depth (ft)		4.67	
Conv. Total (cfs)	43523.1	Conv. (cfs)		43523.1	
Length Wtd. (ft)	66.00	Wetted Per. (ft)		137.61	
Min Ch El (ft)	584.00	Shear (lb/sq ft)		0.57	
Alpha	1.00	Stream Power (lb/ft s)	512.00	0.00	0.00
Frctn Loss (ft)	0.20	Cum Volume (acre-ft)		2.40	
C & E Loss (ft)	0.02	Cum SA (acres)		0.70	

Plan: Plan 02 Pettibone Creek Main RS: 207 Profile: PF 7

E.G. Elev (ft)	589.25	Element	Left OB	Channel	Right OB
Vel Head (ft)	0.41	Wt. n-Val.		0.055	
W.S. Elev (ft)	588.83	Reach Len. (ft)	144.00	206.00	134.00
Crit W.S. (ft)		Flow Area (sq ft)		386.62	
E.G. Slope (ft/ft)	0.005006	Area (sq ft)		386.62	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	84.59	Top Width (ft)		84.59	
Vel Total (ft/s)	5.16	Avg. Vel. (ft/s)		5.16	

Plan: Plan 02 Pettibone Creek Main RS: 207 Profile: PF 7 (Continued)

Max Chl Dpth (ft)	6.83	Hydr. Depth (ft)		4.57	
Conv. Total (cfs)	28198.3	Conv. (cfs)		28198.3	
Length Wtd. (ft)	206.00	Wetted Per. (ft)		87.16	
Min Ch El (ft)	582.00	Shear (lb/sq ft)		1.39	
Alpha	1.00	Stream Power (lb/ft s)	495.00	0.00	0.00
Frctn Loss (ft)	1.83	Cum Volume (acre-ft)		1.66	
C & E Loss (ft)	0.02	Cum SA (acres)		0.54	

Plan: Plan 02 Pettibone Creek Main RS: 0 Profile: PF 7

		Element	Left OB	Channel	Right OB
E.G. Elev (ft)	587.39				
Vel Head (ft)	0.63	Wt. n-Val.		0.055	
W.S. Elev (ft)	586.76	Reach Len. (ft)			
Crit W.S. (ft)	586.37	Flow Area (sq ft)		313.48	
E.G. Slope (ft/ft)	0.020003	Area (sq ft)		313.48	
Q Total (cfs)	1995.20	Flow (cfs)		1995.20	
Top Width (ft)	142.42	Top Width (ft)		142.42	
Vel Total (ft/s)	6.36	Avg. Vel. (ft/s)		6.36	
Max Chl Dpth (ft)	4.76	Hydr. Depth (ft)		2.20	
Conv. Total (cfs)	14107.0	Conv. (cfs)		14107.0	
Length Wtd. (ft)		Wetted Per. (ft)		145.82	
Min Ch El (ft)	582.00	Shear (lb/sq ft)		2.68	
Alpha	1.00	Stream Power (lb/ft s)	477.00	0.00	0.00
Frctn Loss (ft)		Cum Volume (acre-ft)			
C & E Loss (ft)		Cum SA (acres)			

APPENDIX M

ERTEC BANK STABILIZATION REFERENCE DOCUMENTS

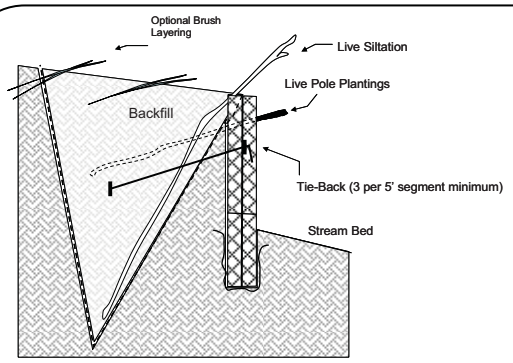
ERTEC Environmental Systems

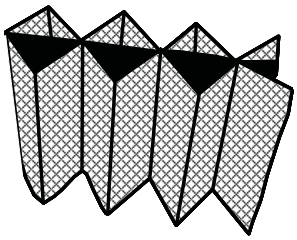
Protecting Global Lands and Waterways™

Bank Guard™

Bank Stabilization System

Bank Guard™ is a tested and patented high performance and cost effective system for **biotechnical** bank, bluff and cliff stabilization in river, stream, creek, wetland, and lake environments. Bank Guard supports habitat enhancement and complexity. The integrated woven monofilament filter allows water flow-thru while retaining soil particles, allowing vegetation establishment. Bank Guard is made from tough and UV stable HDPE. Any number or size of modules can be joined together to form a structure that adapts to any requirement.





- Height – 30”, 40”, 60”
- Interconnecting segments
- Fast installation
- Ideal for remote areas
- Lightweight, easy to transport
- Configurable for different requirements

Product Characteristics

Unit weight (lbs per sq. ft.)	2.2	Jacket Tensile Strength ASTM D4595 (lbs)	400
Configurable for different requirements	YES	UV Stability ASTM D4355 (% retained)	96
Filter permittivity ASTM D-4491 sec^{-1}	Variable	Strand Deform 0.375” pull through at 68°F (lbs)	38
Filter flow rate variable ASTM D-4491	Variable	Recycled Material Content (min %)	90
Filter AOS ASTM D-4751 (min) microns	Variable	Service temperature (deg F)	-30 to 160

Before

After (2 yrs)

Product Designation	Dimensions
Interconnecting Segments (BG20, BG30, BG40, BG48)	Segment Height: 20, 30, 40 or 48 inches Segment Length: 5 ft long Segment Width (depth): = 10” (max)

Design and Installation	For proper design and installation, refer to the Installation and Maintenance guide.

ERTEC Environmental Systems.
866-521-0724
info@ertecsystems.com

Bank Stabilization
Land Stabilization
GUIDE SPECIFICATION

PRODUCT:
Bank Guard™

MANUFACTURER:

ERTEC®
1150 Ballena Blvd. Suite 250
Alameda, CA 94501
Phone: 866-521-0724
Fax: 510-521-3972
email: sales@ertecsystems.com
Web: www.ertecsystems.com

1.0 Description:

Bank Guard™ (BG) is an erosion control system for **biotechnical** bank, bluff and cliff stabilization in river, stream, creek, wetland, and lake environments. BG supports vegetation restoration, habitat enhancement and complexity. The integrated woven monofilament filter allows water flow-thru while retaining soil particles. Bank Guard is made from tough and UV stable HDPE. Any number or size of modules can be joined together to form a structure that adapts to any requirement. BS is a very effective, low cost, and "soft" alternative to gabions, rip rap, concrete structures and other measures. The system comprises substantially hollow diamond shaped assemblies constructed of overlapping layers of polymeric apertured sheet and one or more integrated filters. They are typically assembled into a continuous assembly. The system allows permanent soil stabilization and restoration of vegetation and complex habitat. BG is highly effective when used in combination with re-vegetation practices.

2.0 Material:

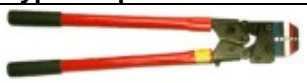
A. Furnish Bank Stabilization System (BSS) manufactured from non-biodegradable materials. The system shall comprise semi-rigid, overlapping layers of thermally extruded, apertured polymeric high density polyethylene (HDPE) sheets, and optional integrated filter sheets.
B. BSS shall be configured as detailed above from at least 90% HDPE by weight, by a manufacturer whose principle business is the manufacture of sediment and erosion control devices. The materials shall be UV-stabilized.
C. The BSS shall meet the minimum performance requirements of Table 1. The product must meet all numeric performance values in Table 1 under the specific conditions as stated. Materials used in the manufacture of BSS should be UV stable – containing 1-3 percent by weight of carbon black.
D. Materials used in the manufacture of BSS should be chemically resistant to acids, bases and hydrocarbons.
E. BSS segments or modules should be capable of being assembled together in any configuration to meet site requirements, and shippable in easy to carry configurations, without the use of pallets, providing ease of movement at the job site and installation in remote areas.
F. BSS should provide variable filtration as per the characteristics of the native soil.
G. BSS should be fill-able via slurry or via compaction with native soil and or gravel.
H. Product Sheet. A copy of the manufacturer's product sheet together with instructions for installation shall be furnished to the Engineer 5 days before installation.
I. Approved Bank Stabilization Systems are as follows:
    a. **Bank Guard™ as manufactured by: ERTEC Environmental Systems, 1150 Ballena Blvd, Suite 250, Alameda, CA 94501 510-521-0724**

TABLE 1: BSS material property requirements

Specification	Value
Structure Height (in)	20, 30, 40 or 48
Section Length (ft)	5
Strand Deformation – 0.375" sphere – aperture pull-through at 68°F (lbs) (minimum)	38
Distance between strands (in) (maximum)	0.185
Strand thickness (in) (maximum)	0.10
Distance between strand centers (in) (maximum)	0.25
Jacket Material - Mass per Unit Weight range (lbs/ft^2)	0.16 to 0.19
Tensile Strength – machine direction ASTM D4595 (lbs) (minimum)	400
Tensile Strength – transverse direction ASTM D4595 (lbs) (minimum)	325
Aperture Size – Cylinder PASS (dimensional range within which a cylinder will pass thru) (in)	0.141 - 0.156
Aperture Size – Cylinder NO PASS (smallest dimension that will not pass) (in)	0.212
Ultraviolet stability - percent tensile strength retained ASTM D 4355	96%
Jacket Material - Thickness ASTM 5199 minimum (in)	0.115
Shore Hardness (published base polymer data) at 68°F	95
CBR Puncture strength ASTM D 6241 nominal (lbs)	237
Jacket Material - Flow Rate ASTM D 4491 minimum gal/min/ft^2	650
Low Temperature Brittleness (published base polymer data) ASTM D 746 (°F)	-106
Operating Temperature (published base polymer data) range (°F)	-30 to 160
Integrated Filtration – aperture size, permittivity, % open area	Selected for project Mirafi FW700 or 402

3.0 Installation:

3.1 Recommended Tools

Item	**Typical specs**
Crimp tool (or swaging tool) For setting crimps in tie-backs	 HSC-600 Combination hand swaging tool
Wire Rope cutter For trimming tie-back wire	 C-7 Felco wire rope cutter

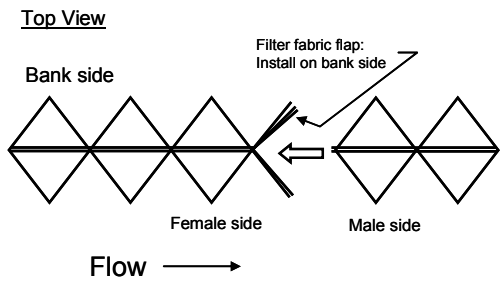
Cable Tensioning tool (Cable grip) For setting tie-backs	 Klein Haven Grip 1604-10
Anchor Drive Steel with extensions as required	For Duckbill Anchor 88-DB DS-88 (Part No. 50012) Length 48” Diameter 0.75” Head Diameter 1.5” Tip Diameter 0.75”
Sledge Hammer (for manual anchor driving)	
Shovels	
Pneumatic Driver (optional – for mechanical anchor driving)	
Excavator (optional)	
Portable Water or slurry pump, 100 ft hose (optional) – for filling modules, compacting soil	

3.2 Required Accessories

Item	Typical Spec	Average quantity per linear foot of bank (will vary with each project)
Tie-Back anchor	Duckbill Anchor: DB-88	0.6 / ft
Crimp sleeves	1/8” Diameter Zinc plated copper oval sleeves	1.5 / ft
ERTEC matrix screws		2.5 / ft
Base Geotextile filter		5 sq ft / ft
Plantings – native grasses, willows, etc.		As required

3.3 Installation Procedures

Step 1: Clear debris and unwanted material from site. Excavate soil to provide level footing to set the modules. Prepare trench depth as necessary in front of the bank to compensate for expected total scour.	**See Section 4.4**

Trench depth should be at least 1/4th the height of the structure. The top of the structure should be located as near as possible to bank full discharge (see link). http://chl.erdc.usace.army.mil/library/publications/chetn/pdf/chetn-viii-5.pdf When trenching in tidal areas, dig enough trench to support the day's work. Install a layer of geo-textile material at the base of BG as shown in the installation guidelines to eliminate the effects of hydraulic piping. Locate the Bank Guard sections into the trench. Each section fits into the adjoining section. Be sure that direction of male-female connection is consistent with flow (shown below). Butt sections together tightly. Fasten connecting flaps on female side to male side with ERTEC matrix screws. 4 to 6 screws on each side (front and bank side – from top to bottom on 10" c-c). Integrated filter fabric flap should be directed to bank side of module as shown.  	**See ERTEC Installation Guidelines, page 2.**
Step 2: Temporarily reinforce (stabilize) structure in upright position with t-posts or other method so that modules do not lean away from bank during backfilling operations. It is not necessary to install the modules against a smooth vertical face. Fill segments to the height shown in the installation guidelines with gravel (about ¼ to ⅓ of height) before beginning activities on bank side of structure. Excavate bank-side of Bank Guard in preparation for live siltation. Fill bank side of Bank Guard segments with in-situ materials or sand or gravel. Consolidate soil within and on the bank-side of structure by filling with water (slurry). If a water source is available, slurry soil into segments to provide soil compaction.	**See installation guidelines, page 3.** **See Section ____ (live siltation)**
Step 3: Plant live siltation.	**See Section ____** **(live siltation)** **See Installation Guidelines Page 4.**
Step 4: Backfill excavated area on bank-side of Bank Guard™. Install 3 tie-backs per structure at least 3.5 to 4 feet into the bank. Swage two crimps (oval sleeves) around each tie-back cable. Use the cable grips to tension cables tightly while sleeves are swaged (requires 2	**See section 4.3**

installers). Install live pole plantings thru the structure if required in the plans. Install brush layering up-bank of the structure if required by the plans. Plant surface area with native grasses, willows, etc.	

4.0 Design Considerations

All of the general bank stabilization considerations should be followed. The following are specific considerations for BSS structures

4.1 General Considerations

Bank Guard™ structures are appropriate solutions where:

- The vertical integrity of a soil bank needs higher strength to reduce sloughing of the bank
- There is moderate to excessive sub-surface water movements that may be creating erosion and damage other types of non-permeable structures
- Where bank must be stabilized and heavy machinery is not available to the site
- A retaining or toe wall is needed to stabilize the bank
- An excessively steep slope must be stabilized and vegetative or mechanical means of stabilization (i.e. pulling back bank) are not feasible due to site conditions and location

4.2 Tie-Backs and Anchors

Recommended anchor for cable tie-back system: Duckbill Anchors

The DUCKBILL earth anchor has been developed to function in the total range of soils.

The DUCKBILL anchor works very much like a toggle bolt. The anchor body is driven into the soil with the re-useable drive steel (drive rod). Once the anchor body is placed to the proper depth the drive steel is removed. A backward pull on the cable then rotates the anchor body in the ground until it is perpendicular to the cable. This is called anchor-locking the anchor. Because the DUCKBILL is driven into the earth, it compacts the soil around it. As the anchor is anchor-locked it cuts through the compacted soil into undisturbed soil and compacts the soil further. One of the most important features of the DUCKBILL anchoring concept is the ability to proof-test the anchor during normal installation. The anchor locking operation can be a proof-test of the anchor. By measuring the force required to anchor-lock the anchor the installer knows the actual holding capacity of the installation.

Design must take into account forces and soil characteristics. 88-DB is suitable for most installations. Specifications are as follows:

DUCKBILL MODEL #	RATED CAPACITY	DRIVE ROD DIAMETER	MINIMUM DEPTH OF INSTALLATION INTO BANK
Model 88-DB1	3,000 lbs.	¾"	3 ½'

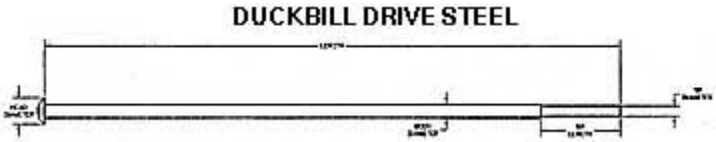
The anchors are rated in an average soil condition. Higher capacities can be expected in harder soils and lower capacities in softer soils. The rating is mainly useful as a reference for anchor selection. Proof-loading is the only way to insure the exact capacity of each installation.

Installation
The first step in any installation is to select the proper anchor for the job. Keep in mind the maximum load expected and add a reasonable safety factor.

Driving the anchor

The DUCKBILL® can be driven to almost any depth at any angle. Start by inserting the drive-steel into the anchor body. Use a sledge hammer, fence post driver or a power driven jack-hammer to drive the anchor to the proper depth.

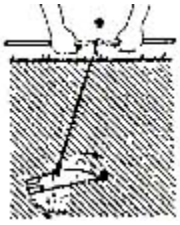
Drive Steel



FOR USE ON ANCHOR	PART NUMBER	DESCRIPTION	LENGTH INCHES	BODY DIAMETER INCHES	HEAD DIAMETER INCHES	TIP LENGTH INCHES	TIP DIAMETER INCHES
88-DB	50012	DS-88	48	.75	1.50	N/A	.75

Locking the Anchor

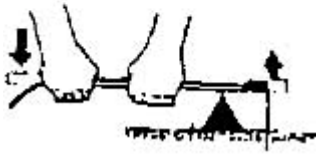
After the anchor has been driven to depth, the drive steel is retracted from the anchor. Pull back on the anchor cable to toggle the anchor into the perpendicular position. In average soils a rule of thumb is that the length of pull should equate to the length of the anchor. For example: Model 88 anchor body measures 6" inches. A pull of 5-6" will rotate the anchor into a completely perpendicular position. Several methods are used to anchor lock the anchors.



Anchor locking by hand
The smaller DUCKBILL models may be locked by hand. Insert the drive steel through the cable loop or wrap the cable around the drive steel to fashion a "T" handle. Pull on the drive steel to anchor-lock the anchor. A fulcrum is also very useful in locking anchors by hand.

Come-alongs and fence stretchers
These tools work very well providing that there is a substantial counter anchor nearby. A truck bumper for example.

No matter what method is used, it is critical that the anchor be properly locked before tying off the object to be anchored.
An anchor not properly locked prior to attaching will result in significant pull out before the anchor self locks. Obviously this is not desired. Failure to install and lock the anchor at the correct angle will result in the anchor cable cutting through the soil until the angles equalize. This will cause slack.



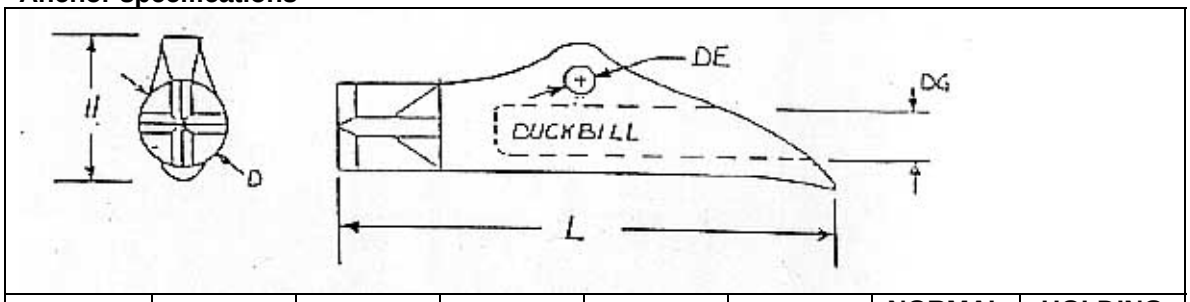
Special Soil Considerations
Soft soils
In areas where the soil proves to be softer than normal, steps should be taken to assure the capacity of the anchor. Proof-loading is especially useful in soft soils. Guesswork as to the capacity is eliminated. The installer will know immediately if the anchor point is adequate or if further steps are necessary. Backfilling and tamping the hole behind the anchor will yield somewhat higher capacity in most soft soils. Fill and tamp the hole in 3" lifts prior to anchor locking the anchor. Another option is to drive the anchor deeper in an effort to penetrate a harder layer of soil. Larger anchors may need to be placed to achieve the required load. As a last resort a number of anchors may be placed in a cluster and bridled together to form one point.

Hard soils and rock
If excessive resistance to driving occurs it may be necessary to drill a hole. If the anchor stops moving and is subjected to excessive pounding (especially from power equipment) metal fatigue can occur and the anchor body can fracture. The DUCKBILL® anchor may be placed in a pre-drilled hole in hard dirt or rocky material, and achieve very good results. Hand augers and gasoline or hydraulic powered earth drills can be used to form the hole. A PIONJAR 120 gasoline powered breaker/drill is very useful due to the fact that it performs both drilling and driving operations.

Clearance hole diameters and hard soil pilot hole diameters
Installation of anchors in hard soils can be greatly helped by the use of a pilot hole. Typically, the pilot hole has no significant affect on the holding power of the anchor. There are many acceptable methods of drilling pilot holes and many manufactures of equipment to do so. Recommended hard soil pilot hole diameters and clearance hole diameters are charted below.

Anchor model	Clearance hole diameter	Minimum pilot hole diameter for hard soil
88-DB	2.25"	2.00"
138-DB	2.75"	2.50"

Anchor specifications



ANCHOR MODEL	D (in)	L (in)	H (in)	DE (in)	DG (in)	NORMAL DEPTH (in)	HOLDING CAPACITY (lbs)
88	1.25	6.25	2.25	0.31	0.75	42	3000
138	1.90	11.50	2.75	0.38	1.13	60	5000

4.3 Filter blanket, Geo-textile:

A synthetic filter fabric should be used under and behind the BSS structure. The following particle size relationships should exist:

Filter fabric covering a base with granular particles containing 50% or less (by weight) of fine particles (less than U.S. Standard Sieve no. 200 (74 microns)

$$D_{85}\ base\ (mm) \Big/ EOS\ of\ \ filter\ \ fabric \quad \geq 1$$

EOS = Equivalent Opening Size compared to a U.S. Standard sieve size

D_{85} = The particle size at which 85% of the constituent particles are smaller

No filter fabric should have less than 4% open area or an EOS less than U.S. Standard Sieve No. 100 (15 microns). The permeability of the fabric must be greater than that of the soil. The fabric

may be made of woven or non-woven monofilament materials and should meet the following minimum requirements:

- Thickness 0.5 to 1.5 mm (20 to 60 mils)
- Grab strength 41 to 54 kg (90 to 120 lbs)
- Conform to ASTM D-1682 or ASTM D-177

Filter blankets should always be provided where seepage is significant or where flow velocity and duration of flow or turbulence may cause the underlying soil particles to move out of the bank. Most geo-textile suppliers can offer assistance, and in some cases, fabric selection software to enable proper selection of the fabric.

4.4 Scour and long-term stability

- BSS should be securely keyed into the bank and ground (bed) to assure that flows do not erode the soils beneath or around it. Start structure where it is stable, and end structure where it is stable. The upstream and downstream keys of a longitudinal structure should never be keyed in at right angles; 20 to 30 degrees relative to the structure is best. Employ smooth expansions and contractions.
- Starting at the lowest point of the slope, excavate the loose material below the bed (ground) elevation until a stable foundation is reached. The designer must take Total Scour (additive effects of Long term, General and Local Scour) into account when determining the depth of excavation below the bed.

4.5 Vegetation – Planting considerations

- Section 4.5 is not comprehensive. Consult with a planting specialist familiar with the location.
- It is possible to plant around and through the BG structures. Vegetation can be integrated into the design and installed during construction in order to receive the maximum geotechnical and habitat benefits e.g., better soil reinforcement, more roots, faster growth, etc. The more stem length in contact with the soil, the more roots will grow; therefore, more cover will result in greater soil reinforcement, and greater habitat enhancement.
- Woody type vegetation that can withstand periods of inundation, such as willow, have been successfully planted, in conjunction with the structural elements, in the upper areas of the toe protection zone. The most important criterion for success is the type of biotechnical technique (i.e. pole planting).
- For un-rooted stock, plant 80% in soil, 20% out
- Good stem to soil contact is critical-tamp and water-in material
- Use a variety of techniques, plant materials and material sizes
- Determine what type and where native vegetation was found in the system
- Consider herbaceous plants (sedges, reeds, emergent aquatics, grasses, etc.)
- Harvested cuttings should be kept moist and out of direct sunlight
- Some cuttings benefit from soaking (up to 31 days for Black Willow). Water for soaking plants should be fresh.
- It is very important to have good soil-to-stem contact.
- Construction personnel must be trained about brush layering and about how to treat live plant material.
- Slow release fertilizers and mycorrhizae should be incorporated into the plantings as appropriate for the site.
- Limit the use of geotextile fabrics where it might inhibit growth of roots

Most vegetative stabilization projects are carried out on banks or slopes that are devoid of topsoil and which have relatively inert subsoil. Only well adapted pioneer plants will survive and

establish under these conditions. The design team should also be aware that the rooting habits of plants are extremely dependent on environmental controls. Even though certain plants are known to have tough active root systems, drought, soil compaction and poor nutrition take their tolls on any root system establishment. The designer should always take precautions to create the best possible soil medium for best possible rooting response. Unless special harvesting and refrigerated storage provisions are employed, biotechnical measures must be installed during dormancy. Identify willow species, growth form, site, and soil conditions on adjacent sites and compare their conditions to the construction site. Planting will be more successful as the soil, site conditions and species selected match stable and vegetated nearby sites. (When harvesting do not take more than 2/3 of plant). Basal end should be at least ¾". For best results, cuttings should be soaked for a minimum for as much as 10 to 14 days. If branch cuttings are not pre-soaked then they shall be harvested no earlier than 24 hours prior to installation. Cuttings must be kept moist and cool at all times between cutting and installation. All cuttings must be thoroughly wet and covered with moistened wrapping before being transported. All plantings should be basal side down.

Biotechnical bank stabilization offers benefits such as relatively simple installation, visual appearance, filtering of sediment, uptake of nutrients, and environmental compatibility to make it an attractive and cost effective approach.

Live Siltation notes and guidelines:

Live siltation performs several functions for bank stabilization:

- Slowing flow along the bank. Vegetation that protrudes from the bank grows into the level of bank full discharge. When the stream rises, live siltation provides hydraulic roughness and slows velocity.
- Encouraging sediment deposition
- Reducing bank erosion
- Embedded branches and roots also reinforce the bank and reduce geotechnical failure while the branches and leaves provide cover, aquatic food sources and organic matter.

Construction Specifications

- Willow cuttings are most commonly used for live siltation.
- Branch cuttings shall be 6-8 feet long, ¾ to 2 inches in diameter at the base
- The surface of the excavated bench shall be sloped sharply so the cuttings are laying at an angle of 45° or more. The basal ends must be down.
- Place 4 to 6 branches per foot of linear bank. The growing tips shall protrude a minimum of 12 inches from the bank face with the basal end in the bank. As soon as possible backfill in 6" to 8" lifts and compact according to construction specifications. Water the lifts immediately to wet the cuttings and achieve adequate compaction. Add fertilizer and mycorrhizae at the specified rate.
- Fill and compact the soil placed above the brush layer in successive lifts, maximum 6-8 inches deep.
- Irrigate, irrigate, irrigate

Brush Layering notes and guidelines:

Brush layering performs several functions for bank stabilization:

- Breaking up the bank-slope length into a series of shorter slopes
- Reinforcing the bank as roots develop, adding significant resistance to flow
- Providing bank stability and allowing vegetative recovery
- Aiding infiltration on dry sites or aiding drying on wet sites

Construction Specifications

- Branch cuttings shall be 4-8 feet long, ¾ to 2 inches in diameter at the base

- The surface of the excavated bench shall be sloped slightly so the outside edge is higher that the inside. The basal ends must be below the tips.
- Place branch cuttings in an over lapping configuration. The growing tips shall protrude 6-12 inches from the slope face with the basal end in the bank. Place at least 4 branches per foot of linear bank.
- Immediately cover brush layer with 6 inches of fill soil and compact according to construction specifications. Water the soil cover immediately to wet the cuttings and achieve adequate compaction.
- Earth moving equipment shall not travel directly over the cuttings.
- Fill and compact the soil placed above the brush layer in successive lifts, maximum 6-8 inches deep.
- Install the next brush layer 3-8 feet above the previous row. (Vertical spacing depends on slope gradient and soil conditions).
- Seed and mulch the bank slope. Shallow slopes, generally 3:1 or flatter may be seeded and mulched by hand. Steeper slopes should have seed applied hydraulically and the mulch shall be anchored with tackifier or other approved methods.
- Irrigate, irrigate, irrigate

4.6 Retaining wall and shear force considerations

The main forces acting on BG walls are the vertical forces from the weight of the BG and fill materials, the lateral earth pressure acting on the back face and shear forces acting on the front face. If other forces are encountered, such as vehicular loads, they must also be included in the analysis.

The lateral earth pressure is usually calculated by the Coulomb equation. Although based on granular material, it is conservative for cohesive material. The active soil pressure force tends to overturn the wall, and this must be properly balanced by the resisting moment developed by the structure's weight and anchoring forces into the wall of the bank.

The tendency of the active earth pressure and active shear forces to cause the wall to slide horizontally must also be opposed by frictional and structural resistance.

5.0 Inspection and Maintenance

Properly designed and installed Bank Stabilization Systems require very little maintenance. BSS should be inspected periodically for scour or damage. Structural damage caused by storm events should be repaired as soon as possible to prevent further damage to the structure or erosion of the bank.

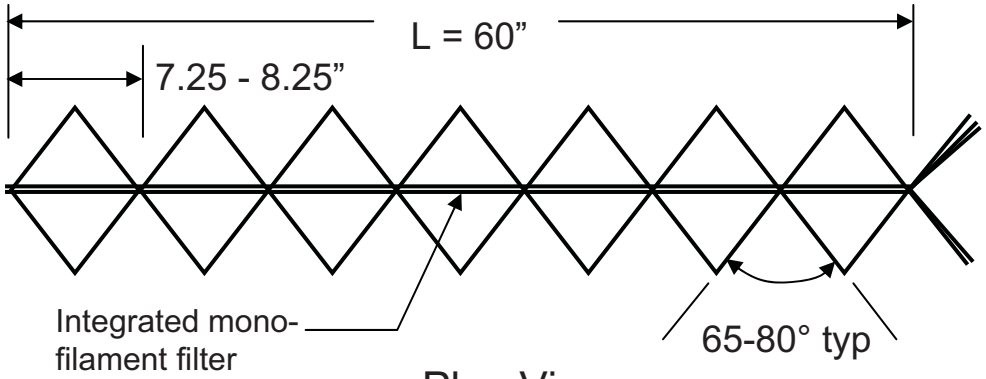
6.0 Method of Measurement:

Quantities of Bank Stabilization System to be paid for will be determined by the linear foot measured along the centerline of the installed barrier. Where Gully Stabilization System modules are joined and overlapped, the overlap will be measured as a single installed strip.

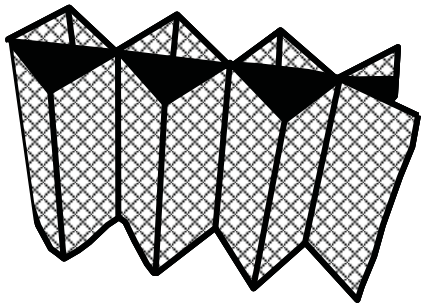
7.0 Basis of payment:

The contract price paid per linear foot for Bank Stabilization System shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in installing the Bank Stabilization System, complete in place, including trench/slot excavation, installation of geo-textile fabric, installation of downstream energy dissipation, and backfill, as shown on the project plans, and in these special provisions, and as directed by the Engineer.

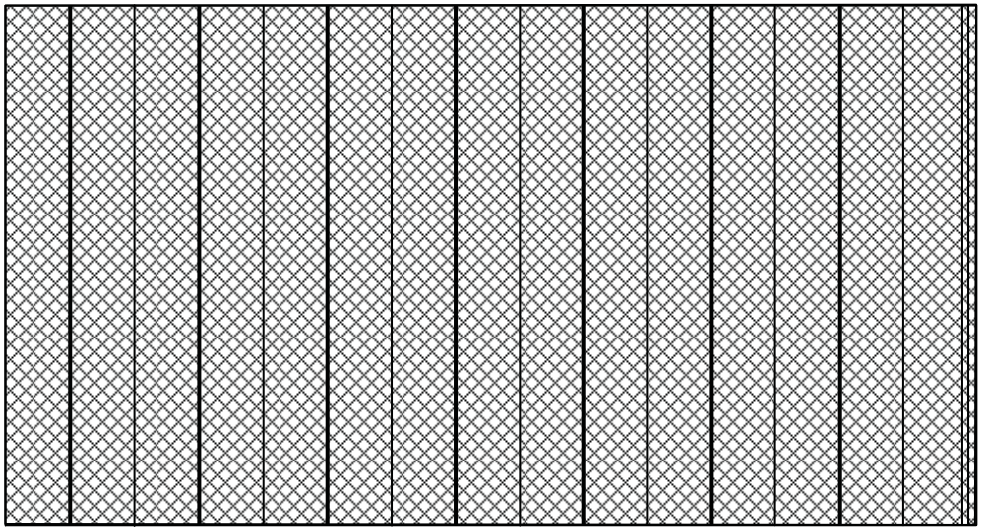
ERTEC Bank Guard™ - Bank Stabilization System



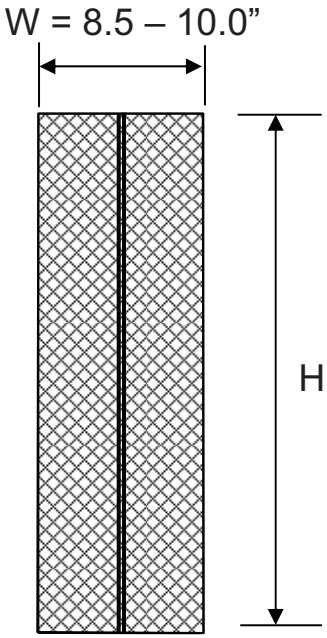
Plan View



Partial ISO View



Elevation View

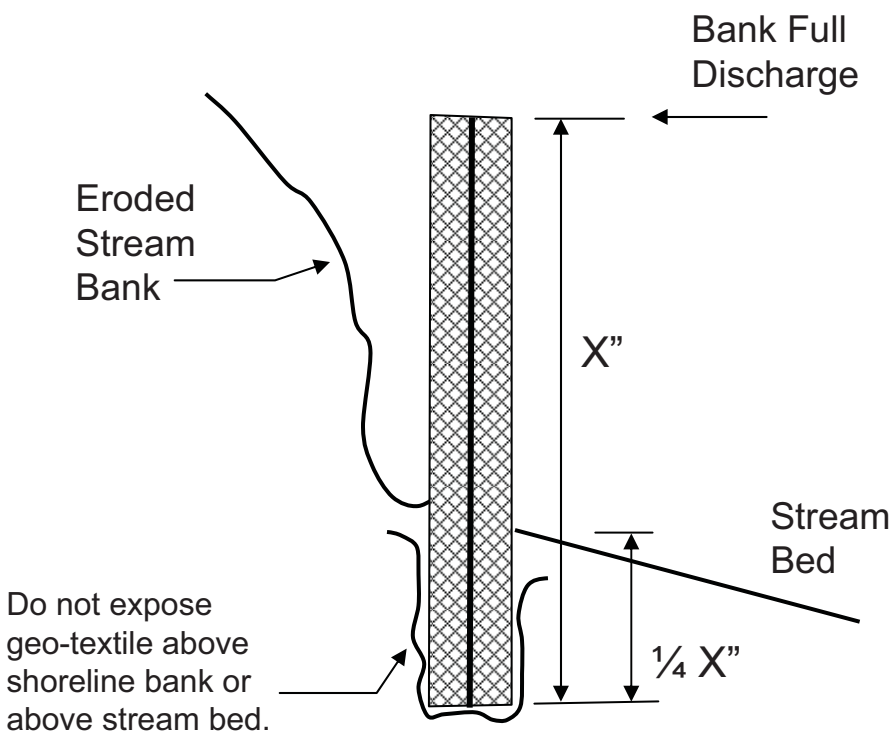


Side View

NOT TO SCALE

Bank Guard Section Dimensions

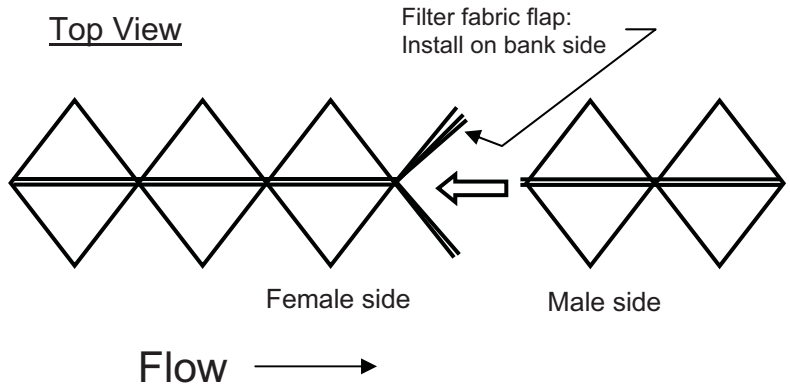
ERTEC Bank Guard™ - Bank Stabilization System



Side View

Step 1:

- Trench and locate BG segments



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Note: Geotextile fabrics: Internal geo-textile is integrated into the structure. Exterior geo-textile is purchased locally.

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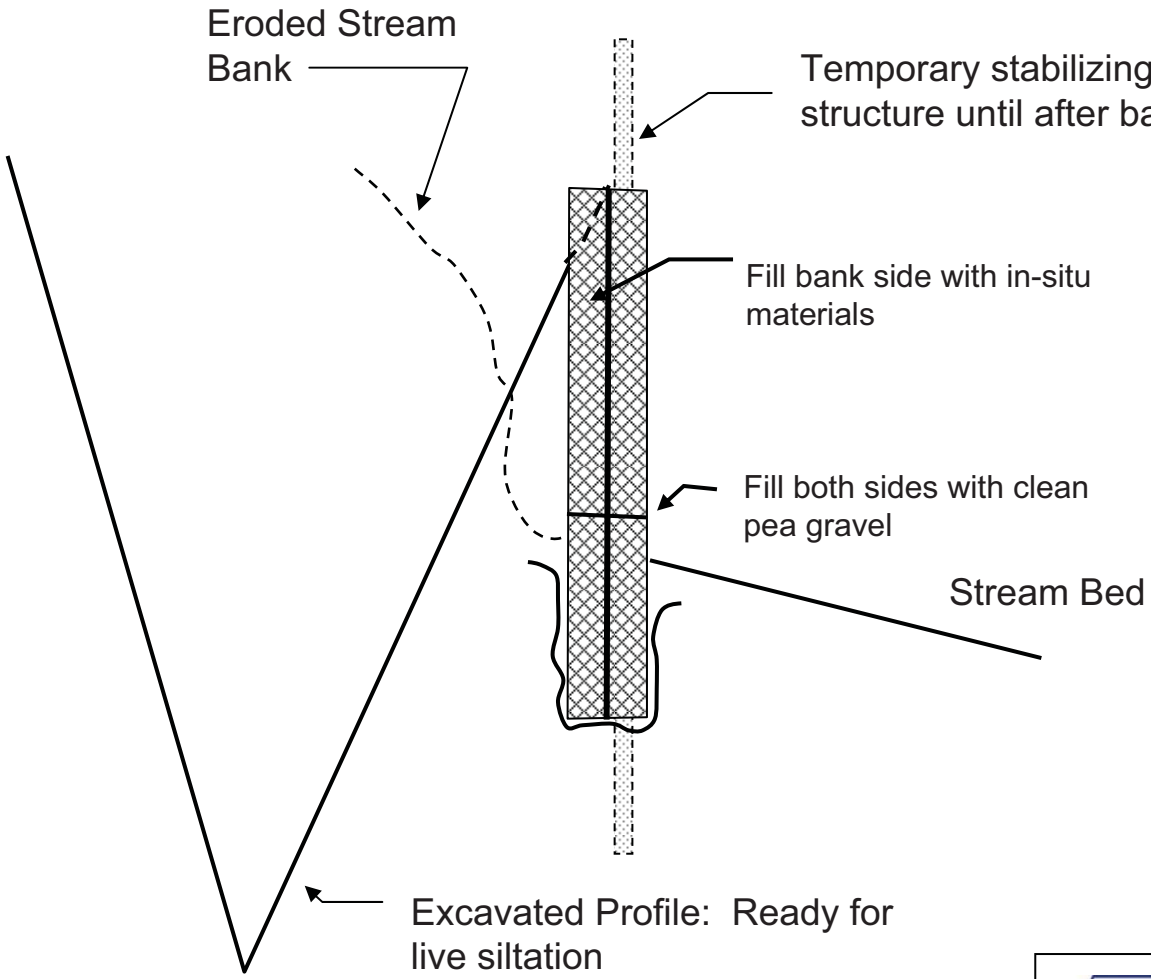

Step 2:

- Install temp stabilizing posts
- Excavate for live siltation
- Fill structure (gravel)

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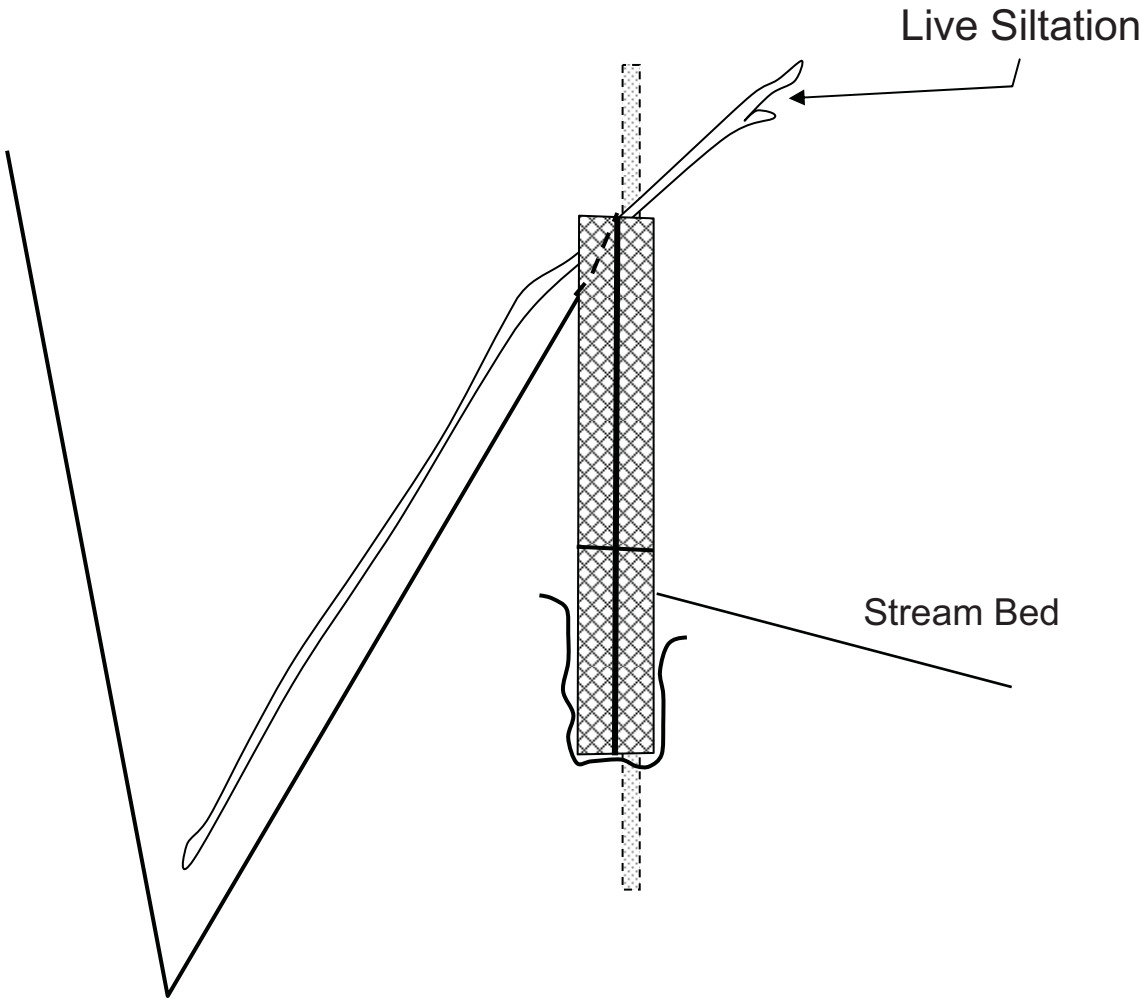

Step 3:
- Plant live siltation

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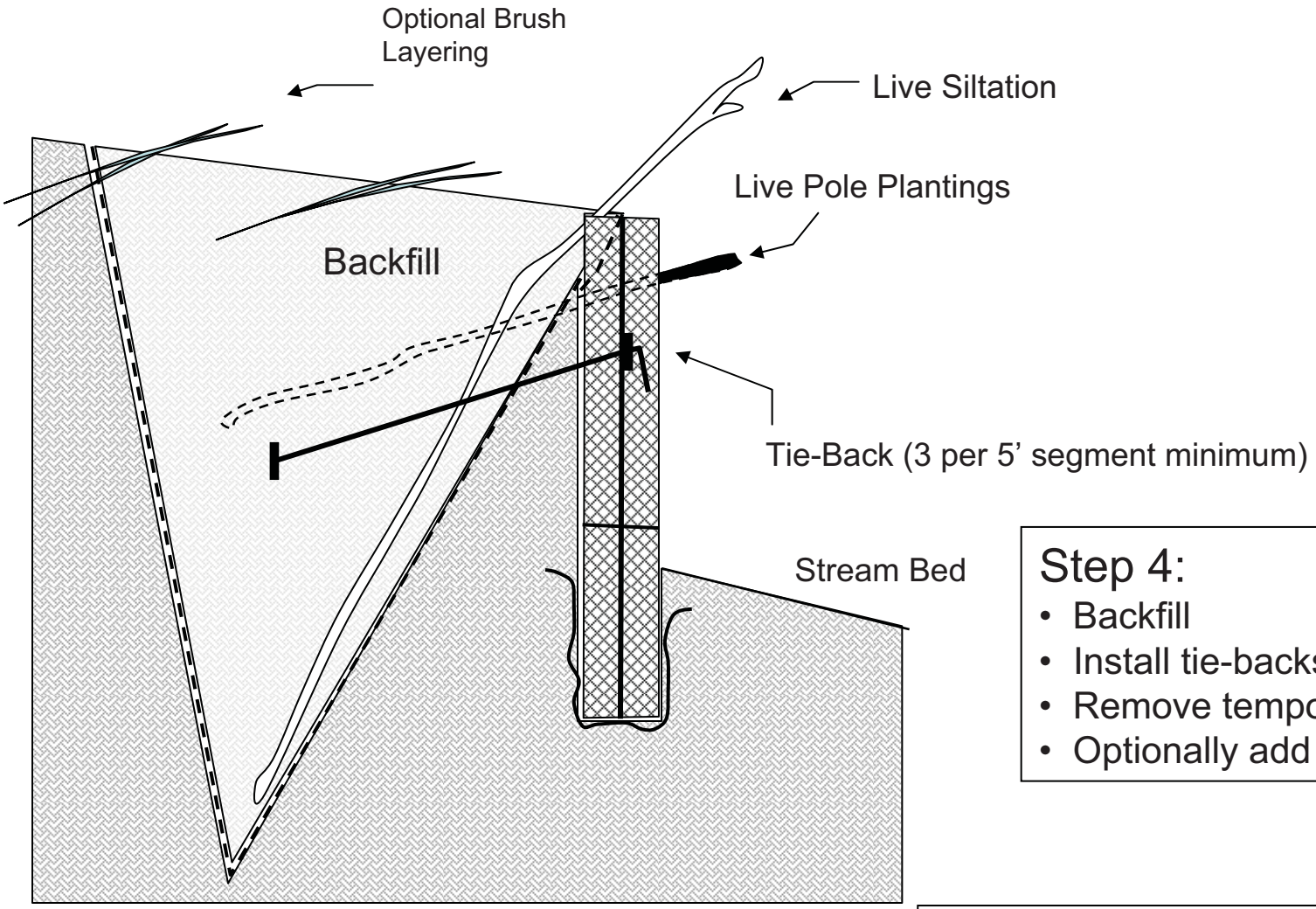

Step 4:

- Backfill
- Install tie-backs
- Remove temporary reinforcement
- Optionally add brush layering

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ERTEC Bank Guard™ - Bank Stabilization System

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NOT TO SCALE

APPENDIX N

ROOTWAD TECHNICAL GUIDANCE DOCUMENT

Rootwad Composites for Streambank Erosion Control and Fish Habitat Enhancement

by Traci Sylte[1] and Craig Fischenich [2]

May 2000

Complexity

Low Moderate High

Environmental Value

Low Moderate High

Cost

Low Moderate High

OVERVIEW

A rootwad composite is a combination of interlocking tree materials where a mass of tree roots, commonly called a rootwad, is utilized with other tree parts and revegetation methods to stabilize streambanks and provide aquatic habitat (Figure 1). Rootwad composites are often a cost-effective bank stabilization and habitat enhancement treatment.

Rootwad composites move the current line away from the streambank so that the bank is less susceptible to erosion through hydraulic forces (Figure 2). This, in effect, reduces the energy environment along the streambank/water interface so that riparian vegetation can provide the necessary bank protection and habitat values. Rootwad composites also generate turbulence that creates streambed scour and provides cover and substrate for aquatic organisms.

Other streambank stabilization measures generally offer less risk, but rootwad composites offer the following advantages: (1) are typically cost-effective because they utilize natural materials that are often found on or near the site; (2) eventually decompose, thus allowing the restored riparian zone to function naturally, (3) create habitat complexity, hydraulic diversity, and substrate sorting (Figure 3), and (4) induce less local sediment deposition than other flow deflection structures.

Figure 1. Rootwad composites after installation along a Montana stream

Figure 2. Project is not complete, but illustrates displacement of the current line away from the streambank (courtesy of Water Consulting, Inc.)

[1] Hydrologist/P.E., Lolo National Forest, Missoula, MT; [2] Research Civil Engineer, ERDC EL, Vicksburg, MS

Rootwad composites, like most bank stabilization treatments, have limitations. Thresholds for allowable shear stress have not been developed, so limits of their applicability have not been well-defined. Field studies suggest that they are susceptible to flanking and that their performance is highly dependent upon their orientation with respect to flow direction. Thus, the use of rootwad composites for erosion control should be limited to conditions where the up- and downstream ends are secured and at least one stable meander sequence exists upstream. However, these requirements do not limit the use of rootwad composites for habitat enhancement or augmenting riparian vegetation restoration.

Rootwad composites require a thorough and immediate revegetation plan for complete and long-term project success, and if not constructed properly, fish habitat enhancement values may be less than desired. Finally, if not orientated correctly with respect to current line and scour depth, and if protective measures for flanking are not accounted for, streambank failure may result.

PLANNING

The first step in the planning process is to determine whether rootwad composites are an appropriate tool to meet project objectives and constraints related to stability and habitat. This determination requires knowledge in many specialty areas including hydrology, hydraulic engineering, fluvial geomorphology, biology, ecology, geology, and landscape architecture.

Questions that must be addressed include the following interrelated items (not exhaustive):

1. Is stabilization necessary, or is the current and projected amount of erosion acceptable?
2. Will a management plan be established that places priority on the health of riparian vegetation after project completion?

Figure 3. Rootwad composites can offer substantial habitat complexity. Prior to installation of rootwad composites, this streambank was raw and eroding

3. Are rootwad composites the appropriate tool, given the magnitude of the erosion problem, e.g. the stream's geomorphic and morphological characteristics?
4. Are rootwad composites the appropriate tool for the desired aquatic habitat and species population dynamics?
5. Will the rootwad composites remain stable and provide the desired habitat for the particular flow regime and vegetative establishment period?
6. Is the level of risk associated with limited knowledge of allowable stress and thresholds acceptable?
7. Have consequences of failure been considered and what are they (e.g., what happens to the site and downstream conditions, if the composite becomes dislodged and moves downstream?)?
8. Are recreationalists subjected to an increased risk relative to other hazards within the stream system?
9. What riparian vegetation should be incorporated; how will the vegetation be planted; are large transplants available and what is the projected success rate based on the transplanting methods, timing, and site conditions?
10. Is there a location outside of the immediate floodplain in which to acquire the rootwad materials?
11. Are costs acceptable?

Rootwad composite projects generally cost less than other habitat enhancement and bank stabilization techniques. The costs in year 2000 dollars generally range from $12.00 to $60.00/lin. ft of streambank treated, with an average cost of about $25.00/lin. ft.

SITE CONSIDERATIONS

Although rootwad composites have the potential to function well on many types of streams, the risk of failure, habitat benefits, complication of design and construction, and overall aesthetics can differ among streams. Project success is often dependent on thorough knowledge of physical stream processes and ecological relations in the project stream, as well as experience in the design and construction of stabilization measures. Considerations when evaluating site viability for rootwad composites include, but are not limited to:

1. *Habitat Requirements*. Streambank stabilization projects where natural materials are sought to produce structural diversity, velocity differentials, scour, undercut banks, and substrate sorting are good candidates.
2. *Sediment Dynamics*. Rootwad composites should not be used where sediment deposition along the bank is desirable.
3. *Stream Size*. Rootwad composites are best suited for streams where the effective rootwad surface spans the distance between base scour elevation and near bank-full elevation (Figure 4).
4. *Planform Stability*. Stable meander geometry must exist at least one meander sequence above and below the project area, e.g. the incoming flow direction must be consistent.
5. *Grade Stability*. Channel incision should be absent or bed elevation must be maintained naturally or by other grade control features. Rootwads do not provide grade control.

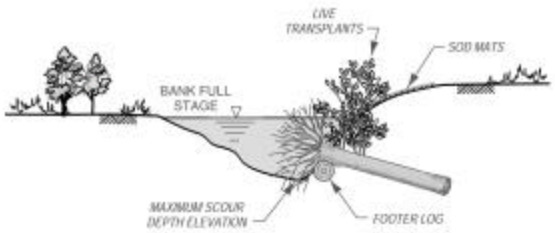

Figure 4. Elevation view. The effective rootwad surface should span the distance between maximum scour depth to near the bank-full elevation.

6. *Bank Soils*. Rootwad composites may have limited success and are considered at high risk of failure on streams where streambed and banks consist of uniform sand (<15 percent silt/clay). (An exception may be very small meandering channels).
7. *Risk*. Rootwad composites should generally be avoided in cases where failure would jeopardize lives or structures. As with many stabilization techniques, the risk of failure is higher on braided streams due to the possibility of flanking and scouring. However, rootwad composites may be more advantageous than other techniques if the cost is less for the same risk.
8. *Life*. Rootwads decompose, so the flow deflection benefits are temporary and vegetation must replace the rootwads to provide long-term stability. Rootwad composites are best where temporary (5-15 yr) stabilization is needed and riparian vegetation will thrive.

HABITAT CONSIDERATIONS

There are several factors to consider when assessing the habitat values of rootwad composites in stream restoration projects. Initially, it is important to consider the geomorphic characteristics of the stream reach. Native macroinvertebrate, algae, and fish species may not be adapted for woody substrates, and unexpected changes in these communities that are counter to the overall project objectives may result.

Limiting factors in the stream reach and overall watershed should also be considered. If woody debris is limited in the stream due to past land

use activities, then rootwad composites may provide additional habitat benefits to the system over and above the benefits to bank stabilization. On the other hand, if spawning substrates are limiting, then adding woody debris in the form of rootwad composites may not improve populations because the factor directly limiting the species is not affected.

Common limiting factors that rootwads address more effectively than many other stabilization techniques include: habitat complexity, structural diversity, primary productivity, substrate attachments, velocity differentials, and overwintering habitat.

Life stage requirements and associated habitat limitations of the species of concern are factors that should also be taken into consideration. Rootwads can provide exceptional habitat for both juvenile and mature age groups of many fish species. Due to the increased complexity and diversity of cover that they provide, they are optimal places for juvenile fish to escape predation. In addition, because they create locally diverse habitat under different flows, they can provide important resting and feeding habitats.

MATERIALS

The rootwad composite consists of the following components (Figure 5):

- Rootwad with tree trunk (bole)
- Footer log
- Bank log
- Habitat limbs and tops
- Vegetation

The rootwad fan is the component that deflects the current line from the stream bank and causes the desired scour and habitat elements. Extending from the rootwad fan, the tree trunk (i.e. the "bole") is securely embedded into the stream bank. The footer log is positioned roughly parallel to the stream bank and is also securely embedded. Primarily, the footer log retains a more vertical stream bank and provides support for live transplants in the eddy zone area. It also provides additional lateral and vertical support for the rootwad bole and helps prevent minor settling and lateral adjustments due to scour and soil consolidation. (Figure 7).

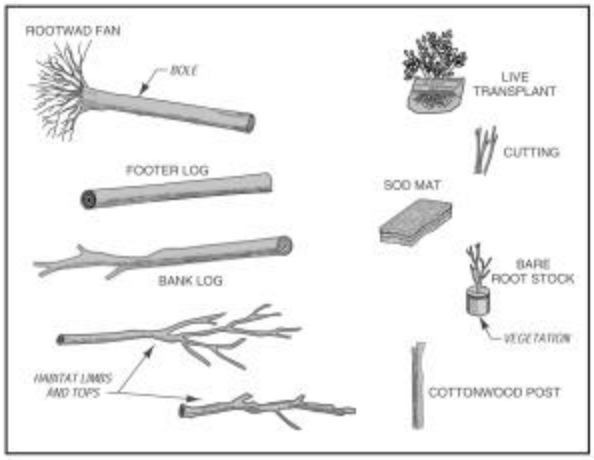

Figure 5. Components of the rootwad composite

Depending on the project design, stream size, and habitat requirements, bank logs can provide scour protection at elevations generally higher than one half bank-full stage. Bank logs also serve as retaining structures for backfill and vegetation and help provide a more vertical bank profile for fish habitat requirements. Depending on channel size, ice, and debris potential, bank logs can also extend into the channel to provide additional habitat complexity. Limbs and tops of trees can provide additional habitat complexity and microcosms for aquatic invertebrates.

Establishing riparian vegetation as part of the design is essential for stream and riparian function. It is also a fundamental requirement for the long-term success of rootwad composites, because the logs themselves are temporary. Life spans of large woody debris (LWD) structures are often underestimated. But reviews of evaluation studies suggest that a realistic life span of LWD structures is 5 to 15 years.

Factors influencing LWD structure life include:

- Tree species used (cypress, cedar, redwood, and oak last longest)
- Climate (dry and cool climates prolong life)
- Position relative to water surface (frequent wetting and drying reduces life;

continuously submerged wood lasts almost indefinitely)

- Soil contact (microbial digestion in soils limits life, but burial in anaerobic soils prolongs life considerably)

DESIGN

Rootwad composites provide streambank stabilization with specific habitat elements. The technique can be used or modified to provide additional habitat in sites that do not need stabilization, or can be used in conjunction with other techniques such as riprap or stone toe armoring to protect upper bank elevations and to provide fish cover at specific elevations. Rootwad composites have also been used successfully with channel control structures such as vanes, weirs, etc. (Figure 6).

Figure 6. Use of rootwad composites with canal check and modified weir design.

The primary design considerations for rootwad composites are a) material dimensions, configuration, and spacing,
b) habitat requirements, c) revegetation, and d) failure mechanisms.

Dimensions, Configuration, and Spacing

Dimensions

Material sizes primarily depend on stream size. The effective rootwad fan width should be sized to span from the maximum scour depth to near the bank-full elevation. If one rootwad is not sufficient, two or more can be combined, provided that backfill and structural integrity are not jeopardized.

The rootwad bole should be firmly attached to the rootwad fan. If the desired tree is standing, deep-rooted species and certain ground conditions often require careful excavation around the base of the tree before it is pushed over. If excessive pressure is applied to the tree without destabilizing the roots, a break in the bole can occur.

The necessary embedment length dictates the length of the bole and footer log. The embedment length should be sufficient to maintain the position of the rootwad structure both vertically and laterally throughout its design life. As a general rule, after the projected scour behind the rootwad, three-quarters of the length should remain securely embedded. For streams with widths less than 15 ft, bole length can be as short as 10 ft, where larger streams may require an embedment length of 20 ft or more.

Generally, specific diameter sizes are not necessary because diameter typically relates to the rootwad fan size, which is the overriding criterion. The diameter of the footer log should be at least three-quarters the diameter of the rootwad bole to provide the necessary support.

Bank logs, habitat limbs, and tops must be sized to provide the necessary function, but not hinder the strength and backfill of the structure.

Configuration

Proper configuration of the rootwad fan in relation to flow and channel elevation can not be overstated. The face of the rootwad fan must intersect the incoming velocity vectors at a 90-deg angle, but can be rotated as much as 15 deg toward the stream channel (away from the stream- bank). The rootwad fan should not be rotated towards the streambank or extend straight out into the channel or excessive bank erosion and failure may result
(Figure 7).

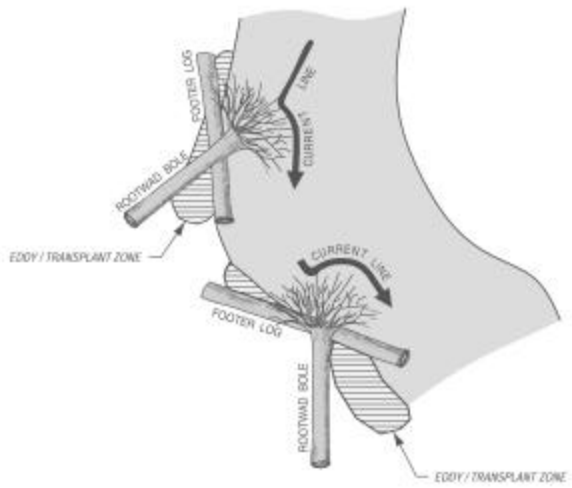

Figure 7. Orientation of the rootwad fan to velocity vectors. Rootwad bole and footer log configuration

Because the lower third of the channel receives the highest shear stress (toe zone), it is important to position the rootwad so that the root material effectively protects this zone (Figure 4). Maximum scour depths can be calculated, but such computations should be confirmed by measuring the maximum scour depth in a channel of similar size under similar energy conditions.

The angle between the footer log and rootwad bole is roughly parallel with the stream bank, but can deviate provided that function is maintained. One footer log can be utilized for two rootwads if the footer is long enough and rootwad spacing and configuration is correct (Figure 7). The rootwad is placed on the streamside of the footer log and the bole rests upon the footer log. The footer log will extend beyond the rootwad fan for a length sufficient to support the vegetation revetment (i.e. sod mats or transplants) in the eddy zone. Vertically, the footer log will be slightly higher than the maximum scour depth with the rootwad fan extended to the scour depth.

Where more conservatism is warranted, the footer log can be placed at maximum scour depth and the rootwad fan placed below maximum scour depth. On very small streams, and other situations where revetment does not need support, footer logs may not be necessary.

If a vertical bank profile is desired to maximize overhanging cover for fish, bank logs offer support for backfill and vegetation as new vegetation increases rooting strength. Bank logs are secured behind the rootwad fan or well embedded in the streambank and are generally oriented parallel to the streambank. They can also protect the upper banks from scour at high flows if the bank does not have vegetation for protection and can extend into the channel to provide additional habitat.

Tree limbs and tops can be placed between the footer log and the rootwad bole and extend downward into the stream along the streambank on the downstream side of the rootwad fan (Figure 8). These structures should extend beyond the rootwad fan only if they will not affect rootwad performance or sediment deposition, or they do not obstruct debris and ice flows.

Figure 8. Tree limbs and tops provide exceptional fish habitat. Bank logs can provide retaining support. Photo taken without stream flow

Spacing

Each composite creates a "shadow effect" downstream. The size of this region of lower velocity is dependent on the size of the rootwad and the channel planform. Spacing between rootwads is designed so that the primary velocity current is deflected away from the streambank for the distance between rootwads.

As a general rule, a spacing of 3 to 4 times the projected length of the rootwad is adequate. Figure 9 displays the maximum allowable spacing and distance of current line deflection for Rc/W (radius of curvature to top width ratios) greater than 3.0. As the radius of the bendway decreases, so should the rootwad spacing. For Rc/W less than about 2.5, the rootwads no longer deflect the flow and must effectively overlap to armor the bank. More conservative approaches can be employed as warranted, but rootwad composites are not generally recommended for such situations and their design exceeds the scope of this technical note.

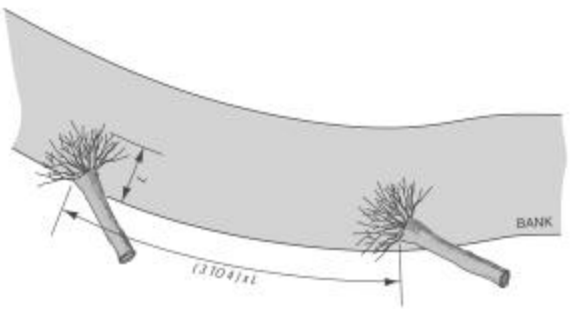

Figure 9. Rootwad spacing

Habitat Requirements

The effectiveness of rootwad composites in providing habitat benefits is dependent upon the physical characteristics of the composite structure and the associated streambed and bank. Rootwad composites are most effective in providing habitat benefits when their fans are within a few feet of the bed and bank. This allows for consistent water circulation on all sides of the structure, and provides important habitat niches along all surfaces of the structure, as well as increasing the scour and textural diversity of the corresponding bed and bank.

This spacing also allows for increased velocity diversity, which is important as flows change and alter the resting and feeding needs of fish species. In short, rootwad composites are generally more effective in providing habitat for fish species when they mimic natural conditions in terms of being less orderly and more complex.

Revegetation

An aggressive revegetation plan should be incorporated into most rootwad composite projects. Ideally, numerous live transplants are incorporated with other revegetation methods such as sod mat placements, bare root plant stock, cuttings, cottonwood posts, etc. Revegetation guidelines will be presented in other technical notes in this series, but site conditions and project objectives will dictate the best methods.

Keeping in mind that some scour is desirable for habitat complexity, vegetation is especially important in the area between the rootwad and the streambank called the "eddy zone." This zone extends slightly upstream and downstream of the rootwad and varies depending on the rootwad size and configuration. As the rootwad deflects primary velocity vectors away from the streambank, secondary velocity currents are created, and although velocities are much lower in the eddy zone, constant flow and wave action can cause bank scour if the bank is unprotected.

Transplanting large woody vegetation such as willows, dogwood, alder, etc., not only expedites revegetation and habitat, but also significantly decreases scouring within the eddy zone. Transplanting sod mats in the eddy zone is another technique that offers immediate protection.

Failure Mechanisms

Failure of rootwad composites, as well as other stabilization methods, can be attributed to several mechanisms, notably flanking, and undercutting.

Flanking occurs when the stream migrates around the structure and usually occurs when there is instability in the upstream or downstream meander geometry. This can be prevented by avoiding unstable situations, by extending the protection limits, or by keying the rootwad composites into natural or constructed control devices such as bedrock outcrops, rock or log sills, etc.

Undercutting occurs when the rootwad is placed too high in the channel and flows scour the underlying soils. The rootwad should be

placed near the maximum projected or measured scour depth. Undercutting failures typically result from setting the rootwad at an improper elevation, but can occur from inadequate embedment length - minor scouring can eventually cause structure adjustments, which can eventually lead to failure.

Stone is commonly incorporated with rootwad composites, and graded stone backfill is recommended in cases where bank drainage must be maintained. When used for this purpose, some settling topsoil overburden can be expected. The practice of placing large boulders on the footer log is recommended only when it is necessary to provide additional support to the transplants and when additional bank protection in the eddy zone is warranted. In many circumstances the boulders do not improve structure stability and can add unnecessary cost to the project, especially when an aggressive revegetation plan is incorporated.

Impacts of ice flows are largely unknown, but observations of hundreds of structures suggest that correctly designed and installed rootwad composites have minimal impacts from and upon ice under normal events. But impacts could occur depending on the stream size, the magnitude of the ice event, and the nature of freeze and breakup.

CONSTRUCTION

The primary considerations concerning construction are diversion, trenching, backfill, equipment selection, and revegetation. If possible, stream flow should be diverted from the construction area, or the composites should be installed under dry or low-flow channel conditions (Figure 10).

Figure 10. Temporary water diversion through point bar

Terrace heights and location and soil conditions dictate trench heights and construction techniques. Normally, a trench is excavated for both the rootwad bole and footer log, working from the streambank (Figure 11). On streams less than 30 ft in width and where soils are unstable, it may be more desirable to eliminate individual trenches, excavate a large hole, place the materials, then backfill.

Figure 11. Trenches for rootwad bole and footer log

Where terraces are encountered, a "bench" in front of the terrace should be constructed where possible (Figure 12). This technique reduces stream bank stress on the rootwad stabilization and places vegetation at a better location in relation to the water table.

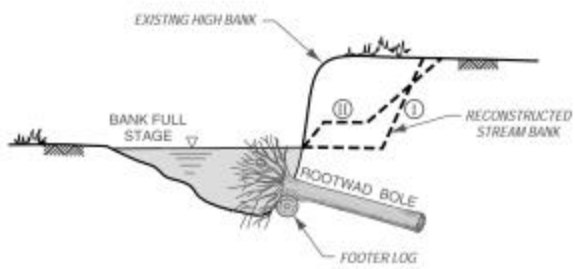

Figure 12. Bench construction at base of terrace minimizes trenching depths, reduces risk of streambank failure, and places vegetation closer to the water table

If soils have the potential to liquefy, equipment should be staged from the streambed, or construction undertaken during winter when water tables are lower or the ground surface is frozen and can support equipment. However, if the frost layer becomes too thick, backfilling and transplanting become difficult and costs can increase.

Sharpening the end of the rootwad bole and footer log with the intention of driving the ends into the bank to avoid trenching has limited success and is not recommended. Under this method, the rootwad can be destroyed, quality control for elevation and orientation is very difficult, and adequate penetration is often not possible.

Once the trenches are excavated to the proper elevations, the footer log is placed into position and the rootwad bole and fan are placed on top of the footer log according to the desired configurations. Static water level can complicate placement and often requires creativity. The excavator can place a track on one end of the footer log to hold it in place while placing the rootwad bole on top. Large boulders can sometimes hold the material in place, and then can be removed or incorporated into the backfill. It is good practice to have a person in the channel measuring elevations and checking for proper placement.

Backfilling with good materials and obtaining appropriate soil densities at specific locations is very important. There are two "zones" of backfill. The first zone is the area directly behind the rootwad called the eddy zone, which is composed of transplanted soil, roots, and vegetation, sod mats, or other revegetation media capable of protecting the bank. The second zone is the trench backfill, which is conserved from the initial excavation. Typically backfill is compacted through stringent compaction with the excavation bucket. The method of compaction should correspond with the acceptable failure risk as it relates to stream size and possible failure mechanisms.

An additional concern regarding backfill and possible failure mechanisms is the alteration of ground seepage flow patterns. Backfill material should be relatively free-draining. It should not be placed in a manner that blinds seepage horizons and creates high pore water pressures that could fail the fill.

Live transplants should be incorporated around the rootwad fan whenever possible. A divot should be dug to the desired elevation and dimensions for optimum transplant success and as much root and soil as possible should be retrieved with the transplant. For most transplants, positioning the roots in a desirable location relative to the water table is paramount and often this may mean that the base of the transplant may be buried by backfill. Transplants should be moved quickly or kept in a location and condition where the roots remain moist.

An excavator with a thumb is best suited for the majority of the work. End loaders are effective in digging and transporting sod mats and transplants. An excavator is better for digging the divot for the transplant and in compacting around the transplant. Other equipment (such as dozers) is useful for earthwork such as sloping banks and channel shaping.

APPLICABILITY AND LIMITATIONS

Techniques described in this technical note are applicable where primary objectives are to provide temporary (5 - 15 yr) stabilization and habitat enhancement while a streambank and riparian system recover from instability. Rootwad composites offer habitat diversity, erosion control, and aesthetic enhancements.

Thresholds and allowable stress for rootwad composites have not been established, and their

use is in a developmental stage. Limits are somewhat dependent on scale. Caution should be exercised in large stream systems, unstable stream systems, and where a revegetation plan may have limited success. Consideration should be given to safety issues in areas where recreationalists float and swim.

Consequences of failure should be considered if the rootwad composites are washed downstream. Is failure likely to create hazards that otherwise would not occur (e.g., trapping debris and causing undesired local scour, current deflection, and flooding)?

OPERATION AND MAINTENANCE

Operation and maintenance requirements of any treatment will vary depending on the stream system and its associated parameters, such as velocity, flood frequency, flood stage, and timing. With proper placement, an aggressive vegetation plan, and consideration of precautionary measures, operation and maintenance should be minimal.

In any case, one should be prepared, at least early in the project life, to repair the system until plants can become established. Minimally, inspection should occur after each of the first few floods or at least once a year, preferably after the predominant flood season.

Undercutting and flanking of the treatment and any other substantial scour evidence should be observed. Plants should be examined for adequate survival and growth and absence of disease, insect, or other animal damage (e.g., grazing, digging, and cutting). Successful plants will grow vigorously and spread their roots throughout the surrounding substrate.

If animal damage is evident, such as plants being removed or eaten by waterfowl or ungulates, preventative measures, such as use of exclosures, may be required. Such exclosures may only need to be temporary until plants are well-established.

Assuming the rootwad composites remain in place and plants root and become established, maintenance will become much less intensive.

Fish and aquatic invertebrate sampling is always recommended both before and after installation to determine habitat improvement effectiveness.

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Rosgen, D.L. 1996. Applied River Morphology. Printed Media Companies, Minneapolis, Minnesota.

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APPENDIX O

LUNKERS TECHNICAL GUIDANCE DOCUMENT

The Cross-Vane, W-Weir and J-Hook Vane Structures…Their Description, Design and Application for Stream Stabilization and River Restoration

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Abstract

The descriptions, design specifications, placement locations, spacing and various applications of Cross-Vane, W-Weir and J-Hook Vane structures are presented. These structures were developed and subsequently applied to: 1) establish grade control, 2) reduce streambank erosion, 3) facilitate sediment transport, 4) provide for irrigation diversion structures, 5) enhance fish habitat, 6) maintain width/depth ratio, 7) improve recreational boating, 8) maintain river stability, 9) dissipate excess energy, 10) withstand large floods, 11) maintain channel capacity, 12) be compatible with natural channel design, and 13) be visually acceptable to the public.

Relations to determine the minimum size of rock for these structures are presented based on bankfull shear stress. Drawings for each structure are provided that display appropriate use of footers, cross-section shape, profile shape, appropriate channel locations, angles, slopes, spacing and elevations. Velocity isovels are presented to describe changes in the distribution of energy produced by the structures. The structures all reduce near-bank shear stress and stream power, while increasing center channel shear stress and stream power to retain both flood-flow and sediment transport capacity. These structures have been installed on 14 rivers with bankfull widths varying from 9m (Lower Blanco River in Southwestern Colorado) to 150m (Bitterroot River in Northwestern Montana) and slopes varying from 0.05 to .0003 and in bed material ranging from cobble and gravel to sand bed streams. Since 1986, the author has restored and monitored a wide variety of stream types involving over 48 km of rivers and evaluated various structure performance following major floods. This monitoring has resulted in the development, implementation and assessment of the Cross-Vane, W-Weir and J-Hook vane structures.

Introduction

Structures in river engineering are designed to help stabilize channel boundaries. However, monitoring their effectiveness have indicated that many structures, contrary to the intended design, caused river instability. Structures are often selected and installed without an understanding of sediment transport and violate the dimension, pattern and profile of the stable river. Relations for canal design based on rigid boundary theory, clear water discharge, and uniform flow have been implemented on natural channels, with less than effective results. Work conducted by Leopold, et al, (1964) found that river form is associated with an integration of eight interrelated variables, that if any one variable is changed, it sets up mutual, concurrent adjustments of the other variables in the stream system until a new quasi-equilibrium is reached (stability). The eight variables are slope, width, depth, velocity, discharge, boundary roughness, size of sediment transported, and concentration of sediment. The variables can be integrated into morphological relations for stable natural rivers as described by “reference reach” by stream type

(Rosgen, 1998). Structures are often placed in rivers in an attempt to correct some of the adverse effects of channel adjustment due to instability. Unfortunately, many structures are often installed to "patch a symptom" rather than achieve the stable channel form. Appropriately used structures can assist in maintaining the stable dimension pattern and profile (Rosgen, 1996).

River engineering structures need to be incorporated with a clear understanding of the river variables that constitute the stable form. Structure failures are generally associated with designs incompatible with the "rules of the river". For example, cross-channel check dams decrease energy slope upstream of the structure. Data from natural rivers indicate a negative power function relation between sinuosity and slope (Figure 1), thus when slope is decreased there is a corresponding increase in sinuosity through lateral migration following bank erosion. Most failures of check dams occur when they are "out flanked" by the river through lateral adjustment upstream of the structure. Consequently, many check dams often accelerate excess bank erosion. Check dams generally decrease upstream velocity, slope, and depth, increase roughness, and induce sediment deposition. These changes lead to instability and contribute to the failure of the structure. Structures have also failed due to excessive bedload deposition that leads to a loss of channel capacity and subsequent change in the stable dimension, pattern and profile of the river.

Streambank stabilization structures proliferate as bank erosion accelerates. Most of the structures implemented involve "hardening" the banks. Changes in near-bank stress and/or stream power associated with unstable channels can accelerate bank erosion.
Work conducted by Parker (1978), and Bathurst (1979), described secondary circulation patterns and the distribution of boundary shear stress in both straight and meandering rivers. Ikeda, et al, (1988), described the erosion and transport of grains from the bank region to the center of the channel as a result of bank erosion. They also described the process of lateral momentum transfer due to turbulence that resulted in eddy diffusion and induced net lateral transport of longitudinal fluid momentum from regions of high momentum to regions of low momentum. These processes resulted in a lateral redistribution of bed shear stress. Secondary cells associated with down welling (high boundary shear stress) and upwelling (low boundary shear stress) occur in the near-bank region creating very high velocity gradients (Bathhurst, et al, 1979). Boundary shear stresses associated with high velocity gradients, can accelerate erosion rates, and are shown in the velocity isovel constructed from vertical velocity profiles (Figure 2). The streambank erosion prediction methodology developed by Rosgen (1996, 2001), utilizes computations of near-bank stress for assessing various erosion rates. Any structures that can reduce near-bank stress will reduce bank erosion by several orders of magnitude.

New attempts at similar problems

To offset near-bank forces to reduce streambank erosion, Paice and Hey (1989) installed submerged concrete vanes on the outside of meander bends to control secondary circulation and redirect river currents to decrease boundary shear stress in the outer bank region. These attempts were successful in reducing erosion by redirecting erosive currents in the near-bank region. Iowa Vanes (Ogdaard and Mosconi, 1987) were previously used to redirect currents away from streambanks to reduce accelerated erosion. Submerged vanes were installed and tested by Hey (1992) not only to re-direct velocity distribution but to also provide improved fish habitat.

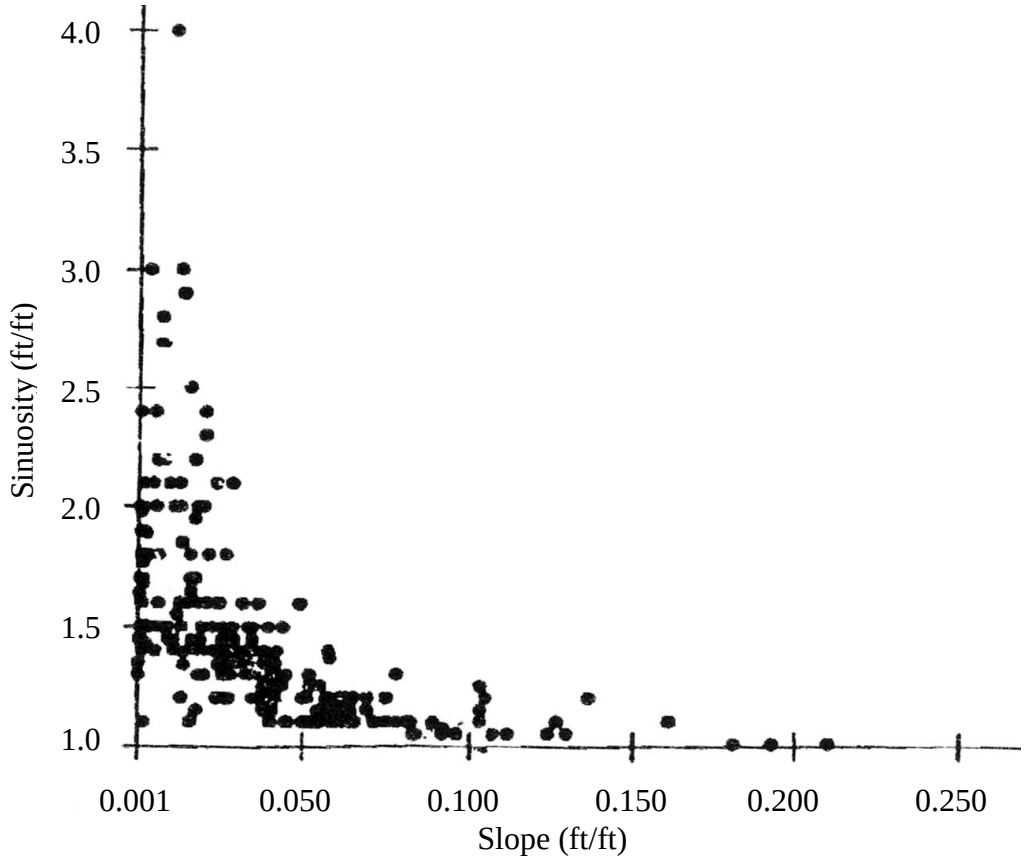

Figure 1. Relation of sinuosity to slope for natural rivers

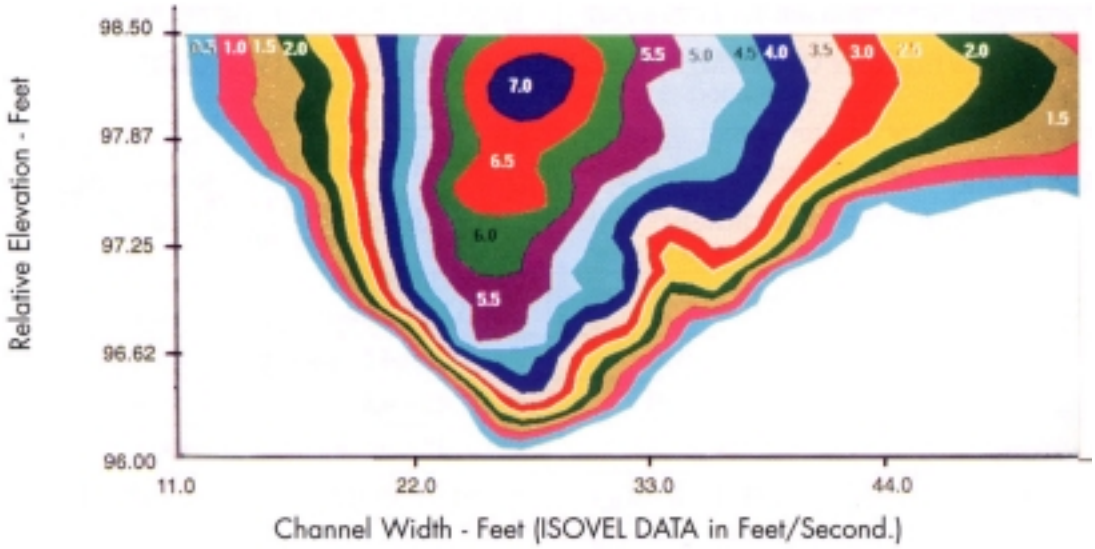

Figure 2. Velocity isovels for a "C3" stream type reach showing variations in velocity distribution (Rosgen, 1996, pg 6-42).

Structures that modify velocity distribution such as deflectors, bank barbs, spur dikes and other similar designs often accompany "bank hardening." The US Army Corps of Engineers recently developed bendway rock weirs (Derrick, et al, 1994). This structure points slightly upstream at a departure angle of 60-70 degrees from a tangent line from the bank. The intent of the bendway weir was initially to "scalp" point bars and re-locate the thalweg to the inside of the bend for navigation. In addition, this structure subsequently induced sediment deposition in the near-bank region. There is generally re-circulation, back eddy erosion on the upstream side of the structure due to the abrupt nature of re-directing the angle of attack of the near-bank velocity vectors. This structure has been installed on large rivers and has been effective in meeting its design objectives in many instances (Derrick, 1996).

Spur dikes and bank barb structures are common bank protection structures but generally produce an upstream and downstream re-circulation eddy that often increases bank erosion. This tends to occur when the thalweg is forced too far across the channel and/or the structures are oriented 45 to 90 degrees upstream from a tangent line to the bank. Bank barbs create a vertical vortices due to their abrupt angle to the bank that is often responsible for bank erosion and accelerated scour at the "point" of the barb. Rock and/or log deflector structures, pointing downstream, often direct the velocity vectors into the bank when flows overtop the structure increasing near-bank velocity gradients and causing accelerated bank erosion. Subsequently, some of these structures have created unexpected adverse adjustments in the channel.

Vortex Rock Weirs and Root Wads were installed in the 1980s for grade control, fish habitat and streambank erosion protection (Rosgen, 1996). After monitoring for approximately 15 years, the author determined that these structures produced back-eddy erosion during major floods resulting in streambank erosion and the loss of some structures. The problems of the Root Wad and Vortex Rock Weir structures were documented which subsequently led to major changes in their design.

As additional objectives of river engineering have evolved there has arisen a need for a "softer" substitute for streambank stabilization. The departure from traditional "hard" procedures has been slow but steady as the use of natural materials and methods have grown in popularity. This has, in turn, encouraged the pursuit of additional techniques to offset existing problems of various structures observed in the field. A properly designed river structure should meet more than one specific objective (such as grade control).
Structures should also:

1. Maintain the stable width/depth ratio of the channel;
2. Maintain the shear stress to move the largest size particle to maintain stability (competence);
3. Decrease near-bank velocity, shear stress or stream power;
4. Maintain channel capacity;
5. Ensure stability of structure during major floods;
6. Maintain fish passage at all flows;
7. Provide safe passage or enhance recreational boating;
8. Improve fish habitat;
9. Be visually compatible with natural channels;
10. Be less costly than traditional structures;

11. Create maintenance-free diversion structures;
12. Reduce bridge pier/footer scour, road fill erosion and prevent sediment deposition.

The use of rip-rap, gabions, concrete lined channels, bin walls, interlocking blocks, groynes, Kelner Jacks, spur dikes, rock jetties, barbs, reinforced revetment, sheet piling, log cribs, concrete check dams, and loose rock check dams are not only expensive but often do not meet the above stated objectives for river structures. A central problem with riprap, gabions, toe rock protection and similar structures is the increase in near-bank velocity, velocity gradient, stream power, and shear stress. These problems often lead to either on-site failures or problems immediately upstream and/or downstream of the structures. This, in combination with their high cost, resultant poor fish habitat and "less than natural" appearance, led to the development in the early 1990's of the Cross-Vane, W-Weir and J-Hook Vane.

Description of Structures

Cross-Vane

General description

The design of the Cross-Vane structure is shown in plan, profile and section view in Figure 3. The Cross-Vane is a grade control structure that decreases near-bank shear stress, velocity and stream power, but increases the energy in the center of the channel. The structure will establish grade control, reduce bank erosion, create a stable width/depth ratio, maintain channel capacity, while maintaining sediment transport capacity, and sediment competence. The Cross-Vane also provides for the proper natural conditions of secondary circulation patterns commensurate with channel pattern, but with high velocity gradients and boundary stress shifted from the near-bank region. The Cross-Vane is also a stream habitat improvement structure due to: 1) an increase in bank cover due to a differential raise of the water surface in the bank region; 2) the creation of holding and refuge cover during both high and low flow periods in the deep pool; 3) the development of feeding lanes in the flow separation zones (the interface between fast and slow water) due to the strong downwelling and upwelling forces in the center of the channel; and 4) the creation of spawning habitat in the tail-out or glide portion of the pool.

The Cross-Vane is also a popular boating feature as kayakers routinely do "enders" and "surf" the vane portion of the structures installed on the Lake Fork of the Gunnison River near Lake City, Colorado and the San Juan River in Pagosa Springs, Colorado. The invert portion (center 1/3, see Figure 3) of the structure creates a standing wave, but is associated with a "run" immediately downstream of the invert. As a result the potential development of a dangerous re-circulation pool that traps "swimming paddlers" is eliminated. The structure "chutes" the swimmers and/ or their boats into the deep, low velocity pool approximately half a bankfull width below the invert.

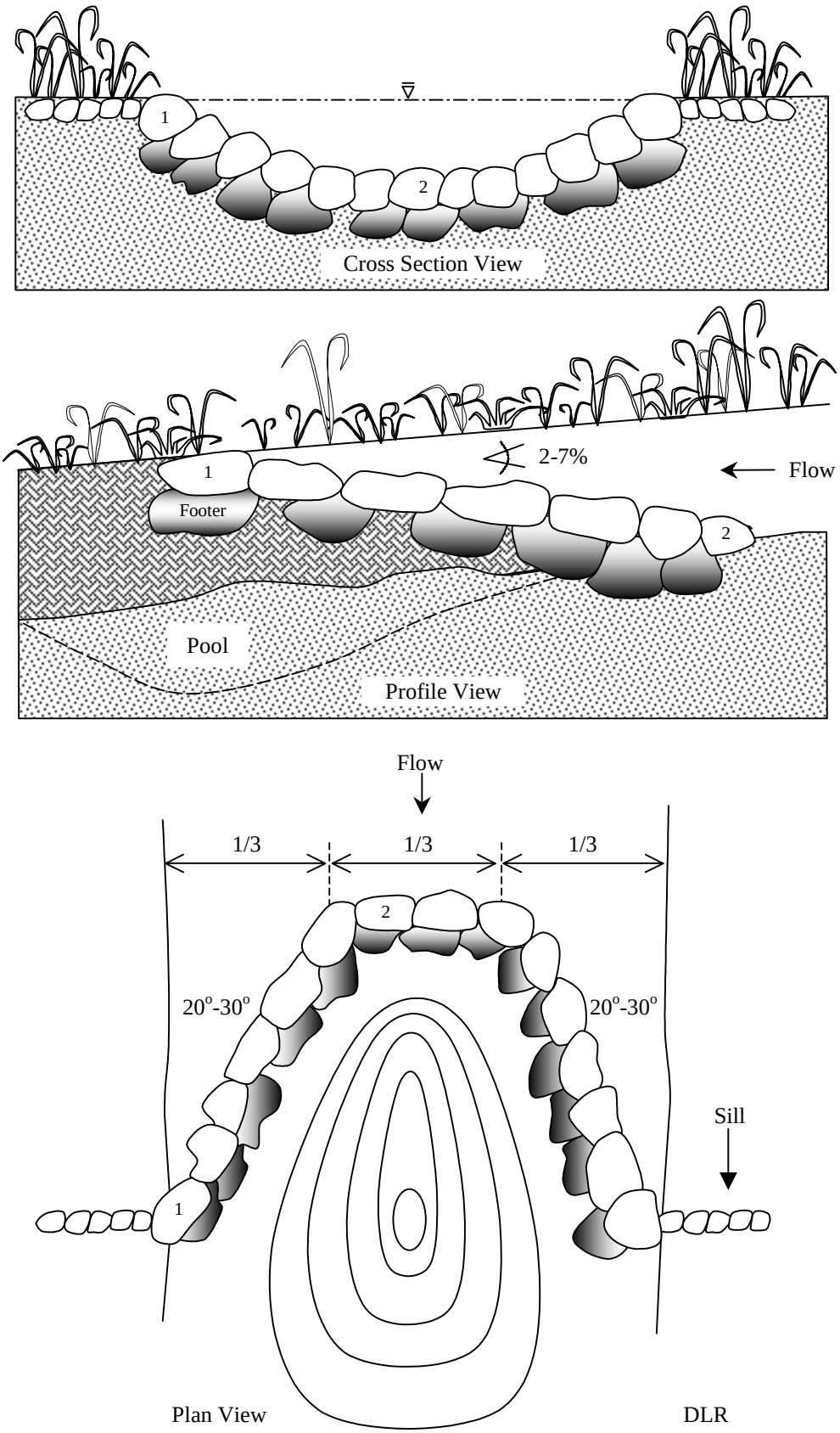

Figure 3. Cross section, profile and plan view of a Cross-Vane

Major floods have tested the Cross-Vane structure such as the 1996 flood on the San Juan River in Pagosa Springs, which passed a flood stage of 3.5 meters above the top of the structures on a 0.005 slope. A detailed contour map prepared in 2000 demonstrates the channel shape and location of the deep pool (Figure 4). The structure did require post-flood maintenance and it is still performing properly as a diversion structure, a kayak playground and an excellent fly-fishing location where fisherman can be frequently observed. Although bedload transport of particle size up to 220 mm occurred during the flood, the pools did not fill. The strong downwelling currents in the center of the channel maintained a high bedload transport keeping the pool deep as evidenced in Figure 4.

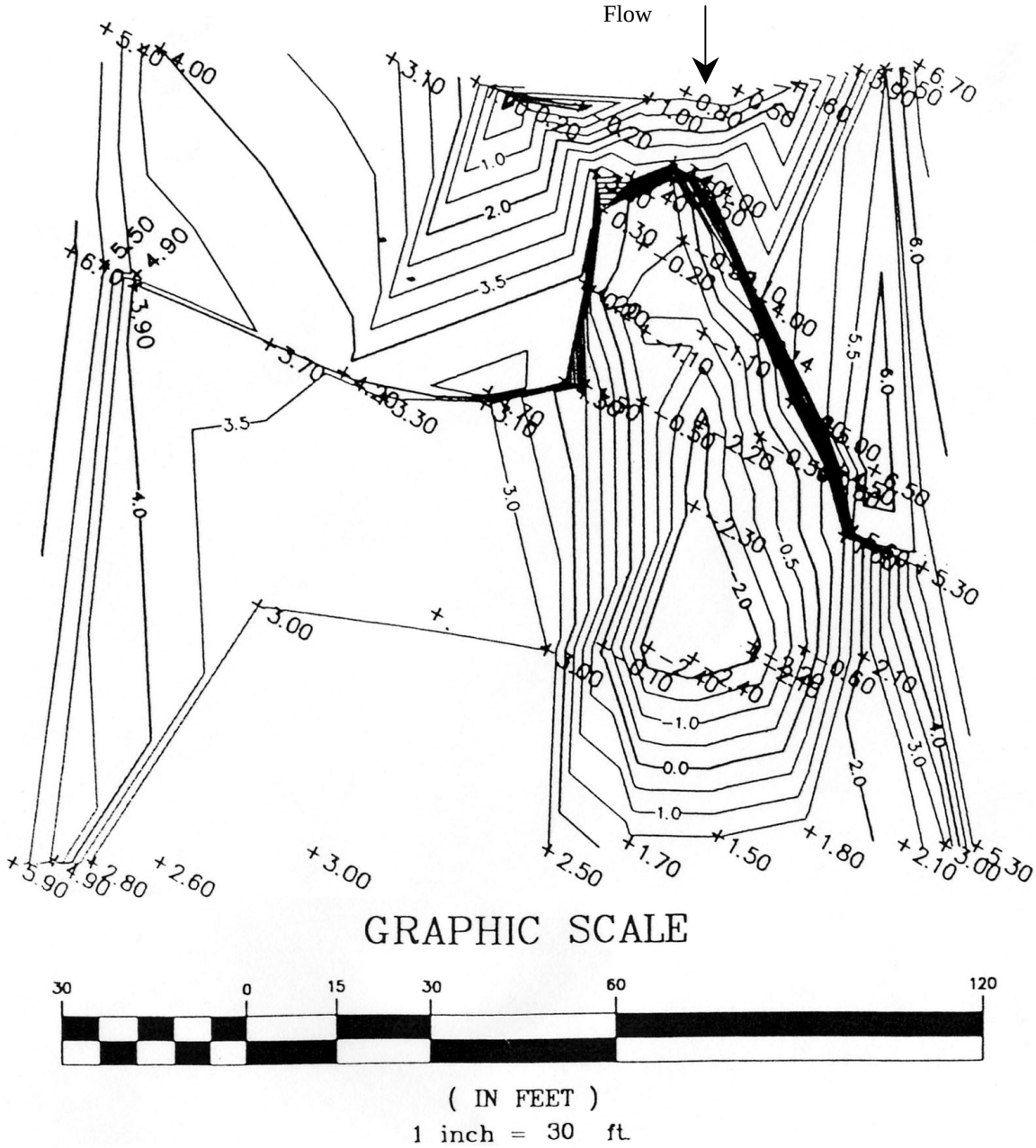

Figure 4. Contour map of Cross-Vane following major flood – San Juan River, CO.

W-Weir

General Description. The design of the W-Weir (W as looking in the downstream direction) was initially developed to resemble bedrock control channels on larger rivers. Various rock weirs installed across larger rivers for fish habitat, grade control and bank protection often create an unnatural and uniform "line of rocks" that detracts from visual values. The W-Weir is similar to a Cross-Vane in that both sides are vanes directed from the bankfull bank upstream toward the bed with similar departure angles. From the bed at ¼ and ¾ channel width, the crest of the weir rises in the downstream direction to the center of the bankfull channel creating two thalwegs (Figure 5). The objectives of the structure are to provide grade control on larger rivers, enhance fish habitat, provide recreational boating, stabilize stream banks, facilitate irrigation diversions, reduce bridge center pier and foundation scour, and increase sediment transport at bridge locations. Double W-Weirs are constructed on very wide rivers and/or where two center pier bridge designs (three cells) require protection.
Habitat for trout is enhanced by maximizing usable holding, feeding and spawning areas. Fish hold in the multiple feeding lanes created by the two thalweg locations and pools. Various age classes of trout also hold in the deep glide created upstream of the structure and against both banks due to the increased depth and reduced velocity of flows in the near-bank region. Spawning habitat is created in the tail-out of the pools due to upwelling currents and a sorting of gravel bed material sizes preferred by trout.

J-Hook Vane

General Description. The J-Hook Vane is an upstream directed, gently sloping structure composed of natural materials. The structure can include a combination of boulders, logs and root wads (Figures 6-7) and is located on the outside of stream bends where strong downwelling and upwelling currents, high boundary stress, and high velocity gradients generate high stress in the near-bank region. The structure is designed to reduce bank erosion by reducing near-bank slope, velocity, velocity gradient, stream power and shear stress. Redirection of the secondary cells from the near-bank region does not cause erosion due to back-eddy re-circulation. The vane portion of the structure occupies 1/3 of the bankfull width of the channel, while the "hook" occupies the center 1/3.

Maximum velocity, shear stress, stream power and velocity gradients are decreased in the near-bank region and increased in the center of the channel. Sediment transport competence and capacity can be maintained as a result of the increased shear stress and stream power in the center 1/3 of the channel. Backwater is created only in the near-bank region, and the small departure angle gently redirects the velocity vectors from the near-bank region, reducing active bank erosion.

The scour pool in the center 1/3 of the channel provides energy dissipation and holding cover for fish. The flow separation zones, or "seams" of fast and slow water that mark the zones of downwelling and upwelling currents, are habitat features utilized by trout. The "hook" portion of the vane produces a longer, wider and deeper pool than that created by vane-only structures. The downstream pool dissipates energy and provides fish habitat. The 1/4 - 1/3 rock diameter gaps between the rocks associated with the hook creates a vortex or corkscrew flow that

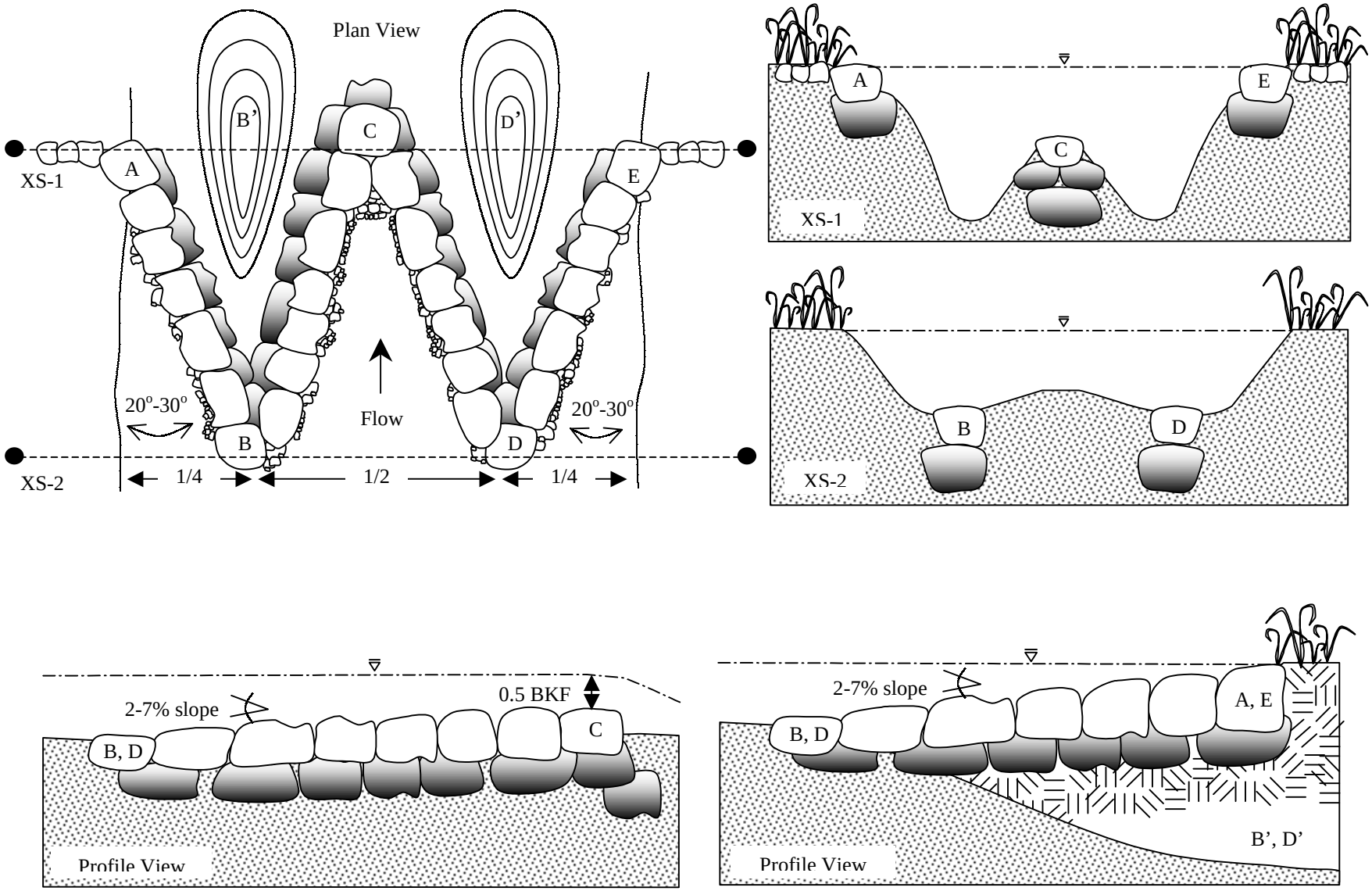

Figure 5. Plan, cross section, and profile views of the W-weir

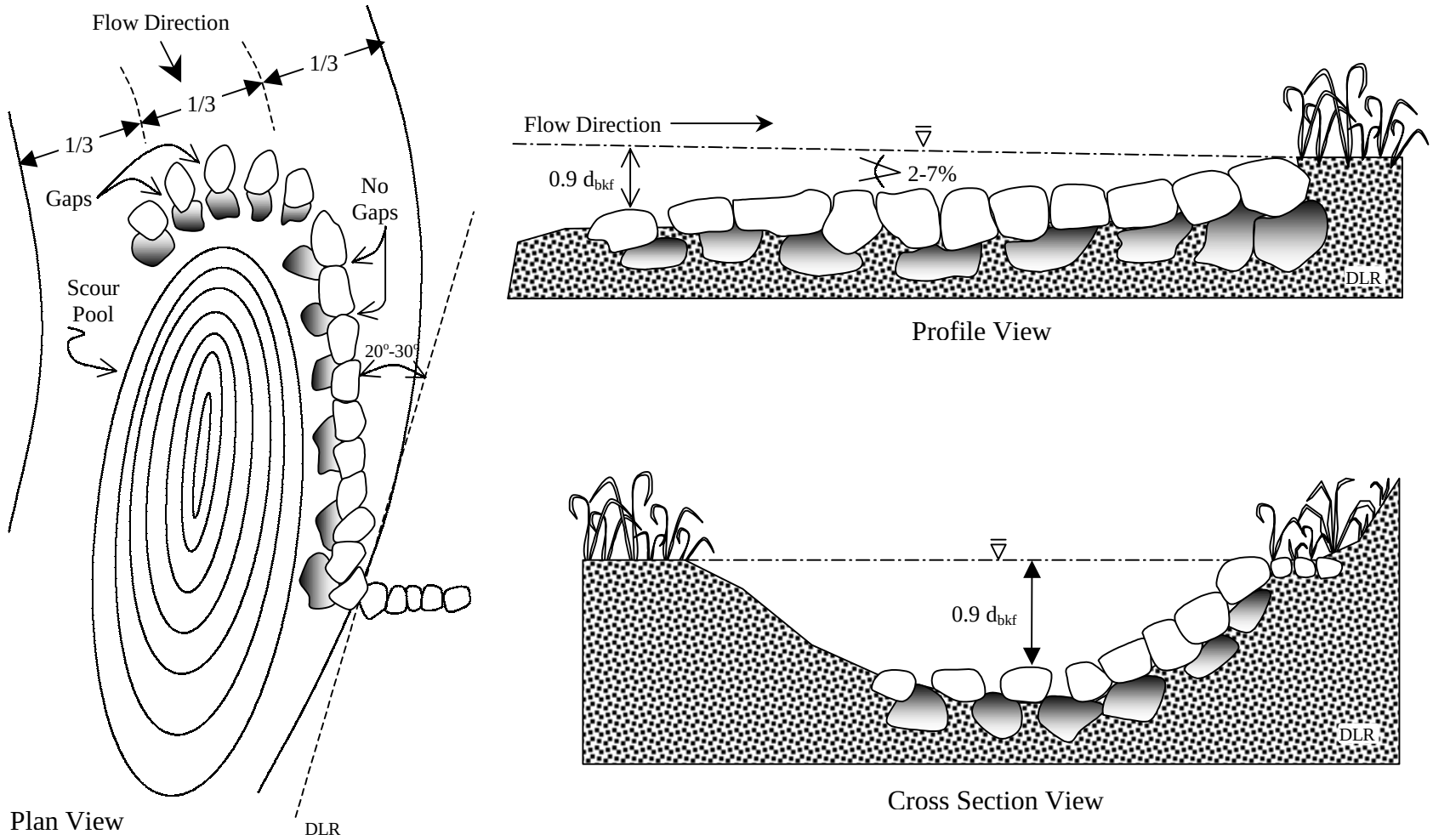

Figure 6. Plan, profile, and section view of the J-Hook Vane

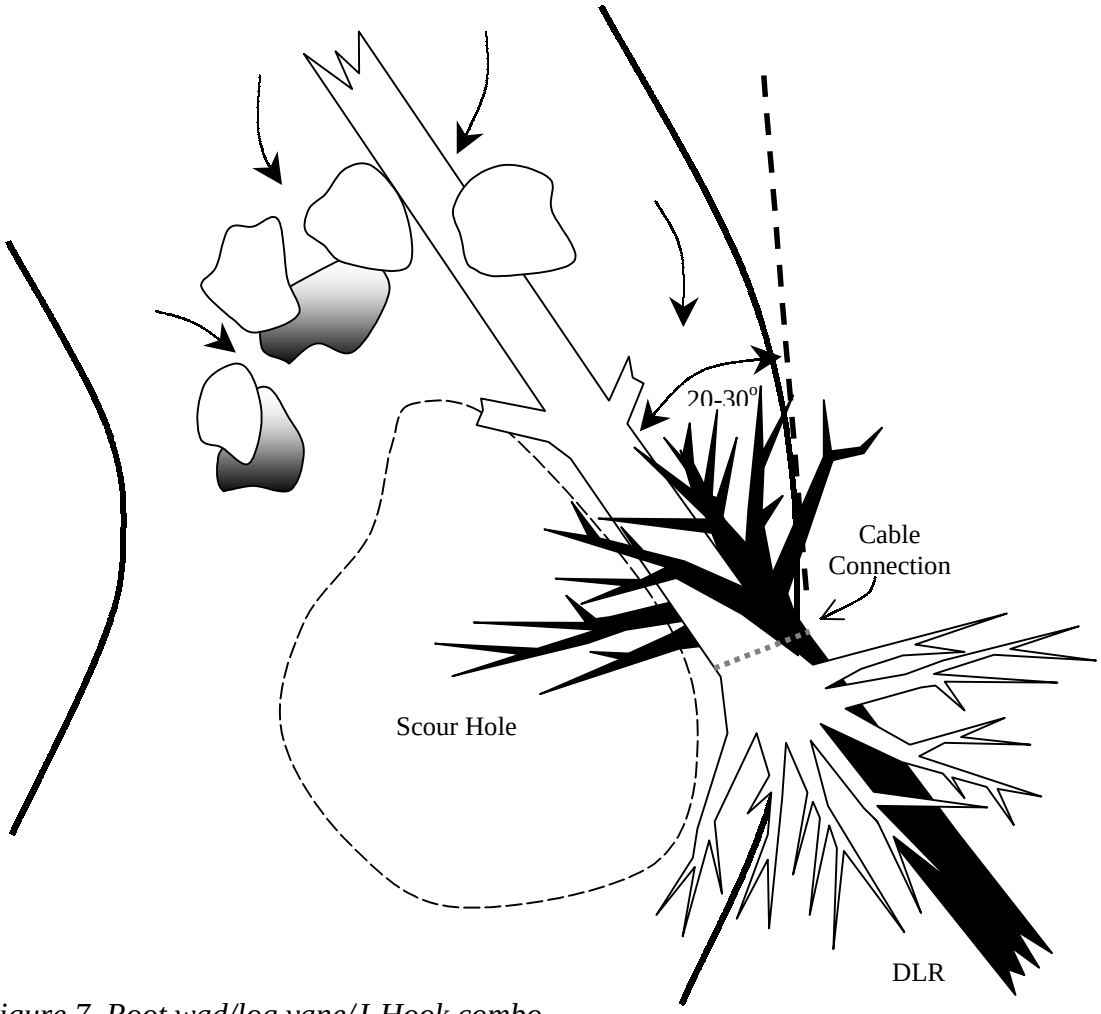

Figure 7. Root wad/log vane/J-Hook combo streambank stabilization and fish habitat structure

increases the "center-channel" shear stress. The center of the channel associated with the hook is efficient at transporting sediment, debris and improving channel capacity and sediment competence. The "shooting flow" associated with the hook portion of the structure provides for recreational boating in moderate to larger sized rivers. Width/depth ratios are maintained by decreasing bank erosion rate and increasing bankfull channel depth, even following major floods.

Design Specifications

Cross-Vanes, W-Weirs and J-Hook Vanes

Vane angle. The vane arm portion of all three structures is generally 20-30 degrees measured upstream from the tangent line where the vane intercepts the bank. The 20-degree angle provides the longest vane length and protects the greatest length of streambank. Variation from 20 to 30 degrees is often utilized in offset Cross-Vanes and/or W-Weirs whose asymmetry disproportionately shift more water to one side of the structure often used for irrigation

diversions. The flatter and smaller vane angle arm will extend farther upstream to intercept proportionately more water and increase the length of bank protected.

Vane slope. The slope of the vane extending from the bankfull stage bank should vary between 2-7 percent. Vane slope is defined by the ratio of bank height/vane length. For installation in meander bends, ratios of J-Hook Vane length/bankfull width is calculated as a function of the ratio of radius of curvature/bankfull width and departure angle (Table 1). Equations for predicting ratios of J-Hook Vane spacing/bankfull width on meander bends based on ratio of radius of curvature/bankfull width and departure angle is shown in Table 2. Vane length is the distance measured from the bankfull bank to the intercept with the invert elevation of the streambed at 1/3 of the bankfull channel width for either Cross-Vanes or J-Hook Vanes. For very large rivers, where it is impractical to extend the vane length to 1/3 of the bankfull width, vane slope is calculated based on the specified angle of departure and the ratio of bank height/vane length where the vane arm intercepts the proposed invert of the structure.

Table 1. Equations for predicting ratio of vane length/bankfull width (V_L) as a function of ratio of radius of curvature/width and departure angle, where W = bankfull width. (SI units)

Rc/W	Departure Angle (degrees)	Equation
3	20	$V_L = 0.0057\ W + 0.9462$
3	30	$V_L = 0.0089\ W + 0.5933$
5	20	$V_L = 0.0057\ W + 1.0462$
5	30	$V_L = 0.0057\ W + 0.8462$

Table 2. Equations for predicting ratio of vane spacing/width (Vs) as a function of ratio of radius of curvature/width and departure angle, where W = bankfull width (SI units)

Rc/W	Departure angle (degrees)	Equation
3	20	$Vs = -0.006\ W + 2.4781$
3	30	$Vs = -0.0114\ W + 1.9077$
5	20	$Vs = -0.0057\ W + 2.5538$
5	30	$Vs = -0.0089\ W + 2.2067$

The spacing of J-Hook Vanes can be increased by 0.40W if there exists a low bank erosion hazard rating (BEHI) of less than 30 (Rosgen, 1996, 2001).

Bank height. The structure should only extend to the bankfull stage elevation. If the bank is higher, a bankfull bench is constructed adjacent to the higher bank and the structure is integrated into the bench. The use of a Cross-Vane is shown in Figure 8 where a bankfull bench is created adjacent to a terrace bank.

Footers. The minimum footer depth at the invert for cobble and gravel bed streams is associated with a ratio of 3 times the protrusion height of the invert rock. This is applicable to all three structures and is shown in Figure 9 for a J-Hook Vane. For sand bed streams, the minimum depth is doubled due to the deeper scour depths that occur. All rocks for all three structures require footers. If spaces are left between the invert rocks for Cross-Vane and W Weirs, then the top of the footer rocks becomes the invert elevation for grade control. If no gaps are left, then the top of the surface rock becomes the base level of the stream.

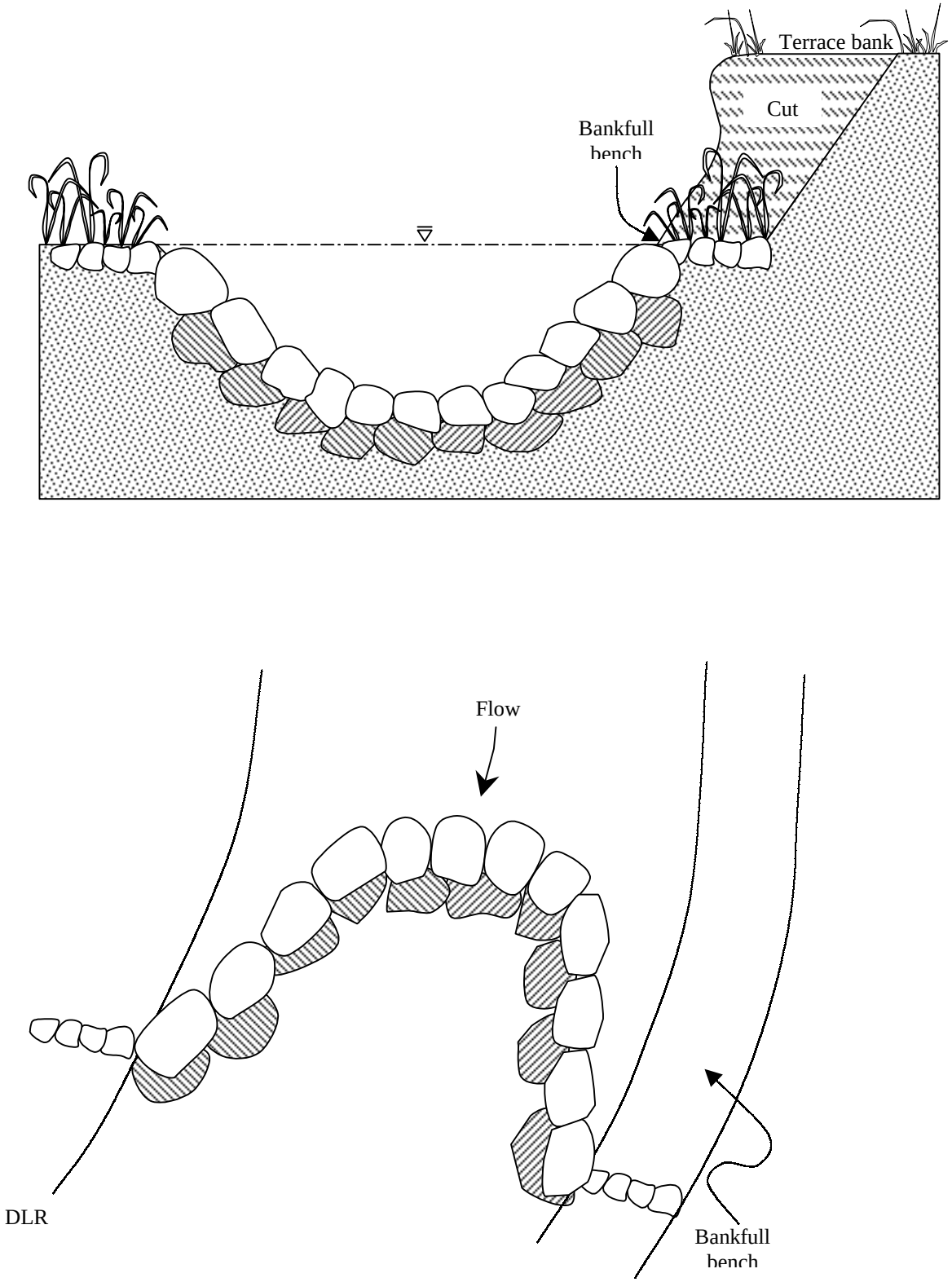

Figure 8. Example of a boulder Cross-Vane and constructed bankfull bench

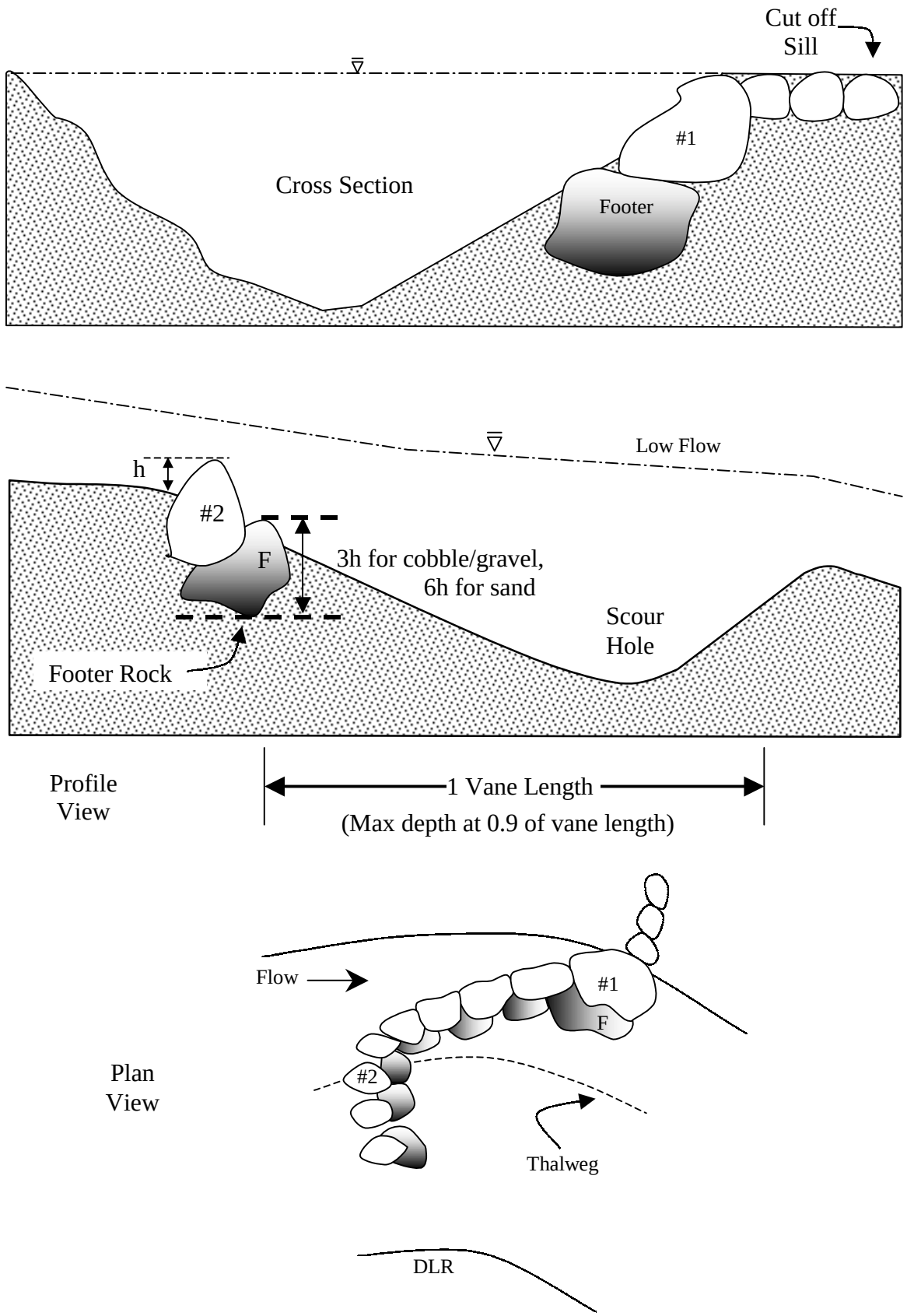

Figure 9. Locations/positions of rocks and footers in relation to channel shape and depths

Rock size. The relationship of bankfull shear stress to minimum rock size used for all three structures is shown in Figure 10. The application of this empirical relation is limited to size of rivers whose bankfull discharge varies from 0.56 cms (20 cfs) to 113.3 cms (4,000 cfs). For example, appropriate minimum rock sizes for values of bankfull shear stress less than 1.7 kg/m^2 (0.35lbs/ft^2) are associated only with stream channel bankfull depths from 0.26 - 1.5m (2 - 5 ft). This relation would *not* be appropriate for applications outside the limits of the data for a river slope of 0.0003 and a mean depth of 6.1m, even though a similar shear stress results as in the example presented.

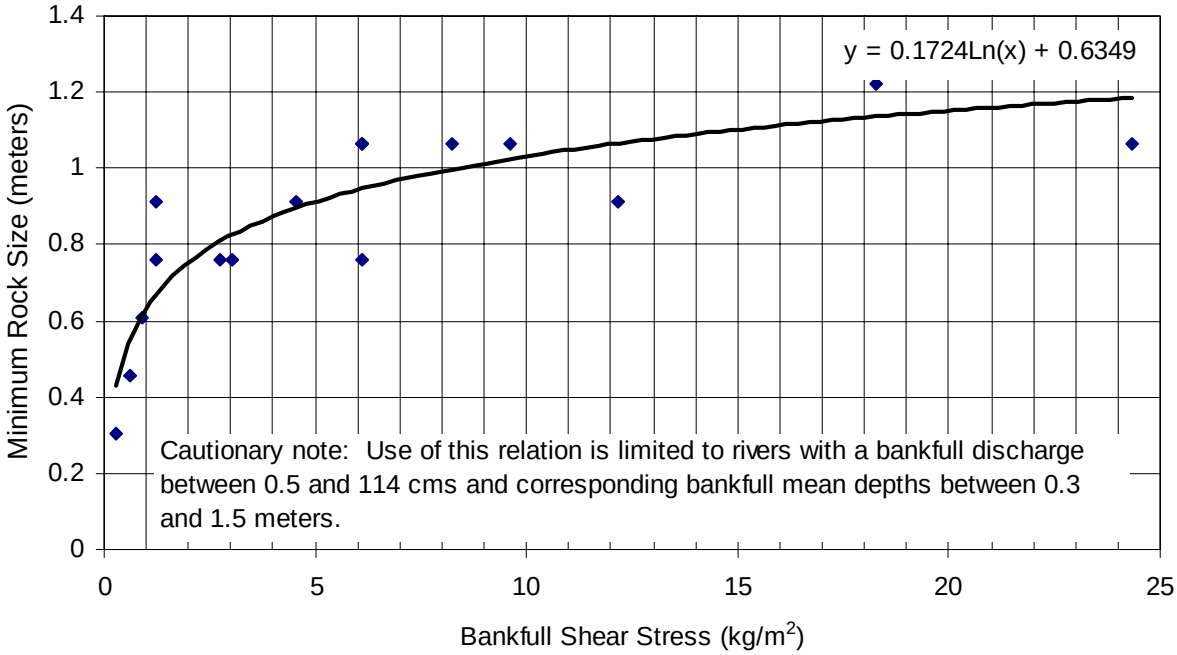

Figure 10. Minimum rock size as a function of bankfull shear stress

Materials. The Cross-Vane can be constructed with boulders, logs and a combination of both. A geotextile fabric is required to prevent scour under the structure when logs are used or when rocks are used in sand or silt/clay bed channels. The design using logs only and a duckbill anchor system is shown in Figure 11. Large flat rocks can be substituted for the duckbill anchor and cable to keep the logs in place.

Hydraulics. The center cell of Cross-Vane and J-Hook Vane structures generally contain 0.80 of the bankfull discharge. The left and right 1/3 cells of the structure each generally contain 0.3 of the mean velocity, 0.02 of the shear stress and 0.01 of the stream power of the entire bankfull channel. A velocity isovel showing the distribution of velocity over a J-Hook Vane on Turkey Creek, Colorado is shown in Figure 12. The Cross-Vane isovels are similar to those of the J-Hook Vane, as they distribute the velocity from the near-bank region to the center of the channel.

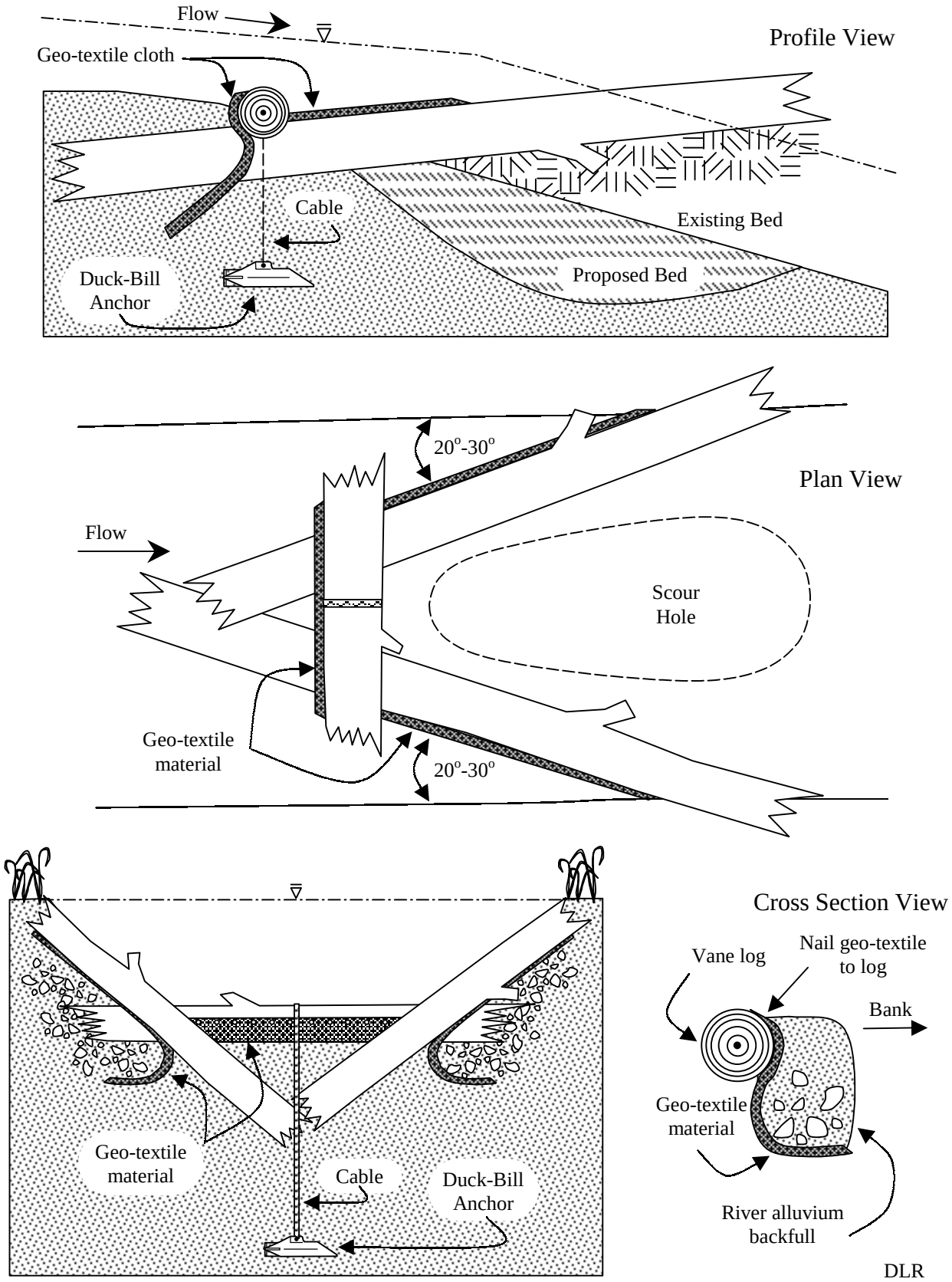

Figure 11. Cross-Vane using logs and a duck-bill anchor

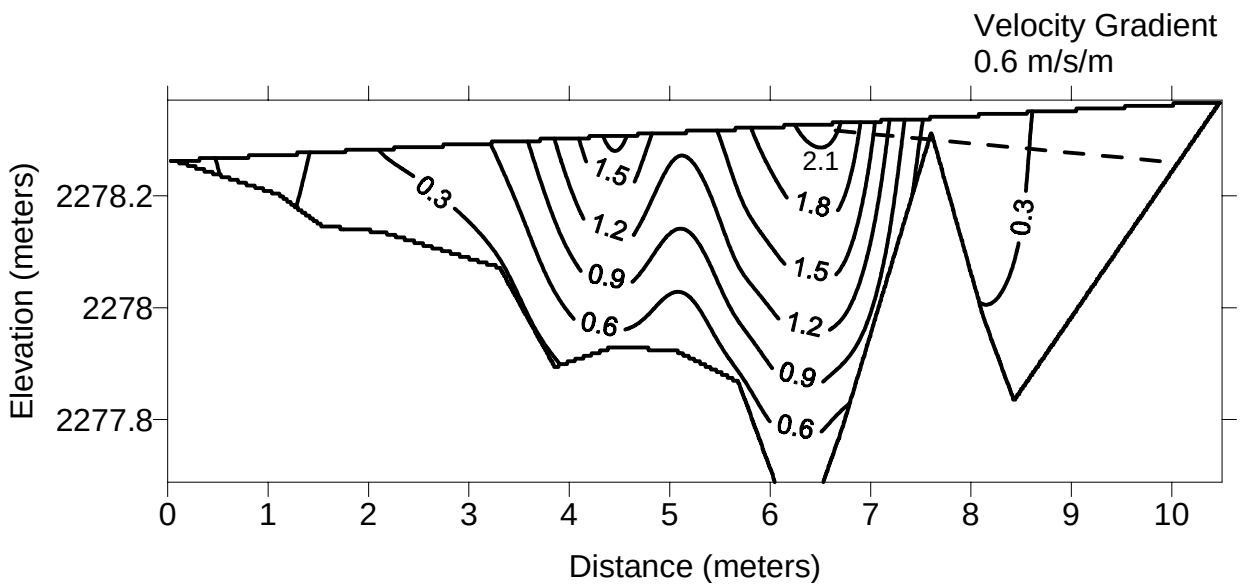

Figure 12. Velocity isovels of a J-Hook at Turkey Creek, CO (Velocity in meters/second)

Applications

Irrigation diversions. The use of a Cross-Vane for an irrigation diversion is shown in Figure 13. Cross-Vanes and W-Weirs have both been used successfully for irrigation structures. Both the Cross-Vane and W-Weir create a differential head in the near-bank region due to the flat slope of the vane leading to the bank. This condition provides the head to deliver water to the head gate at very low flows so that it is not necessary to construct sacrificial dams at low flows. When the head gate is closed during high flows, fine sediments often accumulate. To prevent the sediment deposition at the head gate and in the irrigation canal, a sediment sluice gate is installed so that the sediment is delivered back to the channel during normal high flows (Figure 13).

Grade control. The Cross-Vane is used to maintain base level in both riffle/pool channels, rapids-dominated stream types and in step-pool channels (Figure 14). One aspect of river restoration is associated with the conversion of incised rivers G and F stream types to B stream types (Rosgen, 1994,1996, and 1997). The Cross-Vane, as used for grade control, maintains the new width/depth ratio, entrenchment ratio, reduces bank erosion, dissipates energy and improves fish habitat. Spacing of the structures is based on a negative power function relationship of the ratio of pool spacing / bankfull width as a function of slope.

$$P_s = 8.2513\ S^{-0.9799}$$

Where P_s = the ratio of pool to pool spacing/bankfull width

S = channel slope in percent

This relationship was developed from natural channels and has a correlation coefficient (R^2) of 0.92 and is shown in Figure 15.

Bridge protection. Bridges constructed on a skew to the channel and/or placed on an outside bend often experience abutment scour and embankment erosion. This problem can be reduced by the placement of an offset Cross-Vane in the upstream reach. The vane on the outer bank in the bend has a flatter slope and smaller angle (20°), while the vane arm on the inside bank has a steeper slope and a larger angle (30°) (Figure 16). W-Weirs are particularly useful for reducing

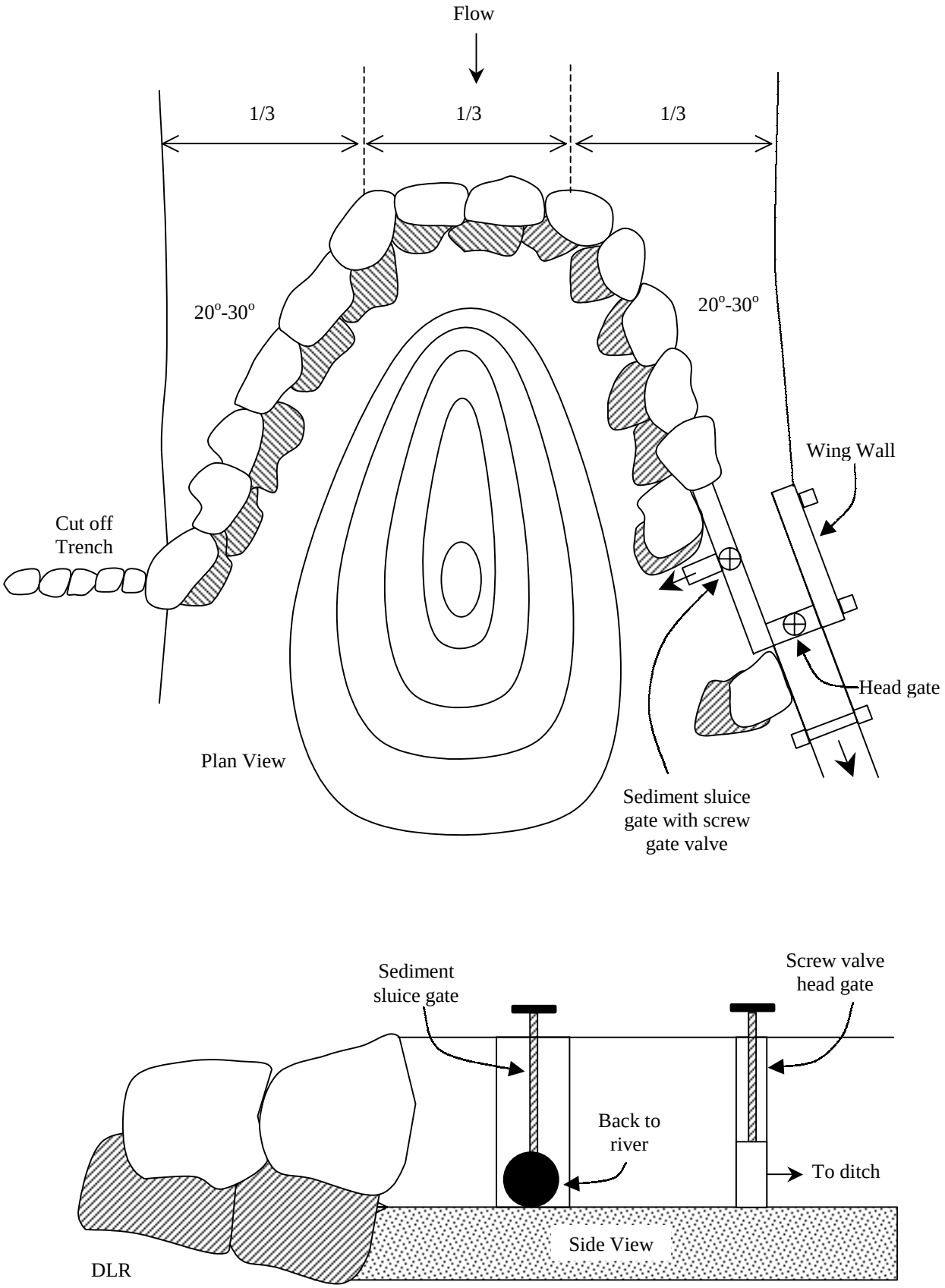

Figure 13. Example of a Cross-Vane/irrigation head gate-sediment sluice

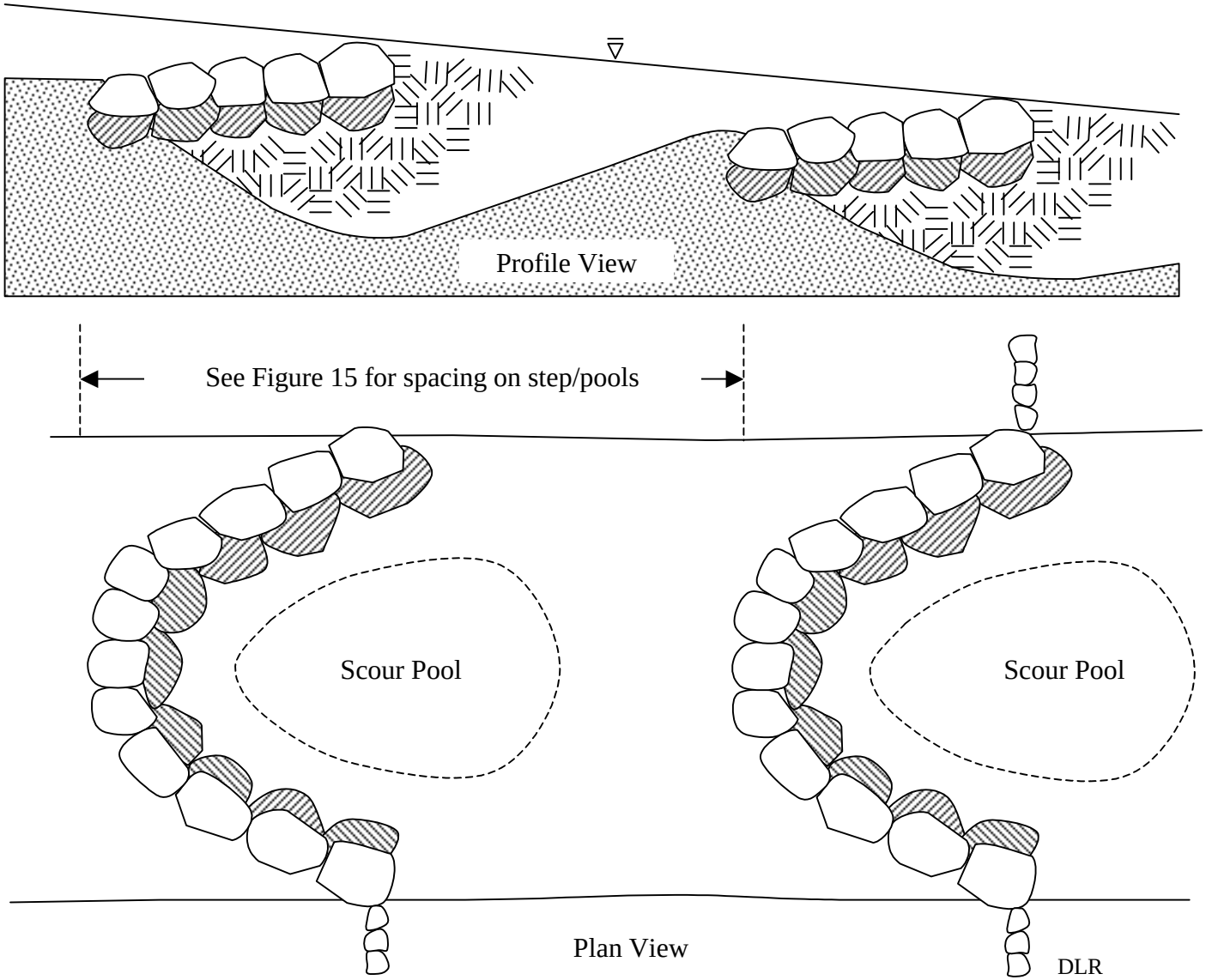

Figure 14. Use of Cross-Vane for step/pool restoration

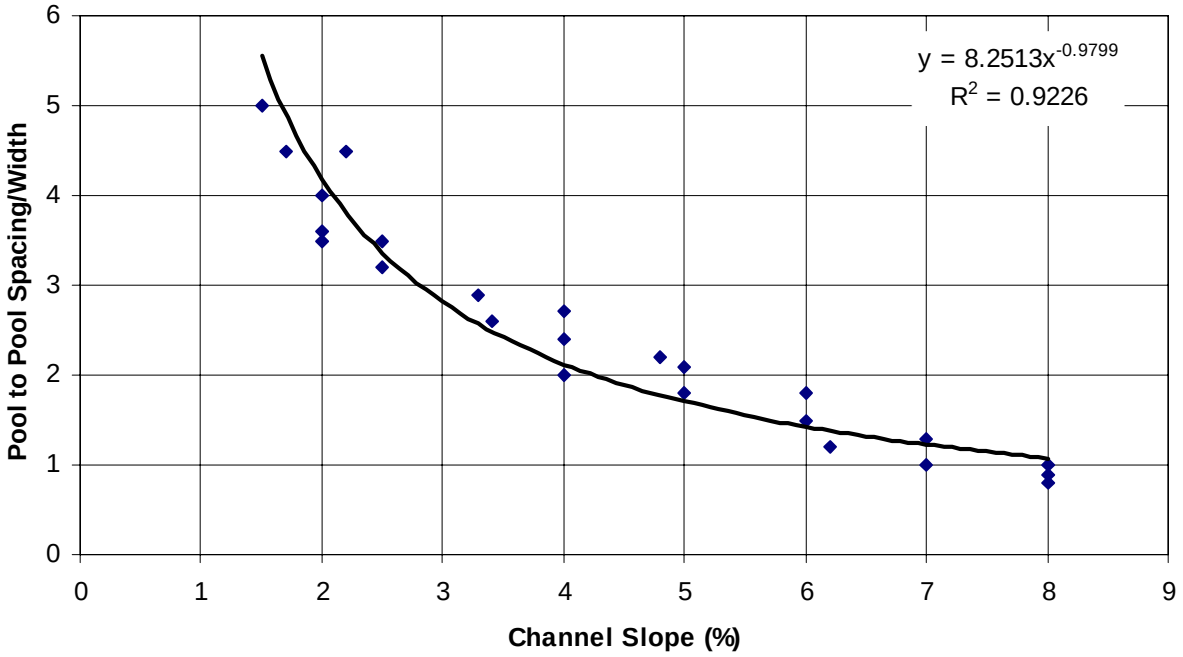

Figure 15. Ratio of pool spacing to bankfull width as a function of channel slope

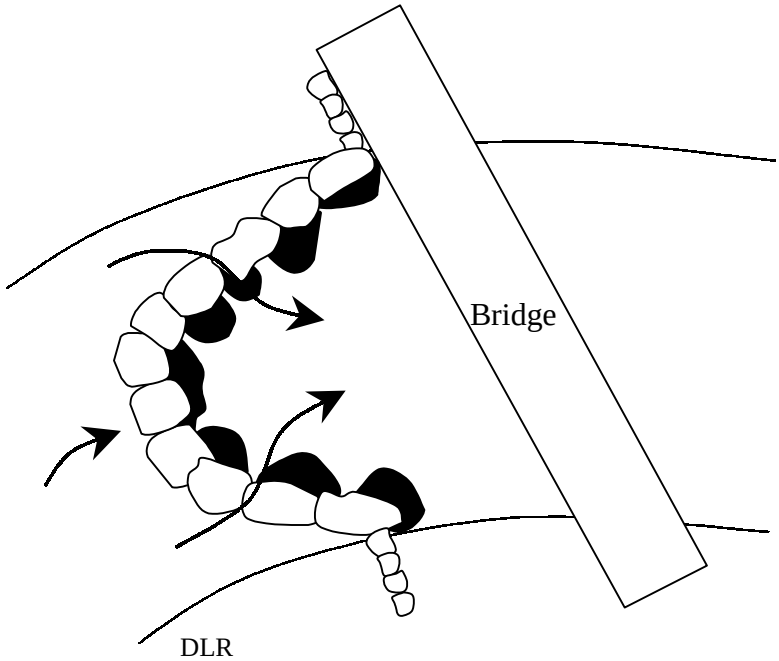

Figure 16. Application of a Cross-Vane for bridge and channel stability.

center pier scour. Both the Cross-Vane and W-Weir can provide grade control, prevent lateral migration of channels, eliminate fish migration barriers, increase sediment transport capacity and competence and reduce footer scour. J-Hook Vanes can reduce bank erosion on outside banks both for the approach and downstream reaches of the bridge.

Streambank stabilization. The J-Hook Vane is designed to reduce accelerated streambank erosion on the outside bend of meanders. As a minimum, the amount of bank protected is 2 times the vane length, while maximum spacing provides approximately 3 times the bank protection to vane length. If both banks are eroding due to confinement (lateral containment) and entrenchment (vertical containment), then the Cross-Vane decreases the stream power and shear stress concurrently on both banks. This avoids lining or hardening both banks through a reach to provide protection.

Summary

The Cross-Vane, W-Weir and J-Hook Vane are structures that can be implemented to maintain or enhance river stability and function to facilitate multiple objectives. These structures have been successfully applied in natural channel design for river restoration, bank stabilization, grade control, irrigation diversions, fish habitat enhancement, bridge protection, and recreational boating. Continued monitoring will provide the information necessary to improve the designs to further their application to meet the ever-increasing demand for environmentally "softer" structures that meet multiple objectives.

Acknowledgement. The author wishes to thank J.D. Kurz for computer assisted graphics and field assistance along with Art Parola, Jeremy Mondock and Jean Kapusnick for the Cross-Vane map in Figure 4, and to Dr. Richard Hey and Owen Williams for their thorough technical review of this manuscript.

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APPENDIX P

SOIL LOSS/BASIN SIZING CALCULATIONS

CLIENT: NAVAL STATION GREAT LAKES		JOB NUMBER: 112G01021	
SUBJECT: Sediment Transport Estimation - Northern Branch Pettibone Creek			
BASED ON:		DRAWING NUMBER:	
BY: RLS Date:	CHECKED BY: Date:	APPROVED BY:	DATE:

OBJECTIVE:

To estimate the amount the sediment conveyed by the northern branch of Pettibone Creek as a result of runoff from on and off site sources in order to size a concrete sediment basin to be located at the headwaters of Pettibone Creek.

APPROACH:

The RUSLE2 computer program was used to estimate the sediment flowing into Pettibone Creek based on localized climate, soil, and management zone criteria.

The resulting annual sediment load (in tons/ac/year) will be used to size the a concrete sediment retention basin at the headwaters of Pettibone Creek.

REFERENCES:

1) RUSLE2 Computer program; Version 1.26.6.4, Build Date: November 13, 2006, USDA-ARS, USDA-NRCS.
2) Calculation, "Peak Storm Water Flows - Northern Branch Pettibone Creek", TtNUS, July, 2011.
3) Custom Soils Report for Lake County, Illinois, July 19, 2011, USDA-NRCS.

CALCULATIONS:

The RUSLE2 computer program was utilized to estimate annual sediment loads to the Northern Branch of Pettibone Creek based on localized climate, soil, and zone management criteria for the Pettibone Creek watershed vicinity.

Soil loss estimates were estimated for each soil type on an annual basis and totaled to estimate the total erosion (in tons/ac/year). As shown in the attached NRCS Soil Report, the soils present in the Pettibone Creek Watershed include:

23A	Blount silt Loam, 0 to 2 % slopes.
153A	Pella silty clay loam, 0 to 2% slopes.
192A	Del Ray silt loam, 0 to 2% slopes
232A	Ashkum silty clay loam, 0 to 2% slopes.
298A	Beecher silt loam, 0 to 2% slopes.
298B	Beecher silt loam, 2 to 4% slopes.
330A	Peotone silty clay loam, 0 to 2% slopes.
365A	Aptakisic silt loam, 0 to 2% slopes.
367	Beach sand.
530B	Ozaukee silt loam, 2 to 4% slopes.
530C	Ozaukee silt loam, 4 to 6% slopes.
530C2	Ozaukee silt loam, 4 to 6% slopes, eroded.
530D2	Ozaukee silt loam, 6 to 12% slopes, eroded.
530F	Ozaukee silt loam, 20 to 30% slopes.
697A	Wauconda silt loam, 2 to 4% slopes.
698A	Grays silt loam, 0 to 2% slopes.
698B	Grays silt loam, 2 to 4% slopes.
802B	Orthentis, loamy undulating.
805B	Orthentis, clayey undulating.
839B	Udipsamments complex, undulating.
978A	Wauconda and Beecher silt loams, 0 to 2% slopes.
979A	Grays and Markham silt loams, 0 to 2% slopes.
979B	Grays and Markham silt loams, 2 to 4% slopes.

As per conversations with the local USDA office, the soils for Lake County are being updated to reflect rapidly increased urbanization. Subsequently, recent soil data are not available for use to estimate soil loss through erosion are not available. However, a reasonable estimate can be made of the impact of urbanization and the associated increase in developed areas. By viewing photogrammetric images of the Northern Pettibone Creek watershed, a reasonable estimate of the reduced soil loss via increased area of impermeable surfaces was assumed to be 50%. An additional analysis of the soil loss once updated regional soil data is available is recommended.

CLIENT:	NAVAL STATION GREAT LAKES	JOB NUMBER:	112G01021
SUBJECT:	Sediment Transport Estimation - Northern Branch Pettibone Creek		
BASED ON:		DRAWING NUMBER:	
BY: RLS Date:	CHECKED BY: Date:	APPROVED BY:	DATE:

The following table presents the estimated soil losses per year for each soil type:

Map Unit Symbol	Map Unit Name	Acreage	Soil Loss (T/Ac/Yr.)	Total Estimated Soil Loss (T/ac/yr)
153A	Pella silty clay loam, 0 to 2% slopes.	2.3129	2.5	5.8
232A	Ashkum silty clay loam, 0 to 2% slopes.	46.3470	2.0	92.7
298A	Beecher silt loam, 0 to 2% slopes.	20.9050	3.2	66.9
330A	Peotone silty clay loam, 0 to 2% slopes.	16.8130	2.5	42.0
330C	Peotone silty clay loam, 4 to 6% slopes.	4.1810	5.0	20.9
530B	Ozaukee silt loam, 2 to 4% slopes.	416.5009	15.0	6247.5
530C	Ozaukee silt loam, 4 to 6% slopes.	43.0556	30.0	1291.7
530F	Ozaukee silt loam, 20 to 30% slopes.	4.8037	180.0	864.7
697A	Wauconda silt loam, 0 to 2% slopes.	295.6962	4.3	1271.5
698A	Grays silt loam, 0 to 2% slopes.	59.6016	4.3	256.3
698B	Grays silt loam, 2 to 4% slopes.	33.3591	17.0	567.1
802B	Orthentis, loamy undulating.	182.0076	4.2	764.4
805B	Orthentis, clayey undulating.	14.4112	4.1	59.1
			Total Tons/year=	11550.6

COMPARISON TO WAUKEGAN RIVER WATERSHED SEDIMENT LOSS ESTIMATION

The 2006 Waukegan River Watershed Plan was referred to for comparison of the Northern Branch of Pettibone Creek estimated annual sediment losses. According to the 2006 report, approximately 6,000 tons per year of sediment is lost via erosion emanating from storm water flows (as estimated as the total suspended and dissolved solid estimates provided in table 3.1 of the report. The approximate size of the watershed 12 square miles.

By comparison, the size of the watershed depositing sediments into the Northern Branch of Pettibone Creek is slightly under 2 square miles. Given the basic similarities in use and existing urbanization between both watersheds, a reasonable estimate of 2,000 tons/ac/year of sediment loss would be expected to enter Pettibone Creek from off site sources, or 4,000 tons/year. Also, as per discussions with representatives at the regional office of the NRCS, the soil mapping in the Pettibone Creek watershed area is currently being updated. Current soil mapping for the Pettibone Creek watershed area likely over estimates soil losses when used in soil loss computer simulations due to the lack of development reflected in the current soil mapping.

CONCLUSIONS:

The total estimated quantity of soil loss through sediment erosion is calculated to be 11,550.6 ton/year. However, given the comparison to the estimate sediment losses in the Waukegan River Watershed and lack of available accurate soil mapping, the actual sediment losses would likely be closer to 4,000 tons/ac/year. It is recommended that additional soil loss calculations are performed once the updated soil mapping for the Pettibone Creek Watershed area are available.

United States Department of Agriculture

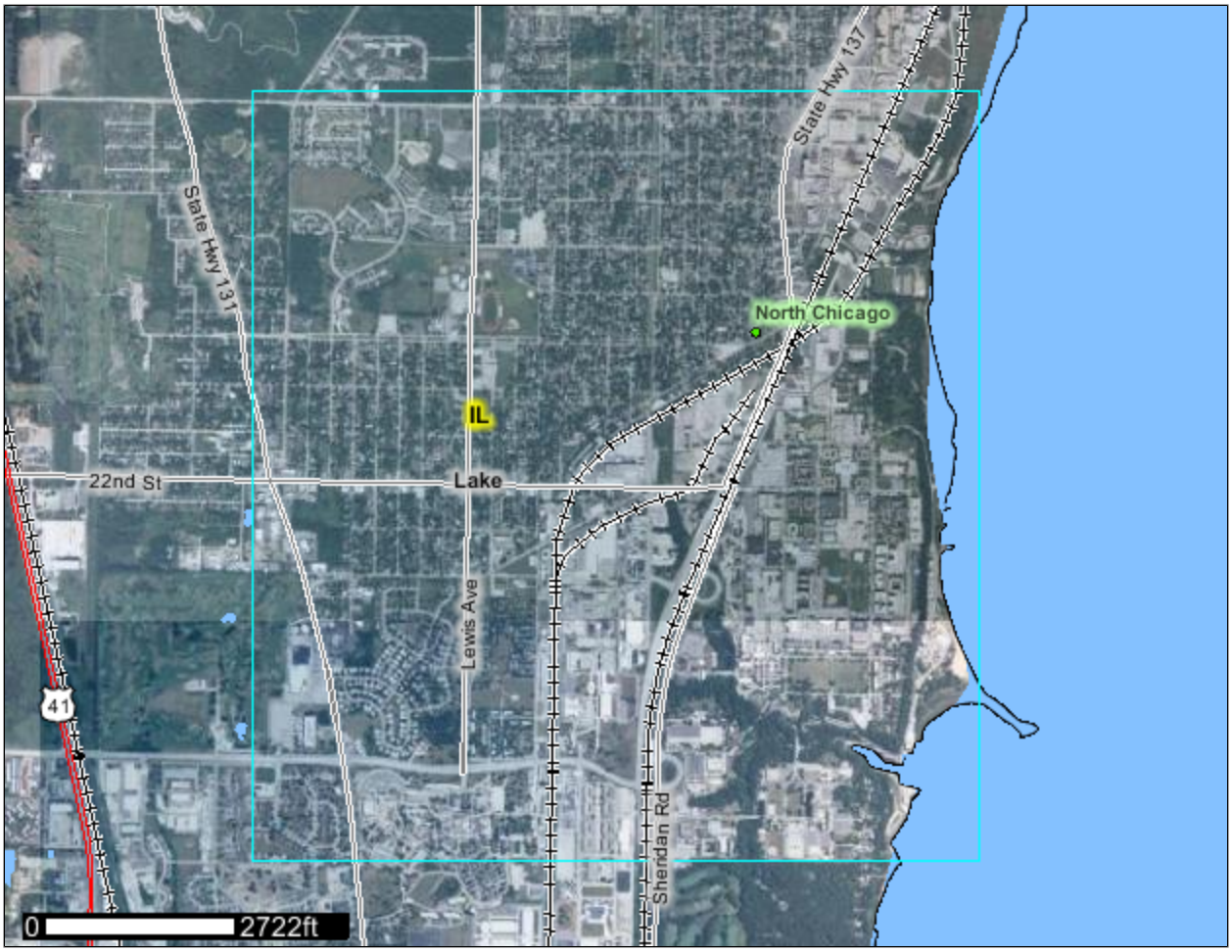
Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Lake County, Illinois

Naval Station Great Lakes



July 19, 2011

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

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Contents

Preface.....2
How Soil Surveys Are Made.....5
Soil Map.....7
Soil Map.....8
Legend.....9
Map Unit Legend.....10
Map Unit Descriptions.....10
Lake County, Illinois.....13
23A—Blount silt loam, 0 to 2 percent slopes.....13
153A—Pella silty clay loam, 0 to 2 percent slopes.....13
192A—Del Rey silt loam, 0 to 2 percent slopes.....14
232A—Ashkum silty clay loam, 0 to 2 percent slopes.....15
298A—Beecher silt loam, 0 to 2 percent slopes.....16
330A—Peotone silty clay loam, 0 to 2 percent slopes.....17
367—Beach sand.....18
530B—Ozaukee silt loam, 2 to 4 percent slopes.....18
530C—Ozaukee silt loam, 4 to 6 percent slopes.....19
530D2—Ozaukee silt loam, 6 to 12 percent slopes, eroded.....20
530F—Ozaukee silt loam, 20 to 30 percent slopes.....21
697A—Wauconda silt loam, 0 to 2 percent slopes.....21
698A—Grays silt loam, 0 to 2 percent slopes.....22
698B—Grays silt loam, 2 to 4 percent slopes.....23
802B—Orthents, loamy, undulating.....24
805B—Orthents, clayey, undulating.....25
839B—Udipsamments complex, undulating.....25
978A—Wauconda and Beecher silt loams, 0 to 2 percent slopes.....27
979A—Grays and Markham silt loams, 0 to 2 percent slopes.....28
979B—Grays and Markham silt loams, 2 to 4 percent slopes.....29
W—Water.....31
References.....32

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the

individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

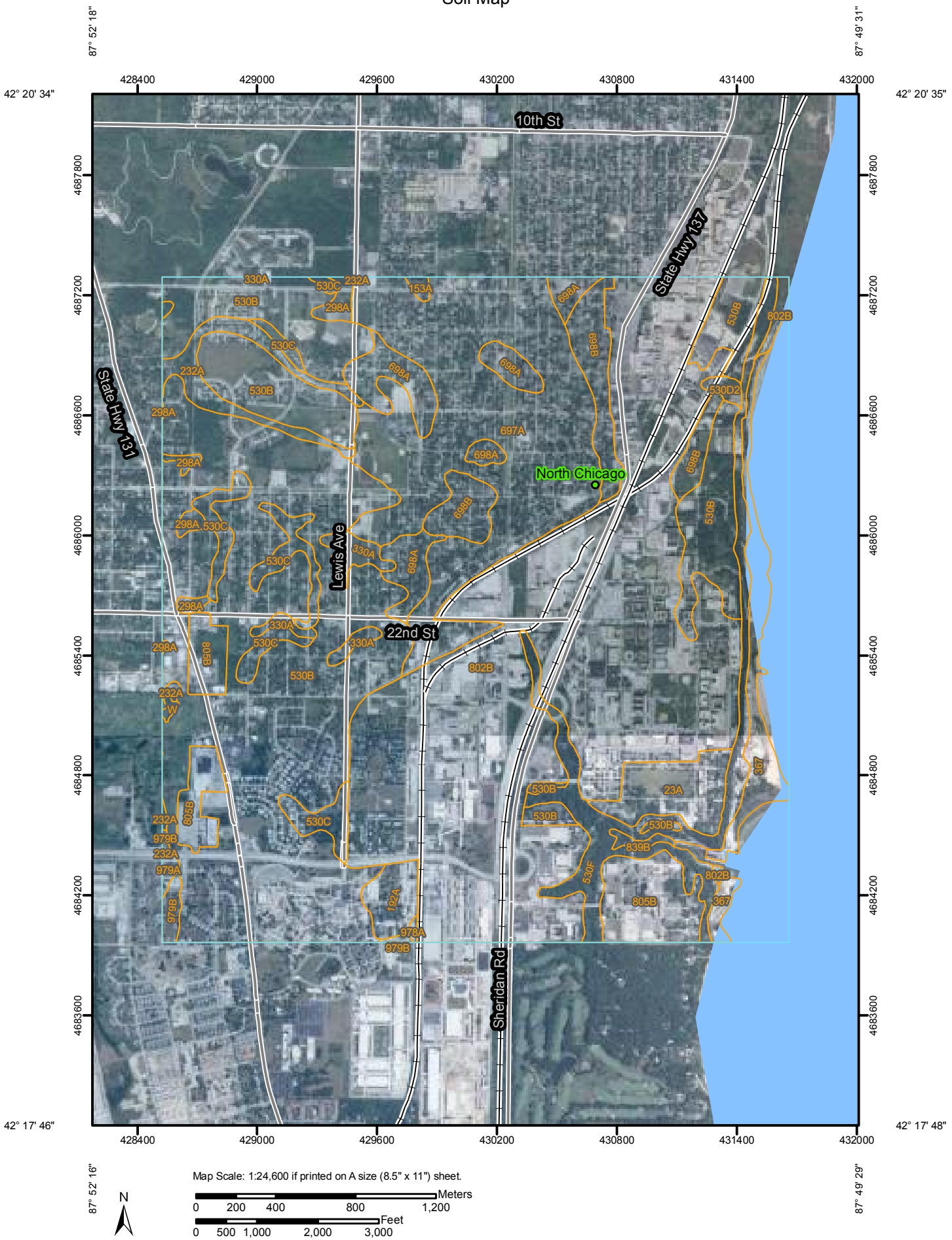
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map



MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

- Gully
- Short Steep Slope
- Other

Political Features

- Cities

Water Features

- Oceans
- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:24,600 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 16N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Lake County, Illinois
Survey Area Data: Version 5, Feb 12, 2010

Date(s) aerial images were photographed: 7/7/2007; 8/13/2007; 7/31/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Lake County, Illinois (IL097)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
23A	Blount silt loam, 0 to 2 percent slopes	43.9	1.7%
153A	Pella silty clay loam, 0 to 2 percent slopes	2.4	0.1%
192A	Del Rey silt loam, 0 to 2 percent slopes	20.7	0.8%
232A	Ashkum silty clay loam, 0 to 2 percent slopes	36.1	1.4%
298A	Beecher silt loam, 0 to 2 percent slopes	15.1	0.6%
330A	Peotone silty clay loam, 0 to 2 percent slopes	19.5	0.8%
367	Beach sand	54.6	2.1%
530B	Ozaukee silt loam, 2 to 4 percent slopes	757.6	29.4%
530C	Ozaukee silt loam, 4 to 6 percent slopes	57.5	2.2%
530D2	Ozaukee silt loam, 6 to 12 percent slopes, eroded	4.5	0.2%
530F	Ozaukee silt loam, 20 to 30 percent slopes	100.8	3.9%
697A	Wauconda silt loam, 0 to 2 percent slopes	331.5	12.9%
698A	Grays silt loam, 0 to 2 percent slopes	68.5	2.7%
698B	Grays silt loam, 2 to 4 percent slopes	67.7	2.6%
802B	Orthents, loamy, undulating	765.2	29.7%
805B	Orthents, clayey, undulating	87.8	3.4%
839B	Udipsamments complex, undulating	3.7	0.1%
978A	Wauconda and Beecher silt loams, 0 to 2 percent slopes	1.2	0.0%
979A	Grays and Markham silt loams, 0 to 2 percent slopes	3.0	0.1%
979B	Grays and Markham silt loams, 2 to 4 percent slopes	7.9	0.3%
W	Water	1.5	0.1%
Subtotals for Soil Survey Area		**2,450.6**	**95.0%**
Totals for Area of Interest		**2,578.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability

of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and

relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Lake County, Illinois

23A—Blount silt loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Blount and similar soils: 90 percent

Description of Blount

Setting

Landform: End moraines, ground moraines
Landform position (two-dimensional): Footslope, summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 30 to 48 inches to dense material
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Available water capacity: Low (about 5.9 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 7 inches: Silt loam
7 to 13 inches: Silt loam
13 to 26 inches: Silty clay
26 to 32 inches: Silty clay loam
32 to 60 inches: Silty clay loam

153A—Pella silty clay loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 510 to 1,020 feet
Mean annual precipitation: 30 to 40 inches
Mean annual air temperature: 45 to 52 degrees F

Frost-free period: 140 to 180 days

Map Unit Composition

Pella and similar soils: 90 percent

Description of Pella

Setting

Landform: Outwash plains, ground moraines, lake plains
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 40 percent
Available water capacity: High (about 12.0 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 12 inches: Silty clay loam
12 to 33 inches: Silty clay loam
33 to 42 inches: Silt loam
42 to 60 inches: Stratified loamy sand to silty clay loam

192A—Del Rey silt loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Del rey and similar soils: 92 percent

Description of Del Rey

Setting

Landform: Lake plains
Landform position (two-dimensional): Summit, footslope
Landform position (three-dimensional): Rise

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Lacustrine deposits

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Moderate (about 8.9 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 4 inches: Silt loam
4 to 9 inches: Silt loam
9 to 33 inches: Silty clay
33 to 41 inches: Silty clay loam
41 to 60 inches: Silty clay loam

232A—Ashkum silty clay loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ashkum and similar soils: 90 percent

Description of Ashkum

Setting

Landform: Ground moraines, end moraines
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Colluvium and in the underlying till

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)

Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 25 percent
Available water capacity: High (about 9.8 inches)

Interpretive groups
Land capability (nonirrigated): 2w

Typical profile
0 to 12 inches: Silty clay loam
12 to 29 inches: Silty clay
29 to 54 inches: Silty clay loam
54 to 60 inches: Silty clay loam

298A—Beecher silt loam, 0 to 2 percent slopes

Map Unit Setting
Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Beecher and similar soils: 90 percent

Description of Beecher

Setting
Landform: Ground moraines, end moraines
Landform position (two-dimensional): Summit, footslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities
Slope: 0 to 2 percent
Depth to restrictive feature: 24 to 45 inches to dense material
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Available water capacity: Moderate (about 6.2 inches)

Interpretive groups
Land capability (nonirrigated): 2w

Typical profile
0 to 9 inches: Silt loam

9 to 21 inches: Silty clay loam
21 to 37 inches: Silty clay loam
37 to 60 inches: Silty clay loam

330A—Peotone silty clay loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 510 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Peotone and similar soils: 90 percent

Description of Peotone

Setting

Landform: Ground moraines
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Dip
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Colluvium

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 15 percent
Available water capacity: High (about 10.3 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 13 inches: Silty clay loam
13 to 50 inches: Silty clay
50 to 60 inches: Silty clay loam

367—Beach sand

Map Unit Setting

Elevation: 540 to 680 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Beach sand: 100 percent

Description of Beach Sand

Setting

Landform: Beaches, lakeshores
Parent material: Beach sand

530B—Ozaukee silt loam, 2 to 4 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting

Landform: End moraines, ground moraines
Landform position (two-dimensional): Backslope, summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None

Calcium carbonate, maximum content: 40 percent
Available water capacity: Moderate (about 6.5 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 4 inches: Silt loam
4 to 10 inches: Silt loam
10 to 21 inches: Silty clay loam
21 to 39 inches: Silty clay loam
39 to 60 inches: Silty clay loam

530C—Ozaukee silt loam, 4 to 6 percent slopes

Map Unit Setting
Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting
Landform: Ground moraines, end moraines
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities
Slope: 4 to 6 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Moderate (about 6.4 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 5 inches: Silt loam
5 to 10 inches: Silt loam
10 to 33 inches: Silty clay loam

33 to 38 inches: Silty clay loam
38 to 60 inches: Silty clay loam

530D2—Ozaukee silt loam, 6 to 12 percent slopes, eroded

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting

Landform: Ground moraines, end moraines
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 6 to 12 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Low (about 4.7 inches)

Interpretive groups

Land capability (nonirrigated): 3e

Typical profile

0 to 6 inches: Silt loam
6 to 20 inches: Silty clay loam
20 to 28 inches: Silty clay loam
28 to 60 inches: Silty clay loam

530F—Ozaukee silt loam, 20 to 30 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting

Landform: End moraines, ground moraines
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 20 to 30 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Low (about 5.8 inches)

Interpretive groups

Land capability (nonirrigated): 6e

Typical profile

0 to 5 inches: Silt loam
5 to 29 inches: Silty clay loam
29 to 36 inches: Silty clay loam
36 to 60 inches: Silty clay loam

697A—Wauconda silt loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 600 to 970 feet
Mean annual precipitation: 28 to 40 inches

Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Wauconda and similar soils: 90 percent

Description of Wauconda

Setting
Landform: Outwash plains, stream terraces
Landform position (two-dimensional): Summit, footslope
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities
Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.6 inches)

Interpretive groups
Land capability (nonirrigated): 2w

Typical profile
0 to 9 inches: Silt loam
9 to 14 inches: Silt loam
14 to 30 inches: Silty clay loam
30 to 38 inches: Loam
38 to 60 inches: Stratified loamy sand to silt loam

698A—Grays silt loam, 0 to 2 percent slopes

Map Unit Setting
Elevation: 600 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Grays and similar soils: 90 percent

Description of Grays

Setting
Landform: Outwash plains, stream terraces

Landform position (two-dimensional): Summit
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 10.0 inches)

Interpretive groups

Land capability (nonirrigated): 1

Typical profile

0 to 9 inches: Silt loam
9 to 12 inches: Silt loam
12 to 35 inches: Silty clay loam
35 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

698B—Grays silt loam, 2 to 4 percent slopes

Map Unit Setting

Elevation: 600 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Grays and similar soils: 92 percent

Description of Grays

Setting

Landform: Outwash plains, stream terraces
Landform position (two-dimensional): Summit, backslope
Landform position (three-dimensional): Interfluve, tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches

Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.9 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 8 inches: Silt loam
8 to 11 inches: Silt loam
11 to 34 inches: Silty clay loam
34 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

802B—Orthents, loamy, undulating

Map Unit Setting
Elevation: 510 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Orthents, loamy and similar soils: 92 percent

Description of Orthents, Loamy

Setting
Landform: Outwash plains, ground moraines
Landform position (two-dimensional): Summit, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Earthy fill

Properties and qualities
Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 42 to 60 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Available water capacity: High (about 9.8 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 6 inches: Loam

6 to 60 inches: Clay loam

805B—Orthents, clayey, undulating

Map Unit Setting

Elevation: 510 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Orthents, clayey and similar soils: 92 percent

Description of Orthents, Clayey

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Summit, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Earthy fill

Properties and qualities

Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low (0.02 to 0.06 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 25 percent
Available water capacity: Low (about 4.4 inches)

Interpretive groups

Land capability (nonirrigated): 3e

Typical profile

0 to 6 inches: Silty clay
6 to 60 inches: Silty clay

839B—Udipsamments complex, undulating

Map Unit Setting

Elevation: 540 to 680 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F

Frost-free period: 140 to 180 days

Map Unit Composition

Udipsamments, typic, and similar soils: 55 percent
Udipsamments, aquic, and similar soils: 35 percent

Description of Udipsamments, Typic

Setting

Landform: Beach ridges, beach terraces
Landform position (two-dimensional): Summit, backslope
Parent material: Wind-worked beach sand

Properties and qualities

Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Low (about 3.1 inches)

Interpretive groups

Land capability (nonirrigated): 6s

Typical profile

0 to 4 inches: Sand
4 to 12 inches: Sand
12 to 60 inches: Sand

Description of Udipsamments, Aquic

Setting

Landform: Beach terraces, beach ridges
Landform position (two-dimensional): Footslope
Parent material: Wind-worked beach sand

Properties and qualities

Slope: 1 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: About 12 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Low (about 3.3 inches)

Interpretive groups

Land capability (nonirrigated): 4s

Typical profile

0 to 7 inches: Sand
7 to 20 inches: Sand

20 to 60 inches: Sand

978A—Wauconda and Beecher silt loams, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Wauconda and similar soils: 46 percent
Beecher and similar soils: 44 percent

Description of Wauconda

Setting

Landform: Outwash plains, lake plains
Landform position (two-dimensional): Summit, footslope
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.6 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 9 inches: Silt loam
9 to 14 inches: Silt loam
14 to 30 inches: Silty clay loam
30 to 38 inches: Loam
38 to 60 inches: Stratified loamy sand to silt loam

Description of Beecher

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Footslope, summit
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: 24 to 45 inches to dense material
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Available water capacity: Low (about 5.8 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 9 inches: Silt loam
9 to 21 inches: Silty clay loam
21 to 37 inches: Silty clay loam
37 to 60 inches: Silty clay loam

979A—Grays and Markham silt loams, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Grays and similar soils: 46 percent
Markham and similar soils: 44 percent

Description of Grays

Setting

Landform: Outwash plains, lake plains
Landform position (two-dimensional): Summit
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 10.0 inches)

Interpretive groups

Land capability (nonirrigated): 1

Typical profile

0 to 9 inches: Silt loam
9 to 12 inches: Silt loam
12 to 35 inches: Silty clay loam
35 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

Description of Markham

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Summit
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 20 to 55 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Moderate (about 6.6 inches)

Interpretive groups

Land capability (nonirrigated): 2s

Typical profile

0 to 8 inches: Silt loam
8 to 11 inches: Silt loam
11 to 24 inches: Silty clay loam
24 to 37 inches: Silty clay loam
37 to 60 inches: Silty clay loam

979B—Grays and Markham silt loams, 2 to 4 percent slopes

Map Unit Setting

Elevation: 540 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Grays and similar soils: 46 percent
Markham and similar soils: 44 percent

Description of Grays

Setting

Landform: Outwash plains, lake plains
Landform position (two-dimensional): Backslope, summit
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.9 inches)

Interpretive groups

Land capability (nonirrigated): 2e

Typical profile

0 to 8 inches: Silt loam
8 to 11 inches: Silt loam
11 to 34 inches: Silty clay loam
34 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

Description of Markham

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Backslope, summit
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: 20 to 55 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Moderate (about 6.0 inches)

Interpretive groups

Land capability (nonirrigated): 2e

Typical profile

0 to 8 inches: Silt loam
8 to 21 inches: Silty clay loam
21 to 32 inches: Silty clay loam
32 to 60 inches: Silty clay loam

W—Water

Map Unit Composition

Water: 100 percent

Description of Water

Setting

Landform: Channels, drainageways, lakes, oxbows, perenial streams, rivers
Parent material: Water

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United States Department of Agriculture

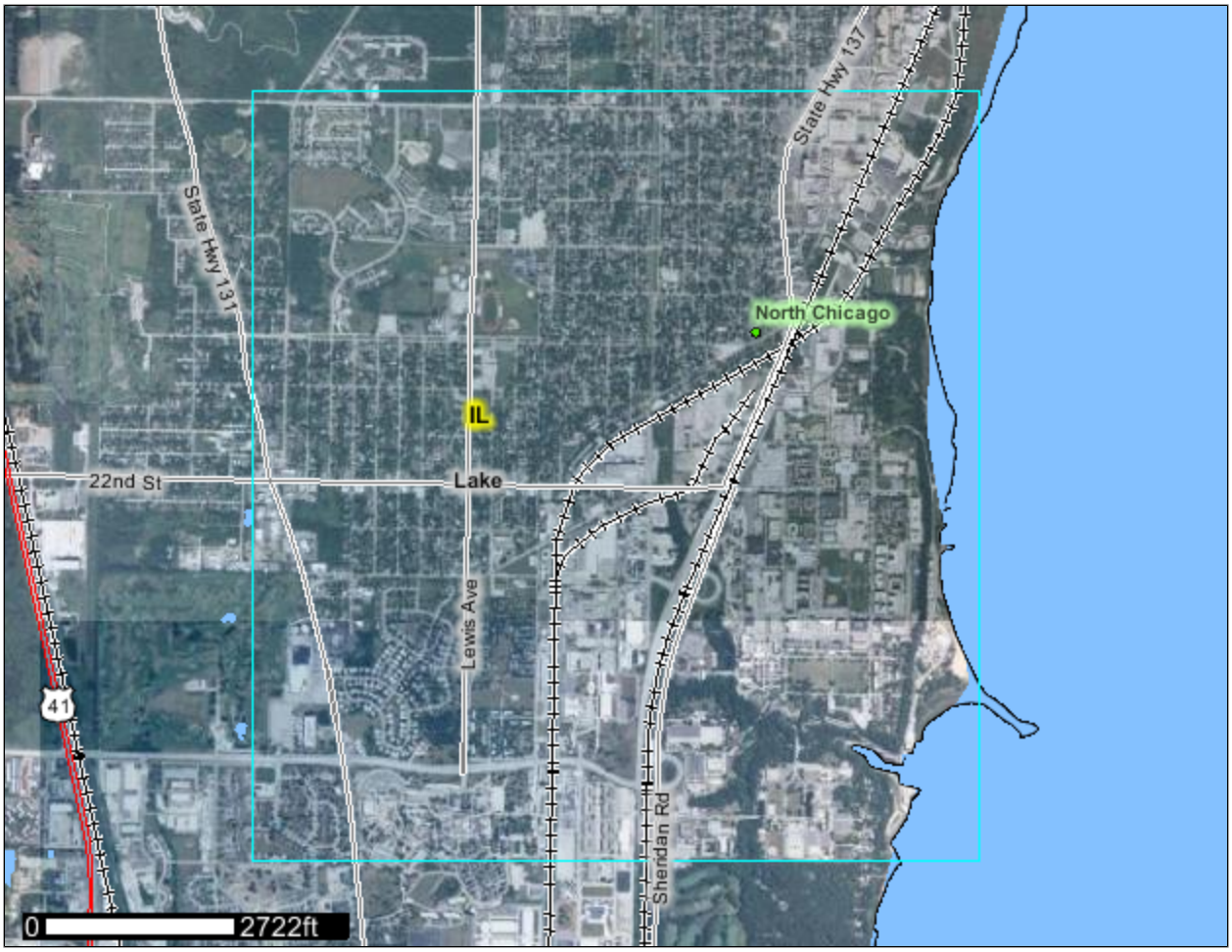
Natural Resources Conservation Service

A product of the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local participants

Custom Soil Resource Report for

Lake County, Illinois

Naval Station Great Lakes



July 19, 2011

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (http://soils.usda.gov/sqi/) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (http://offices.sc.egov.usda.gov/locator/app?agency=nrcs) or your NRCS State Soil Scientist (http://soils.usda.gov/contact/state_offices/).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Soil Data Mart Web site or the NRCS Web Soil Survey. The Soil Data Mart is the data storage site for the official soil survey information.

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Contents

Preface.....2
How Soil Surveys Are Made.....5
Soil Map.....7
Soil Map.....8
Legend.....9
Map Unit Legend.....10
Map Unit Descriptions.....10
Lake County, Illinois.....13
23A—Blount silt loam, 0 to 2 percent slopes.....13
153A—Pella silty clay loam, 0 to 2 percent slopes.....13
192A—Del Rey silt loam, 0 to 2 percent slopes.....14
232A—Ashkum silty clay loam, 0 to 2 percent slopes.....15
298A—Beecher silt loam, 0 to 2 percent slopes.....16
330A—Peotone silty clay loam, 0 to 2 percent slopes.....17
367—Beach sand.....18
530B—Ozaukee silt loam, 2 to 4 percent slopes.....18
530C—Ozaukee silt loam, 4 to 6 percent slopes.....19
530D2—Ozaukee silt loam, 6 to 12 percent slopes, eroded.....20
530F—Ozaukee silt loam, 20 to 30 percent slopes.....21
697A—Wauconda silt loam, 0 to 2 percent slopes.....21
698A—Grays silt loam, 0 to 2 percent slopes.....22
698B—Grays silt loam, 2 to 4 percent slopes.....23
802B—Orthents, loamy, undulating.....24
805B—Orthents, clayey, undulating.....25
839B—Udipsamments complex, undulating.....25
978A—Wauconda and Beecher silt loams, 0 to 2 percent slopes.....27
979A—Grays and Markham silt loams, 0 to 2 percent slopes.....28
979B—Grays and Markham silt loams, 2 to 4 percent slopes.....29
W—Water.....31
References.....32

How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil scientists classified and named the soils in the survey area, they compared the

individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

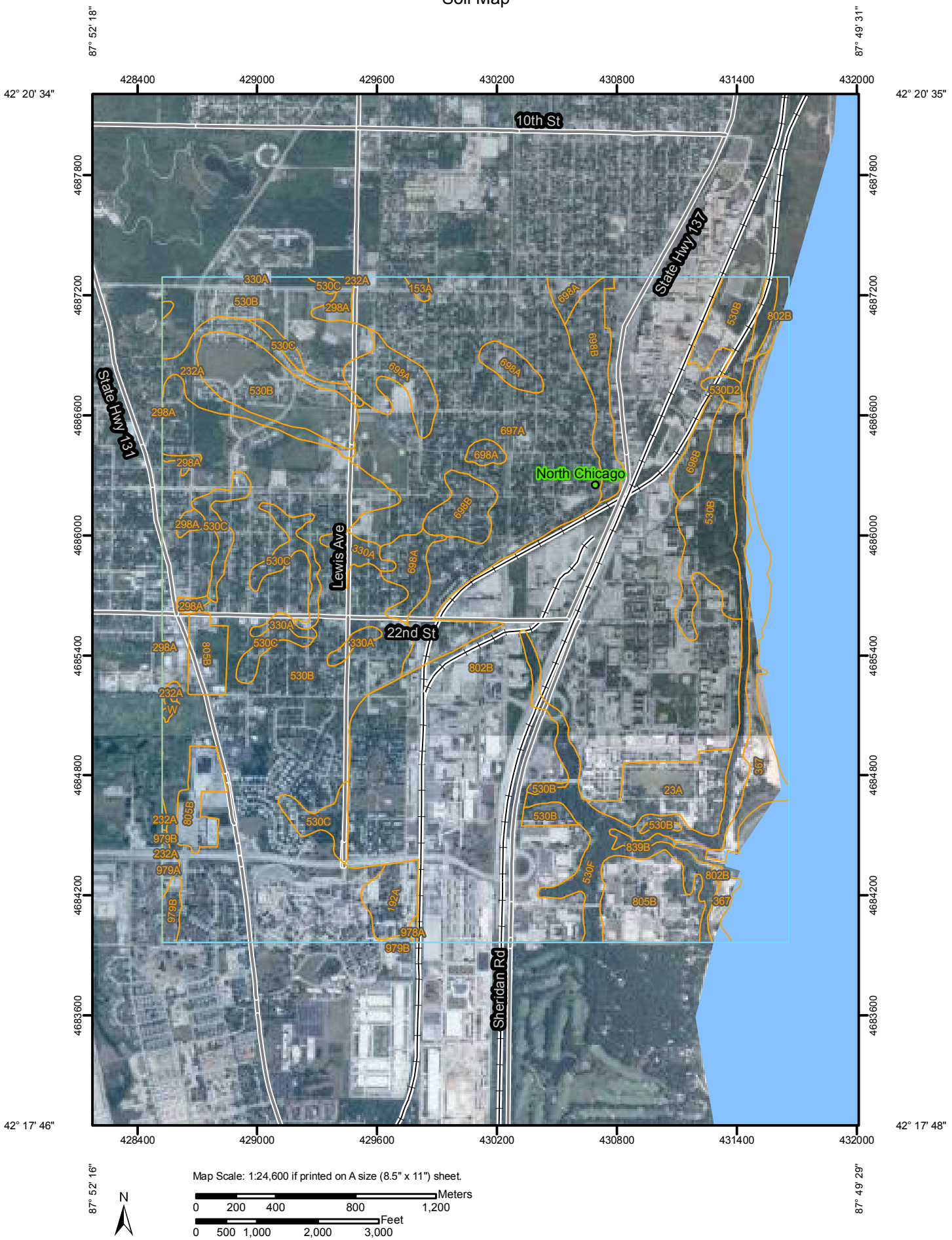
Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report
Soil Map



MAP LEGEND

Area of Interest (AOI)

- Area of Interest (AOI)

Soils

- Soil Map Units

Special Point Features

- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other

Special Line Features

- Gully
- Short Steep Slope
- Other

Political Features

- Cities

Water Features

- Oceans
- Streams and Canals

Transportation

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

MAP INFORMATION

Map Scale: 1:24,600 if printed on A size (8.5" × 11") sheet.

The soil surveys that comprise your AOI were mapped at 1:12,000.

Please rely on the bar scale on each map sheet for accurate map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: UTM Zone 16N NAD83

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Lake County, Illinois
Survey Area Data: Version 5, Feb 12, 2010

Date(s) aerial images were photographed: 7/7/2007; 8/13/2007; 7/31/2007

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Lake County, Illinois (IL097)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
23A	Blount silt loam, 0 to 2 percent slopes	43.9	1.7%
153A	Pella silty clay loam, 0 to 2 percent slopes	2.4	0.1%
192A	Del Rey silt loam, 0 to 2 percent slopes	20.7	0.8%
232A	Ashkum silty clay loam, 0 to 2 percent slopes	36.1	1.4%
298A	Beecher silt loam, 0 to 2 percent slopes	15.1	0.6%
330A	Peotone silty clay loam, 0 to 2 percent slopes	19.5	0.8%
367	Beach sand	54.6	2.1%
530B	Ozaukee silt loam, 2 to 4 percent slopes	757.6	29.4%
530C	Ozaukee silt loam, 4 to 6 percent slopes	57.5	2.2%
530D2	Ozaukee silt loam, 6 to 12 percent slopes, eroded	4.5	0.2%
530F	Ozaukee silt loam, 20 to 30 percent slopes	100.8	3.9%
697A	Wauconda silt loam, 0 to 2 percent slopes	331.5	12.9%
698A	Grays silt loam, 0 to 2 percent slopes	68.5	2.7%
698B	Grays silt loam, 2 to 4 percent slopes	67.7	2.6%
802B	Orthents, loamy, undulating	765.2	29.7%
805B	Orthents, clayey, undulating	87.8	3.4%
839B	Udipsamments complex, undulating	3.7	0.1%
978A	Wauconda and Beecher silt loams, 0 to 2 percent slopes	1.2	0.0%
979A	Grays and Markham silt loams, 0 to 2 percent slopes	3.0	0.1%
979B	Grays and Markham silt loams, 2 to 4 percent slopes	7.9	0.3%
W	Water	1.5	0.1%
Subtotals for Soil Survey Area		**2,450.6**	**95.0%**
Totals for Area of Interest		**2,578.4**	**100.0%**

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability

of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and

relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Lake County, Illinois

23A—Blount silt loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Blount and similar soils: 90 percent

Description of Blount

Setting

Landform: End moraines, ground moraines
Landform position (two-dimensional): Footslope, summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 30 to 48 inches to dense material
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Available water capacity: Low (about 5.9 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 7 inches: Silt loam
7 to 13 inches: Silt loam
13 to 26 inches: Silty clay
26 to 32 inches: Silty clay loam
32 to 60 inches: Silty clay loam

153A—Pella silty clay loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 510 to 1,020 feet
Mean annual precipitation: 30 to 40 inches
Mean annual air temperature: 45 to 52 degrees F

Frost-free period: 140 to 180 days

Map Unit Composition

Pella and similar soils: 90 percent

Description of Pella

Setting

Landform: Outwash plains, ground moraines, lake plains
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 40 percent
Available water capacity: High (about 12.0 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 12 inches: Silty clay loam
12 to 33 inches: Silty clay loam
33 to 42 inches: Silt loam
42 to 60 inches: Stratified loamy sand to silty clay loam

192A—Del Rey silt loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Del rey and similar soils: 92 percent

Description of Del Rey

Setting

Landform: Lake plains
Landform position (two-dimensional): Summit, footslope
Landform position (three-dimensional): Rise

Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Lacustrine deposits

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Moderate (about 8.9 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 4 inches: Silt loam
4 to 9 inches: Silt loam
9 to 33 inches: Silty clay
33 to 41 inches: Silty clay loam
41 to 60 inches: Silty clay loam

232A—Ashkum silty clay loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ashkum and similar soils: 90 percent

Description of Ashkum

Setting

Landform: Ground moraines, end moraines
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Talf
Down-slope shape: Linear
Across-slope shape: Concave
Parent material: Colluvium and in the underlying till

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)

Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 25 percent
Available water capacity: High (about 9.8 inches)

Interpretive groups
Land capability (nonirrigated): 2w

Typical profile
0 to 12 inches: Silty clay loam
12 to 29 inches: Silty clay
29 to 54 inches: Silty clay loam
54 to 60 inches: Silty clay loam

298A—Beecher silt loam, 0 to 2 percent slopes

Map Unit Setting
Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Beecher and similar soils: 90 percent

Description of Beecher

Setting
Landform: Ground moraines, end moraines
Landform position (two-dimensional): Summit, footslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities
Slope: 0 to 2 percent
Depth to restrictive feature: 24 to 45 inches to dense material
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Available water capacity: Moderate (about 6.2 inches)

Interpretive groups
Land capability (nonirrigated): 2w

Typical profile
0 to 9 inches: Silt loam

9 to 21 inches: Silty clay loam
21 to 37 inches: Silty clay loam
37 to 60 inches: Silty clay loam

330A—Peotone silty clay loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 510 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Peotone and similar soils: 90 percent

Description of Peotone

Setting

Landform: Ground moraines
Landform position (two-dimensional): Toeslope
Landform position (three-dimensional): Dip
Down-slope shape: Concave
Across-slope shape: Concave
Parent material: Colluvium

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Very poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 0 to 12 inches
Frequency of flooding: None
Frequency of ponding: Frequent
Calcium carbonate, maximum content: 15 percent
Available water capacity: High (about 10.3 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 13 inches: Silty clay loam
13 to 50 inches: Silty clay
50 to 60 inches: Silty clay loam

367—Beach sand

Map Unit Setting

Elevation: 540 to 680 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Beach sand: 100 percent

Description of Beach Sand

Setting

Landform: Beaches, lakeshores
Parent material: Beach sand

530B—Ozaukee silt loam, 2 to 4 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting

Landform: End moraines, ground moraines
Landform position (two-dimensional): Backslope, summit
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None

Calcium carbonate, maximum content: 40 percent
Available water capacity: Moderate (about 6.5 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 4 inches: Silt loam
4 to 10 inches: Silt loam
10 to 21 inches: Silty clay loam
21 to 39 inches: Silty clay loam
39 to 60 inches: Silty clay loam

530C—Ozaukee silt loam, 4 to 6 percent slopes

Map Unit Setting
Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting
Landform: Ground moraines, end moraines
Landform position (two-dimensional): Shoulder, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities
Slope: 4 to 6 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Moderate (about 6.4 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 5 inches: Silt loam
5 to 10 inches: Silt loam
10 to 33 inches: Silty clay loam

33 to 38 inches: Silty clay loam
38 to 60 inches: Silty clay loam

530D2—Ozaukee silt loam, 6 to 12 percent slopes, eroded

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting

Landform: Ground moraines, end moraines
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 6 to 12 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Low (about 4.7 inches)

Interpretive groups

Land capability (nonirrigated): 3e

Typical profile

0 to 6 inches: Silt loam
6 to 20 inches: Silty clay loam
20 to 28 inches: Silty clay loam
28 to 60 inches: Silty clay loam

530F—Ozaukee silt loam, 20 to 30 percent slopes

Map Unit Setting

Elevation: 540 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Ozaukee and similar soils: 92 percent

Description of Ozaukee

Setting

Landform: End moraines, ground moraines
Landform position (two-dimensional): Backslope
Landform position (three-dimensional): Side slope
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 20 to 30 percent
Depth to restrictive feature: 20 to 45 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 40 percent
Available water capacity: Low (about 5.8 inches)

Interpretive groups

Land capability (nonirrigated): 6e

Typical profile

0 to 5 inches: Silt loam
5 to 29 inches: Silty clay loam
29 to 36 inches: Silty clay loam
36 to 60 inches: Silty clay loam

697A—Wauconda silt loam, 0 to 2 percent slopes

Map Unit Setting

Elevation: 600 to 970 feet
Mean annual precipitation: 28 to 40 inches

Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Wauconda and similar soils: 90 percent

Description of Wauconda

Setting
Landform: Outwash plains, stream terraces
Landform position (two-dimensional): Summit, footslope
Landform position (three-dimensional): Rise
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities
Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.6 inches)

Interpretive groups
Land capability (nonirrigated): 2w

Typical profile
0 to 9 inches: Silt loam
9 to 14 inches: Silt loam
14 to 30 inches: Silty clay loam
30 to 38 inches: Loam
38 to 60 inches: Stratified loamy sand to silt loam

698A—Grays silt loam, 0 to 2 percent slopes

Map Unit Setting
Elevation: 600 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Grays and similar soils: 90 percent

Description of Grays

Setting
Landform: Outwash plains, stream terraces

Landform position (two-dimensional): Summit
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 10.0 inches)

Interpretive groups

Land capability (nonirrigated): 1

Typical profile

0 to 9 inches: Silt loam
9 to 12 inches: Silt loam
12 to 35 inches: Silty clay loam
35 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

698B—Grays silt loam, 2 to 4 percent slopes

Map Unit Setting

Elevation: 600 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Grays and similar soils: 92 percent

Description of Grays

Setting

Landform: Outwash plains, stream terraces
Landform position (two-dimensional): Summit, backslope
Landform position (three-dimensional): Interfluve, tread
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches

Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.9 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 8 inches: Silt loam
8 to 11 inches: Silt loam
11 to 34 inches: Silty clay loam
34 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

802B—Orthents, loamy, undulating

Map Unit Setting
Elevation: 510 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition
Orthents, loamy and similar soils: 92 percent

Description of Orthents, Loamy

Setting
Landform: Outwash plains, ground moraines
Landform position (two-dimensional): Summit, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Earthy fill

Properties and qualities
Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 42 to 60 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 20 percent
Available water capacity: High (about 9.8 inches)

Interpretive groups
Land capability (nonirrigated): 2e

Typical profile
0 to 6 inches: Loam

6 to 60 inches: Clay loam

805B—Orthents, clayey, undulating

Map Unit Setting

Elevation: 510 to 930 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Orthents, clayey and similar soils: 92 percent

Description of Orthents, Clayey

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Summit, backslope
Landform position (three-dimensional): Interfluve
Down-slope shape: Convex
Across-slope shape: Convex
Parent material: Earthy fill

Properties and qualities

Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low (0.02 to 0.06 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 25 percent
Available water capacity: Low (about 4.4 inches)

Interpretive groups

Land capability (nonirrigated): 3e

Typical profile

0 to 6 inches: Silty clay
6 to 60 inches: Silty clay

839B—Udipsamments complex, undulating

Map Unit Setting

Elevation: 540 to 680 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F

Frost-free period: 140 to 180 days

Map Unit Composition

Udipsamments, typic, and similar soils: 55 percent
Udipsamments, aquic, and similar soils: 35 percent

Description of Udipsamments, Typic

Setting

Landform: Beach ridges, beach terraces
Landform position (two-dimensional): Summit, backslope
Parent material: Wind-worked beach sand

Properties and qualities

Slope: 1 to 6 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat excessively drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Low (about 3.1 inches)

Interpretive groups

Land capability (nonirrigated): 6s

Typical profile

0 to 4 inches: Sand
4 to 12 inches: Sand
12 to 60 inches: Sand

Description of Udipsamments, Aquic

Setting

Landform: Beach terraces, beach ridges
Landform position (two-dimensional): Footslope
Parent material: Wind-worked beach sand

Properties and qualities

Slope: 1 to 3 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): High to very high (6.00 to 20.00 in/hr)
Depth to water table: About 12 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Low (about 3.3 inches)

Interpretive groups

Land capability (nonirrigated): 4s

Typical profile

0 to 7 inches: Sand
7 to 20 inches: Sand

20 to 60 inches: Sand

978A—Wauconda and Beecher silt loams, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Wauconda and similar soils: 46 percent
Beecher and similar soils: 44 percent

Description of Wauconda

Setting

Landform: Outwash plains, lake plains
Landform position (two-dimensional): Summit, footslope
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.6 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 9 inches: Silt loam
9 to 14 inches: Silt loam
14 to 30 inches: Silty clay loam
30 to 38 inches: Loam
38 to 60 inches: Stratified loamy sand to silt loam

Description of Beecher

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Footslope, summit
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 0 to 2 percent

Depth to restrictive feature: 24 to 45 inches to dense material
Drainage class: Somewhat poorly drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 6 to 24 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 35 percent
Available water capacity: Low (about 5.8 inches)

Interpretive groups

Land capability (nonirrigated): 2w

Typical profile

0 to 9 inches: Silt loam
9 to 21 inches: Silty clay loam
21 to 37 inches: Silty clay loam
37 to 60 inches: Silty clay loam

979A—Grays and Markham silt loams, 0 to 2 percent slopes

Map Unit Setting

Elevation: 540 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Grays and similar soils: 46 percent
Markham and similar soils: 44 percent

Description of Grays

Setting

Landform: Outwash plains, lake plains
Landform position (two-dimensional): Summit
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 10.0 inches)

Interpretive groups

Land capability (nonirrigated): 1

Typical profile

0 to 9 inches: Silt loam
9 to 12 inches: Silt loam
12 to 35 inches: Silty clay loam
35 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

Description of Markham

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Summit
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 0 to 2 percent
Depth to restrictive feature: 20 to 55 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Moderate (about 6.6 inches)

Interpretive groups

Land capability (nonirrigated): 2s

Typical profile

0 to 8 inches: Silt loam
8 to 11 inches: Silt loam
11 to 24 inches: Silty clay loam
24 to 37 inches: Silty clay loam
37 to 60 inches: Silty clay loam

979B—Grays and Markham silt loams, 2 to 4 percent slopes

Map Unit Setting

Elevation: 540 to 970 feet
Mean annual precipitation: 28 to 40 inches
Mean annual air temperature: 45 to 52 degrees F
Frost-free period: 140 to 180 days

Map Unit Composition

Grays and similar soils: 46 percent
Markham and similar soils: 44 percent

Description of Grays

Setting

Landform: Outwash plains, lake plains
Landform position (two-dimensional): Backslope, summit
Parent material: Loess or other silty material and in the underlying outwash

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high to high (0.60 to 2.00 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: High (about 9.9 inches)

Interpretive groups

Land capability (nonirrigated): 2e

Typical profile

0 to 8 inches: Silt loam
8 to 11 inches: Silt loam
11 to 34 inches: Silty clay loam
34 to 42 inches: Loam
42 to 60 inches: Stratified loamy sand to silt loam

Description of Markham

Setting

Landform: Ground moraines, lake plains
Landform position (two-dimensional): Backslope, summit
Parent material: Thin mantle of loess or other silty material and in the underlying till

Properties and qualities

Slope: 2 to 4 percent
Depth to restrictive feature: 20 to 55 inches to dense material
Drainage class: Moderately well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: About 24 to 42 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 30 percent
Available water capacity: Moderate (about 6.0 inches)

Interpretive groups

Land capability (nonirrigated): 2e

Typical profile

0 to 8 inches: Silt loam
8 to 21 inches: Silty clay loam
21 to 32 inches: Silty clay loam
32 to 60 inches: Silty clay loam

W—Water

Map Unit Composition

Water: 100 percent

Description of Water

Setting

Landform: Channels, drainageways, lakes, oxbows, perenial streams, rivers
Parent material: Water

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RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 153A Pella silty clay loam, 0 to 2 percent slopes\Pella silty clay loam 90%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 2.5 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 232A Ashkum silty clay loam, 0 to 2 percent slopes\Ashkum silty clay loam 90%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 2.0 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 298A Beecher silt loam, 0 to 2 percent slopes\Beecher silt loam 90%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 4.0 t/ac/yr
Soil loss for cons. plan: 3.2 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 330A Peotone silty clay loam, 0 to 2 percent slopes\Peotone silty clay loam 90%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 2.5 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 530B Ozaukee silt loam, 2 to 4 percent slopes\Ozaukee silt loam 92%
Slope length (horiz): 1000 ft
Avg. slope steepness: 3.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 4.0 t/ac/yr
Soil loss for cons. plan: 15 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 530C Ozaukee silt loam, 4 to 6 percent slopes\Ozaukee silt loam 92%
Slope length (horiz): 1000 ft
Avg. slope steepness: 5.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 4.0 t/ac/yr
Soil loss for cons. plan: 30 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 530E Ozaukee silt loam, 12 to 20 percent slopes\Ozaukee silt loam 90%
Slope length (horiz): 1000 ft
Avg. slope steepness: 16 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 4.0 t/ac/yr
Soil loss for cons. plan: 180 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 697A Wauconda silt loam, 0 to 2 percent slopes\Wauconda silt loam 90%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 4.3 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 698A Grays silt loam, 0 to 2 percent slopes\Grays silt loam 90%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 4.3 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 698B Grays silt loam, 2 to 4 percent slopes\Grays silt loam 92%
Slope length (horiz): 1000 ft
Avg. slope steepness: 3.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 17 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 802B Orthents, loamy, undulating\Orthents, loamy loam 92%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 4.2 t/ac/yr

RUSLE2 Erosion Calculation Record

Info:

profiles\NSGL

Inputs:
Location: Illinois\Lake County
Soil: 805B Orthents, clayey, undulating\Orthents, clayey silty clay 92%
Slope length (horiz): 1000 ft
Avg. slope steepness: 1.0 %
Contouring: default
Strips/barriers: (none)
Diversion/terrace, sediment basin: (none)

Base management: c.Other Local Mgt Records\default

Outputs:
T value: 5.0 t/ac/yr
Soil loss for cons. plan: 4.1 t/ac/yr

PGH P:\GIS\GREATLAKES_NS\MAPDOCS\MXD\PETTIBONE_CREEK_SOILS.MXD 07/19/11 TW

DRAWN BY	DATE
T. WHEATON	07/19/11
CHECKED BY	DATE
B. SMITH	07/19/11
REVISED BY	DATE
SCALE	
AS NOTED	

NAVFAC

PETTIBONE CREEK SOILS

NS GREAT LAKES
GREAT LAKES, ILLINOIS

CONTRACT NUMBER	CTO NUMBER
APPROVED BY	DATE
APPROVED BY	DATE
FIGURE NO. 1	REV 0

CLIENT: Naval Station Great Lakes		JOB NUMBER: 112G01021.0410	
SUBJECT: Preliminary Estimate of Sedimentation Pond Estimate-Pettibone Creek North			
BASED ON:		DRAWING NUMBER:	
BY: RLS Date:	CHECKED BY: Date:	APPROVED BY:	DATE:

OBJECTIVE:

Estimate the approximate dimensions of a sediment retention basin to be located at the mouth of the North Branch of Pettibone Creek to collect sediment from off-site sources.

APPROACH:

Storm flows enter the North Branch of Pettibone Creek via three (3) existing culverts including two 40-inch culverts and one 60-inch culvert. These flows are believed to contain sediments that may impact Pettibone Creek. In order to potentially reduce the quantity of sediments being deposited within Pettibone Creek, a sediment basin may be constructed at the outlet of the existing stormwater piping to allow settling of sediment prior to a controlled outlet structure releasing retained stormwater into Pettibone Creek.

REFERENCES:

1) Pettibone Creek Drainage Area Flow Calculations, TtNUS, July, 2011.

CALCULATIONS:

2) Estimate the peak flow from the 100 year storm event. As presented in the above-referenced calculation, the peak flow from the 100 year storm event was calculated to be 445.2 cfs. However, the maximum storm water flow from the existing three (3) culverts controls the total flow volume.

- Two, 40-inch culverts and one, 60-inch culvert convey storm water flows into Pettibone Creek. -
The maximum flow capacity of a 40-inch concrete culvert flowing full is approximately 76 cfs assuming a slope of 1% and a manning's roughness coefficient of 0.015. Therefore, the maximum flow from both of these pipes is 152 cfs.
- The maximum flow capacity of a 60-inch culvert flowing full is approximately 226 cfs assuming a slope of 1% and a manning's roughness coefficient of 0.015.
- The total flow capacity from all three pipes is 378 cfs.

2) Assume a 2 hour detention time to allow for settling of sediments. By assuming the peak flow is 378 cfs, the average flow over a two hour period is assumed to half of the peak in a simplified model. Therefore, the total volume of storm water requiring retention would be conservatively estimated to be:

V = 378 cfs/2 x 60 sec/min x 60 min/hr x 2 hour = 1.36 mcf.

CLIENT: Naval Station Great Lakes		JOB NUMBER: 112G01021.0410	
SUBJECT: Preliminary Estimate of Sedimentation Pond Estimate-Pettibone Creek North			
BASED ON:		DRAWING NUMBER:	
BY: RLS Date:	CHECKED BY: Date:	APPROVED BY:	DATE:

3) Estimate the annual sediment load to be retained in the basin. The estimated total volume of sediment loss (Ref 2) is approximately 11,500 cf.

-Assuming a unit weight of sediment to be 1.6 Tons/CY, the total volume required to store an estimated annual sediment load of 11,500 cf would be:

S = 11,500 tons x 1 cy/1.6 tons x 27 cf/1 cy = 194,062 cf

4) Estimate the approximate dimensions of a sediment basin.

-The estimated total volume required is **1.55 mcf** (including sediment and storm water volume).

-Assume a depth of 8 feet, the following sediment basin are required for various geometric shapes:

a) Assuming a squared shape basin, the basin dimensions would be 8 feet Depth x 440 feet Length x 440 Width.
b) Assuming a side length of 600 feet, the basin dimensions would be 8 feet Depth x 600 feet x 323 feet Width.

CONCLUSIONS:

Based on 100 year storm volume and estimated sediment loading, a conceptual size of a sediment basin constructed at the beginning of the Northern Branch of Pettibone Creek

CLIENT: Naval Station Great Lakes		JOB NUMBER: 112G01012.0410	
SUBJECT: Estimate of Sedimentation Pond Size (1,2,5,10 year storms)-Pettibone Creek North			
BASED ON:		DRAWING NUMBER:	
BY: RLS Date: 7/12/11	CHECKED BY: Date:	APPROVED BY:	DATE:

OBJECTIVE:

Estimate the approximate dimensions of a sediment retention basin to be located at the mouth of the North Branch of Pettibone Creek to collect sediment from off-site sources based on the 1, 2, 5, and 10 year storm event peak flows.

APPROACH:

1) Storm flows enter the North Branch of Pettibone Creek via three (3) existing culverts including two 40-inch culverts and one 60-inch culvert. These flows are believed to contain sediments that may impact Pettibone Creek. In order to potentially reduce the quantity of sediments being deposited within Pettibone Creek, a sediment basin may be constructed at the outlet of the existing storm water piping to allow settling of sediment prior to a controlled outlet structure releasing retained storm water into Pettibone Creek.

REFERENCES:

a) Pettibone Creek Drainage Area Flow Calculations, TtNUS, July, 2011.
b) Sediment Transport Estimation, TtNUS, 2011.
c) Plans for Proposed Federal Aid Highway, Lake Front Highway, IDOT, 1989.

CALCULATIONS:

2) Calculate the peak flow from the 1, 2, 5 and 10 year storm events. As presented in the above-referenced calculation, the peak flow from these storms was determined to be 117.4, 143.7, 200.6, and 248 cfs, respectively. However, the maximum storm water flow from the existing three (3) culverts controls the total flow volume.

- Two, 40-inch culverts and one, 60-inch culvert convey storm water flows into Pettibone Creek. -
The maximum flow capacity of a 40-inch concrete culvert flowing full is approximately 76 cfs assuming a slope of 1% and a manning's roughness coefficient of 0.015. Therefore, the maximum flow from both of these pipes is 152 cfs.
- The maximum flow capacity of a 60-inch culvert flowing full is approximately 226 cfs assuming a slope of 1% (slope from Ref 3) and a manning's roughness coefficient of 0.015.
- The total flow capacity from all three pipes is 378 cfs. Therefore, all of the storm event peak flows evaluated herein will pass the existing culverts.

3) Assume a 2 hour detention time to allow for settling of sediments. By assuming the peak flows are 117.4, 143.7, 200.6, and 248 cfs, the average flow over a two hour period is assumed to half of the peak in a simplified model. Therefore, the total volume of storm water requiring retention would be conservatively estimated to be:

V_{SW1} = 117.4 cfs/2 x 60 sec/min x 60 min/hr x 2 hour = 0.845 mcf.
V_{SW2} = 143.7 cfs/2 x 60 sec/min x 60 min/hr x 2 hour = 1.035 mcf.
V_{SW5} = 200.6 cfs/2 x 60 sec/min x 60 min/hr x 2 hour = 1.444 mcf.
V_{SW10} = 248.0 cfs/2 x 60 sec/min x 60 min/hr x 2 hour = 1.786 mcf.

4) Estimate the annual sediment load to be retained in the basin. The estimated total sediment loss (Ref b) is approximately 11,500 tons.
-Assuming a unit weight of sediment to be 1.6 Tons/CY, the total volume required to store an estimated annual sediment load of 11,500 tons would be:
S_1 = 11,500 tons x 1 cy/1.6 tons x 27 cf/1 cy = 194,062 cf

5) The estimated total volume required for each of the storms (including sediment and storm water volume):

V_{T1}=0.845 mcf + 194,062 cf = 1.039 mcf.
V_{T2}=1.035 mcf + 194,062 cf = 1.229 mcf.
V_{T5}=1.444 mcf + 194,062 cf = 1.638 mcf.

CLIENT:	Naval Station Great Lakes	JOB NUMBER:	112G01012.0410
SUBJECT:	Estimate of Sedimentation Pond Size (1,2,5,10 year storms)-Pettibone Creek North		
BASED ON:		DRAWING NUMBER:	
BY: RLS Date: 7/12/11	CHECKED BY: Date:	APPROVED BY:	DATE:

V_{T10}=1.786 mcf + 194,062 cf = 1.980 mcf.

6) Estimate the approximate dimensions of a sediment basin for the storms evaluated. Given the limited area available at the headwaters of the Northern Branch of Pettibone Creek, several basin configurations were evaluated with regard to minimum basin area required. Configurations evaluated include basin depths of 4,6,8,and 10 foot depths and geometries including square and rectangular (2:1 length to width ration):

1 YEAR STORM VOLUME (1,039,000 Cf)

DEPTH OF BASIN (Ft)	SIDE LENGTH (Square) (Ft.)	SIDE LENGTH (2:1) (Ft.)
4	510	360 x 720
6	416	294 x 588
8	360	255 x 510
10	322	228 x 456

2 YEAR STORM VOLUME (1,229,000 Cf)

DEPTH OF BASIN (Ft)	SIDE LENGTH (Square) (Ft.)	SIDE LENGTH (2:1) (Ft.)
4	554	392 X 784
6	453	320 X 640
8	392	277 X 554
10	351	247 X 496

5 YEAR STORM VOLUME (1,638,000 Cf)

DEPTH OF BASIN (Ft)	SIDE LENGTH (Square) (Ft.)	SIDE LENGTH (2:1) (Ft.)
4	640	452 X 905
6	522	370 X 739
8	452	320 X 640
10	405	286 X 572

10 YEAR STORM VOLUME (1,980,000 Cf)

DEPTH OF BASIN (Ft)	SIDE LENGTH (Square) (Ft.)	SIDE LENGTH (2:1) (Ft.)
4	704	497 X 995
6	574	406 X 812
8	497	352 X 704
10	445	315 X 629

7) DISCUSSION OF PROS AND CONS OF AN IN-LINE SEDIMENT DETENTION STRUCTURE

The following describe both the pros and cons of installing a sediment detention structure at the headwaters (outfalls of the three large storm water pipes) of the Northern Branch of Pettibone Creek with the intention of capturing sediment transported by flows carried by the three existing storm water culverts.

CONS:

1) Given the obstructive nature that an in-line sediment detention structure would impose to the Northern Branch of Pettibone Creek, obtaining the required stream obstruction permitting (and all related permitting) may be difficult with pertinent agencies such as the Army Corps of Engineers and other State and Federal Agencies.

2) At the November 4, 2011 meeting at the Naval Station Great Lakes, it was suggested that, in terms of current conditions at the creek, much of the fugitive sediment may be transported to the boat basin from the banks of Pettibone Creek itself during high energy flow storm events. Therefore, the proposed sediment detention structure may not capture the sediment currently being deposited.

CLIENT: Naval Station Great Lakes		JOB NUMBER: 112G01012.0410	
SUBJECT: Estimate of Sedimentation Pond Size (1,2,5,10 year storms)-Pettibone Creek North			
BASED ON:		DRAWING NUMBER:	
BY: RLS Date: 7/12/11	CHECKED BY: Date:	APPROVED BY:	DATE:

3) Preliminary calculations have been performed to estimate the approximate size of a sediment detention basin based on evaluation of various design storm peak flows (from the 1 year return period through the 100 year storm event), and the resulting dimensions of such a structure far exceed the available area required (at the headwaters of the Northern Branch of Pettibone Creek at the outfall of the three existing storm water culverts).

4) Capturing all sediment in the proposed structure prior to deposition in down stream segments could be detrimental to the downstream creek stream bed in that a certain sediment loading is required over the life of the stream to provide fine material required to sustain the benthic zone. Certain macroinvertibrates require a healthy benthic zone for adequate and sustainable population maintenance. Also, it is well documented that many of the past sources of contamination (industrial facilities such as smelting operations) have been removed. Finally, given the proposed future additional urbanization planned by the local community in the up gradient water sheds, less sediment is expected to be transported to the Base over the next several years.

5) The cost to design, install, and maintain such a structure may be excessive versus the perceived benefits, especially given the need to by-pass existing flows from the three existing storm water culverts. Also, such a structure would require minimum yearly maintenance.

6) A sediment detention basin could possibly be not aesthetically pleasing, especially upon instituting stream bank stabilization remedies that could include removal of existing, man-made concrete debris and other structures previously placed in an attempt to provide temporary stream bank stabilization.

7) The structural integrity of the toe of slopes of the existing ravine sides may be compromised through the excavations required to construct a sediment detention basin. As observed during a recent site visit in which representatives from the Navy, tetra Tech, the Army Corps of engineers, the Illinois Environmental Protection Agency, and the Illinois Department Natural Resources attended, it was observed that recent and past sloughing of the ravine side slopes were evident, thus indicating that additional stresses placed on the toes of these potentially unstable slopes may lead to additional slope failure issues.

PROS:

1) Capturing off site sediment deposition from off-site sources may possibly reduce the re-contamination of sediments remaining in the Boat Basin and Inner Harbor upon future sediment removal actions.

CONCLUSIONS:

The table above summarizes the various basin configurations for each of the four design storms evaluated in both cubic feet and acre-feet of total storage volume required:

Even for the smallest design storm investigated, the size of a sediment detention basin to be constructed at the headwaters of the Northern Branch of Pettibone Creek would likely not be accommodated by the limitations imposed by the proximity of the ravine slopes in this area.

APPENDIX Q

THE CROSS-VANE, W-WEIR AND J-HOOK VANE STRUCTURES…THEIR DESCRIPTION, DESIGN AND APPLICATION FOR STREAM STABILIZATION AND RIVER RESTORATION

The Cross-Vane, W-Weir and J-Hook Vane Structures…Their Description, Design and Application for Stream Stabilization and River Restoration

D. L. Rosgen, P.H.*

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Abstract

The descriptions, design specifications, placement locations, spacing and various applications of Cross-Vane, W-Weir and J-Hook Vane structures are presented. These structures were developed and subsequently applied to: 1) establish grade control, 2) reduce streambank erosion, 3) facilitate sediment transport, 4) provide for irrigation diversion structures, 5) enhance fish habitat, 6) maintain width/depth ratio, 7) improve recreational boating, 8) maintain river stability, 9) dissipate excess energy, 10) withstand large floods, 11) maintain channel capacity, 12) be compatible with natural channel design, and 13) be visually acceptable to the public.

Relations to determine the minimum size of rock for these structures are presented based on bankfull shear stress. Drawings for each structure are provided that display appropriate use of footers, cross-section shape, profile shape, appropriate channel locations, angles, slopes, spacing and elevations. Velocity isovels are presented to describe changes in the distribution of energy produced by the structures. The structures all reduce near-bank shear stress and stream power, while increasing center channel shear stress and stream power to retain both flood-flow and sediment transport capacity. These structures have been installed on 14 rivers with bankfull widths varying from 9m (Lower Blanco River in Southwestern Colorado) to 150m (Bitterroot River in Northwestern Montana) and slopes varying from 0.05 to .0003 and in bed material ranging from cobble and gravel to sand bed streams. Since 1986, the author has restored and monitored a wide variety of stream types involving over 48 km of rivers and evaluated various structure performance following major floods. This monitoring has resulted in the development, implementation and assessment of the Cross-Vane, W-Weir and J-Hook vane structures.

Introduction

Structures in river engineering are designed to help stabilize channel boundaries. However, monitoring their effectiveness have indicated that many structures, contrary to the intended design, caused river instability. Structures are often selected and installed without an understanding of sediment transport and violate the dimension, pattern and profile of the stable river. Relations for canal design based on rigid boundary theory, clear water discharge, and uniform flow have been implemented on natural channels, with less than effective results. Work conducted by Leopold, et al, (1964) found that river form is associated with an integration of eight interrelated variables, that if any one variable is changed, it sets up mutual, concurrent adjustments of the other variables in the stream system until a new quasi-equilibrium is reached (stability). The eight variables are slope, width, depth, velocity, discharge, boundary roughness, size of sediment transported, and concentration of sediment. The variables can be integrated into morphological relations for stable natural rivers as described by “reference reach” by stream type

(Rosgen, 1998). Structures are often placed in rivers in an attempt to correct some of the adverse effects of channel adjustment due to instability. Unfortunately, many structures are often installed to "patch a symptom" rather than achieve the stable channel form. Appropriately used structures can assist in maintaining the stable dimension pattern and profile (Rosgen, 1996).

River engineering structures need to be incorporated with a clear understanding of the river variables that constitute the stable form. Structure failures are generally associated with designs incompatible with the "rules of the river". For example, cross-channel check dams decrease energy slope upstream of the structure. Data from natural rivers indicate a negative power function relation between sinuosity and slope (Figure 1), thus when slope is decreased there is a corresponding increase in sinuosity through lateral migration following bank erosion. Most failures of check dams occur when they are "out flanked" by the river through lateral adjustment upstream of the structure. Consequently, many check dams often accelerate excess bank erosion. Check dams generally decrease upstream velocity, slope, and depth, increase roughness, and induce sediment deposition. These changes lead to instability and contribute to the failure of the structure. Structures have also failed due to excessive bedload deposition that leads to a loss of channel capacity and subsequent change in the stable dimension, pattern and profile of the river.

Streambank stabilization structures proliferate as bank erosion accelerates. Most of the structures implemented involve "hardening" the banks. Changes in near-bank stress and/or stream power associated with unstable channels can accelerate bank erosion.
Work conducted by Parker (1978), and Bathurst (1979), described secondary circulation patterns and the distribution of boundary shear stress in both straight and meandering rivers. Ikeda, et al, (1988), described the erosion and transport of grains from the bank region to the center of the channel as a result of bank erosion. They also described the process of lateral momentum transfer due to turbulence that resulted in eddy diffusion and induced net lateral transport of longitudinal fluid momentum from regions of high momentum to regions of low momentum. These processes resulted in a lateral redistribution of bed shear stress. Secondary cells associated with down welling (high boundary shear stress) and upwelling (low boundary shear stress) occur in the near-bank region creating very high velocity gradients (Bathhurst, et al, 1979). Boundary shear stresses associated with high velocity gradients, can accelerate erosion rates, and are shown in the velocity isovel constructed from vertical velocity profiles (Figure 2). The streambank erosion prediction methodology developed by Rosgen (1996, 2001), utilizes computations of near-bank stress for assessing various erosion rates. Any structures that can reduce near-bank stress will reduce bank erosion by several orders of magnitude.

New attempts at similar problems

To offset near-bank forces to reduce streambank erosion, Paice and Hey (1989) installed submerged concrete vanes on the outside of meander bends to control secondary circulation and redirect river currents to decrease boundary shear stress in the outer bank region. These attempts were successful in reducing erosion by redirecting erosive currents in the near-bank region. Iowa Vanes (Ogdaard and Mosconi, 1987) were previously used to redirect currents away from streambanks to reduce accelerated erosion. Submerged vanes were installed and tested by Hey (1992) not only to re-direct velocity distribution but to also provide improved fish habitat.

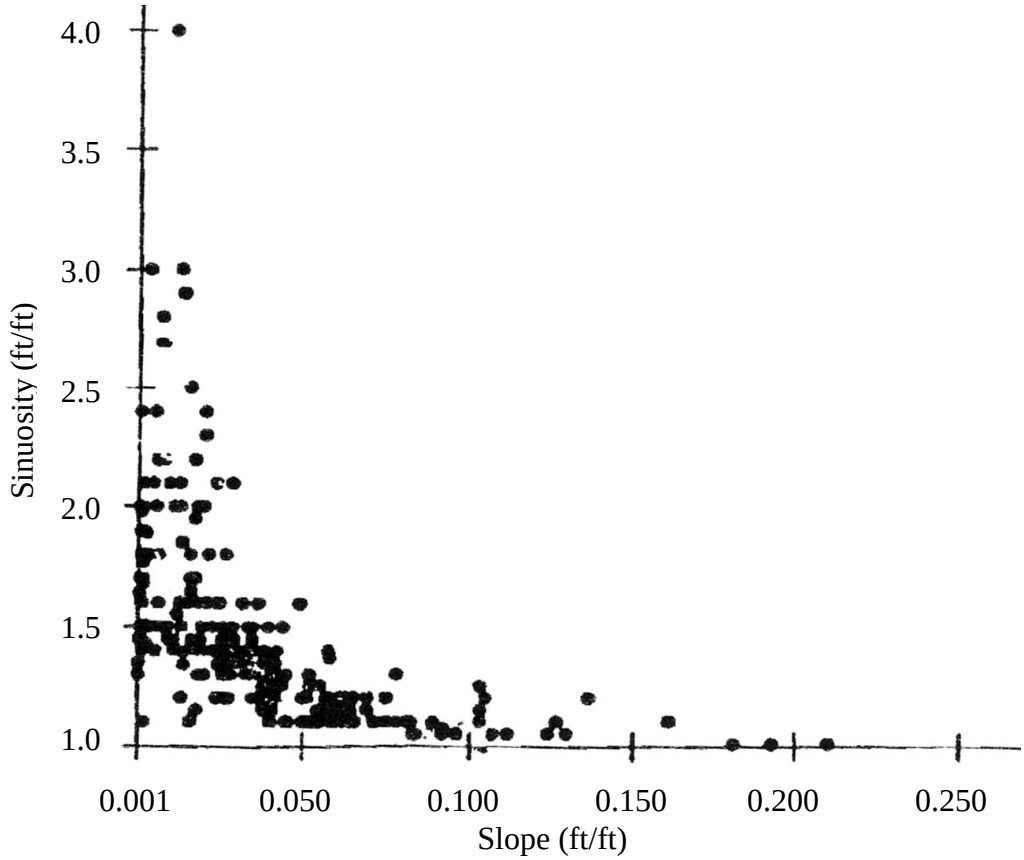

Figure 1. Relation of sinuosity to slope for natural rivers

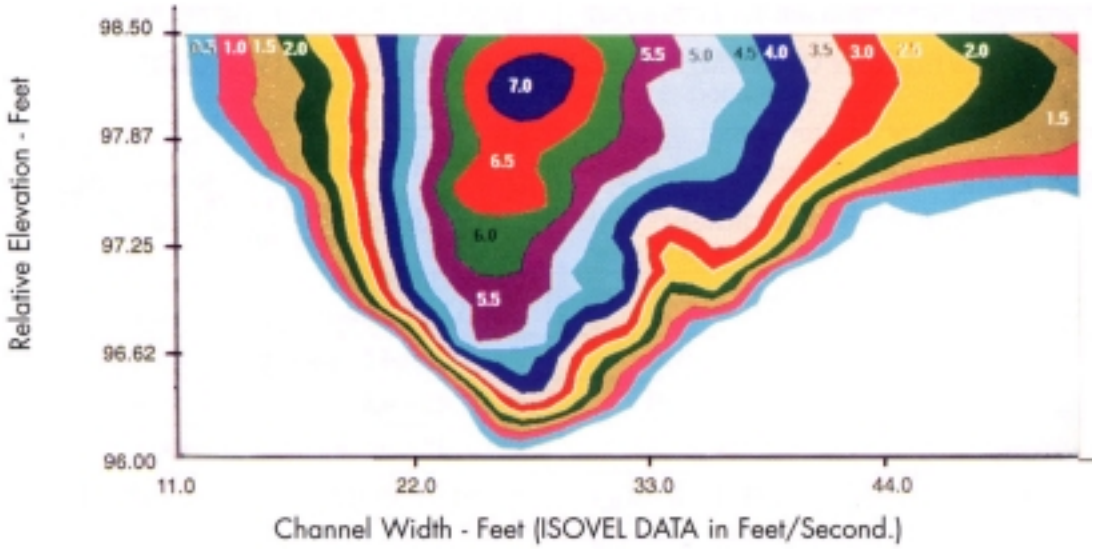

Figure 2. Velocity isovels for a "C3" stream type reach showing variations in velocity distribution (Rosgen, 1996, pg 6-42).

Structures that modify velocity distribution such as deflectors, bank barbs, spur dikes and other similar designs often accompany "bank hardening." The US Army Corps of Engineers recently developed bendway rock weirs (Derrick, et al, 1994). This structure points slightly upstream at a departure angle of 60-70 degrees from a tangent line from the bank. The intent of the bendway weir was initially to "scalp" point bars and re-locate the thalweg to the inside of the bend for navigation. In addition, this structure subsequently induced sediment deposition in the near-bank region. There is generally re-circulation, back eddy erosion on the upstream side of the structure due to the abrupt nature of re-directing the angle of attack of the near-bank velocity vectors. This structure has been installed on large rivers and has been effective in meeting its design objectives in many instances (Derrick, 1996).

Spur dikes and bank barb structures are common bank protection structures but generally produce an upstream and downstream re-circulation eddy that often increases bank erosion. This tends to occur when the thalweg is forced too far across the channel and/or the structures are oriented 45 to 90 degrees upstream from a tangent line to the bank. Bank barbs create a vertical vortices due to their abrupt angle to the bank that is often responsible for bank erosion and accelerated scour at the "point" of the barb. Rock and/or log deflector structures, pointing downstream, often direct the velocity vectors into the bank when flows overtop the structure increasing near-bank velocity gradients and causing accelerated bank erosion. Subsequently, some of these structures have created unexpected adverse adjustments in the channel.

Vortex Rock Weirs and Root Wads were installed in the 1980s for grade control, fish habitat and streambank erosion protection (Rosgen, 1996). After monitoring for approximately 15 years, the author determined that these structures produced back-eddy erosion during major floods resulting in streambank erosion and the loss of some structures. The problems of the Root Wad and Vortex Rock Weir structures were documented which subsequently led to major changes in their design.

As additional objectives of river engineering have evolved there has arisen a need for a "softer" substitute for streambank stabilization. The departure from traditional "hard" procedures has been slow but steady as the use of natural materials and methods have grown in popularity. This has, in turn, encouraged the pursuit of additional techniques to offset existing problems of various structures observed in the field. A properly designed river structure should meet more than one specific objective (such as grade control).
Structures should also:

1. Maintain the stable width/depth ratio of the channel;
2. Maintain the shear stress to move the largest size particle to maintain stability (competence);
3. Decrease near-bank velocity, shear stress or stream power;
4. Maintain channel capacity;
5. Ensure stability of structure during major floods;
6. Maintain fish passage at all flows;
7. Provide safe passage or enhance recreational boating;
8. Improve fish habitat;
9. Be visually compatible with natural channels;
10. Be less costly than traditional structures;

11. Create maintenance-free diversion structures;
12. Reduce bridge pier/footer scour, road fill erosion and prevent sediment deposition.

The use of rip-rap, gabions, concrete lined channels, bin walls, interlocking blocks, groynes, Kelner Jacks, spur dikes, rock jetties, barbs, reinforced revetment, sheet piling, log cribs, concrete check dams, and loose rock check dams are not only expensive but often do not meet the above stated objectives for river structures. A central problem with riprap, gabions, toe rock protection and similar structures is the increase in near-bank velocity, velocity gradient, stream power, and shear stress. These problems often lead to either on-site failures or problems immediately upstream and/or downstream of the structures. This, in combination with their high cost, resultant poor fish habitat and "less than natural" appearance, led to the development in the early 1990's of the Cross-Vane, W-Weir and J-Hook Vane.

Description of Structures

Cross-Vane

General description

The design of the Cross-Vane structure is shown in plan, profile and section view in Figure 3. The Cross-Vane is a grade control structure that decreases near-bank shear stress, velocity and stream power, but increases the energy in the center of the channel. The structure will establish grade control, reduce bank erosion, create a stable width/depth ratio, maintain channel capacity, while maintaining sediment transport capacity, and sediment competence. The Cross-Vane also provides for the proper natural conditions of secondary circulation patterns commensurate with channel pattern, but with high velocity gradients and boundary stress shifted from the near-bank region. The Cross-Vane is also a stream habitat improvement structure due to: 1) an increase in bank cover due to a differential raise of the water surface in the bank region; 2) the creation of holding and refuge cover during both high and low flow periods in the deep pool; 3) the development of feeding lanes in the flow separation zones (the interface between fast and slow water) due to the strong downwelling and upwelling forces in the center of the channel; and 4) the creation of spawning habitat in the tail-out or glide portion of the pool.

The Cross-Vane is also a popular boating feature as kayakers routinely do "enders" and "surf" the vane portion of the structures installed on the Lake Fork of the Gunnison River near Lake City, Colorado and the San Juan River in Pagosa Springs, Colorado. The invert portion (center 1/3, see Figure 3) of the structure creates a standing wave, but is associated with a "run" immediately downstream of the invert. As a result the potential development of a dangerous re-circulation pool that traps "swimming paddlers" is eliminated. The structure "chutes" the swimmers and/ or their boats into the deep, low velocity pool approximately half a bankfull width below the invert.

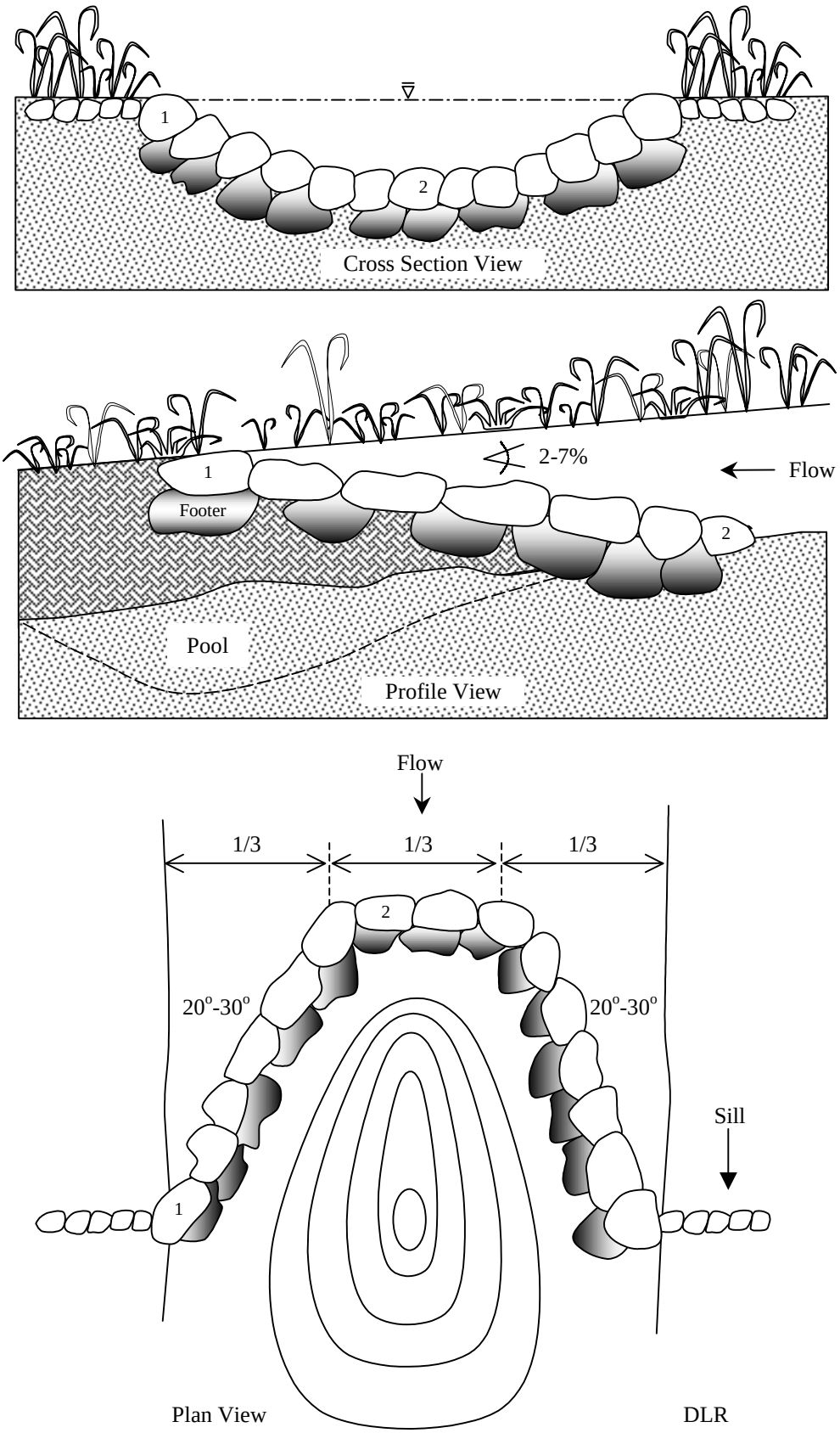

Figure 3. Cross section, profile and plan view of a Cross-Vane

Major floods have tested the Cross-Vane structure such as the 1996 flood on the San Juan River in Pagosa Springs, which passed a flood stage of 3.5 meters above the top of the structures on a 0.005 slope. A detailed contour map prepared in 2000 demonstrates the channel shape and location of the deep pool (Figure 4). The structure did require post-flood maintenance and it is still performing properly as a diversion structure, a kayak playground and an excellent fly-fishing location where fisherman can be frequently observed. Although bedload transport of particle size up to 220 mm occurred during the flood, the pools did not fill. The strong downwelling currents in the center of the channel maintained a high bedload transport keeping the pool deep as evidenced in Figure 4.

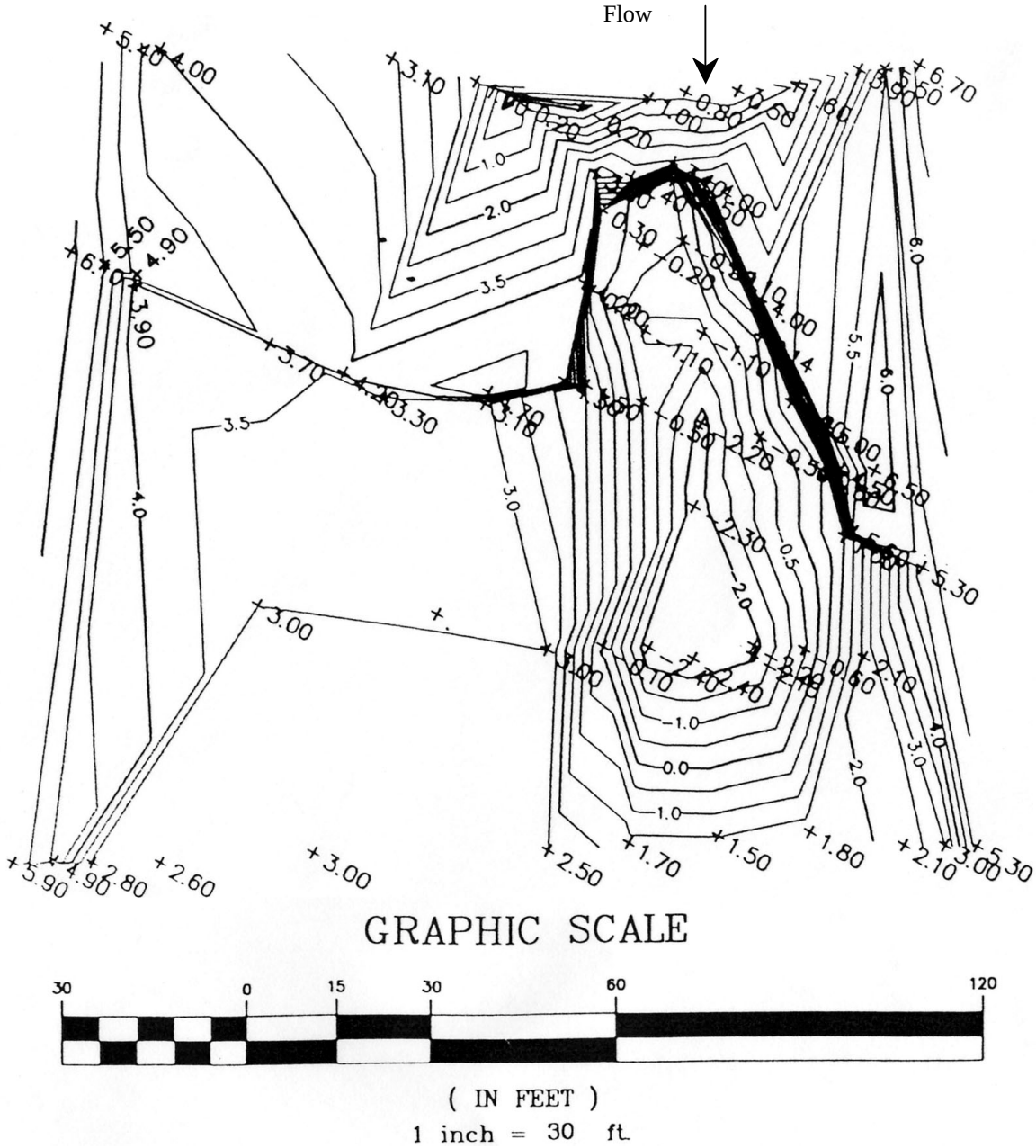

Figure 4. Contour map of Cross-Vane following major flood – San Juan River, CO.

W-Weir

General Description. The design of the W-Weir (W as looking in the downstream direction) was initially developed to resemble bedrock control channels on larger rivers. Various rock weirs installed across larger rivers for fish habitat, grade control and bank protection often create an unnatural and uniform "line of rocks" that detracts from visual values. The W-Weir is similar to a Cross-Vane in that both sides are vanes directed from the bankfull bank upstream toward the bed with similar departure angles. From the bed at ¼ and ¾ channel width, the crest of the weir rises in the downstream direction to the center of the bankfull channel creating two thalwegs (Figure 5). The objectives of the structure are to provide grade control on larger rivers, enhance fish habitat, provide recreational boating, stabilize stream banks, facilitate irrigation diversions, reduce bridge center pier and foundation scour, and increase sediment transport at bridge locations. Double W-Weirs are constructed on very wide rivers and/or where two center pier bridge designs (three cells) require protection.
Habitat for trout is enhanced by maximizing usable holding, feeding and spawning areas. Fish hold in the multiple feeding lanes created by the two thalweg locations and pools. Various age classes of trout also hold in the deep glide created upstream of the structure and against both banks due to the increased depth and reduced velocity of flows in the near-bank region. Spawning habitat is created in the tail-out of the pools due to upwelling currents and a sorting of gravel bed material sizes preferred by trout.

J-Hook Vane

General Description. The J-Hook Vane is an upstream directed, gently sloping structure composed of natural materials. The structure can include a combination of boulders, logs and root wads (Figures 6-7) and is located on the outside of stream bends where strong downwelling and upwelling currents, high boundary stress, and high velocity gradients generate high stress in the near-bank region. The structure is designed to reduce bank erosion by reducing near-bank slope, velocity, velocity gradient, stream power and shear stress. Redirection of the secondary cells from the near-bank region does not cause erosion due to back-eddy re-circulation. The vane portion of the structure occupies 1/3 of the bankfull width of the channel, while the "hook" occupies the center 1/3.

Maximum velocity, shear stress, stream power and velocity gradients are decreased in the near-bank region and increased in the center of the channel. Sediment transport competence and capacity can be maintained as a result of the increased shear stress and stream power in the center 1/3 of the channel. Backwater is created only in the near-bank region, and the small departure angle gently redirects the velocity vectors from the near-bank region, reducing active bank erosion.

The scour pool in the center 1/3 of the channel provides energy dissipation and holding cover for fish. The flow separation zones, or "seams" of fast and slow water that mark the zones of downwelling and upwelling currents, are habitat features utilized by trout. The "hook" portion of the vane produces a longer, wider and deeper pool than that created by vane-only structures. The downstream pool dissipates energy and provides fish habitat. The 1/4 - 1/3 rock diameter gaps between the rocks associated with the hook creates a vortex or corkscrew flow that

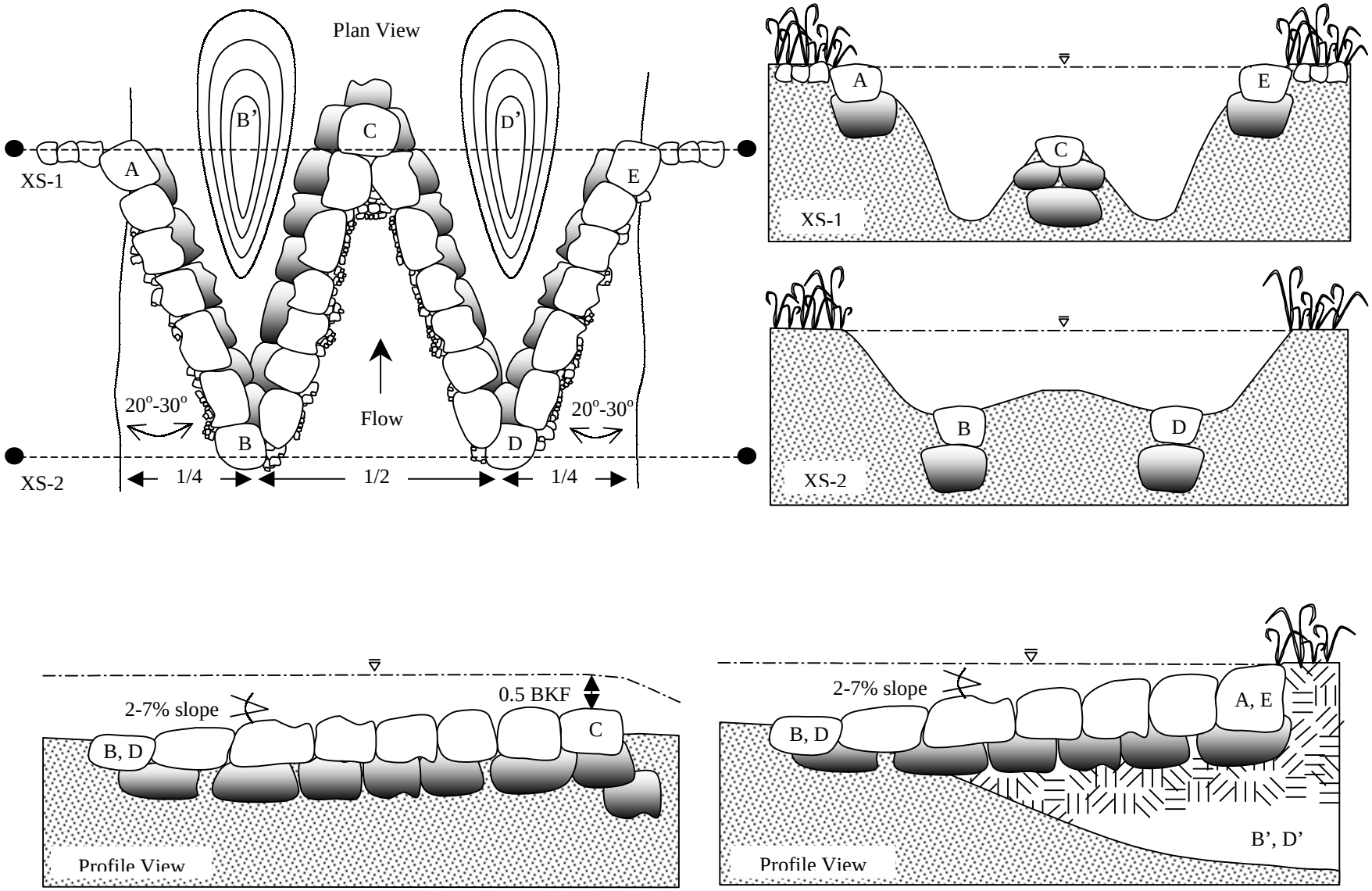

Figure 5. Plan, cross section, and profile views of the W-weir

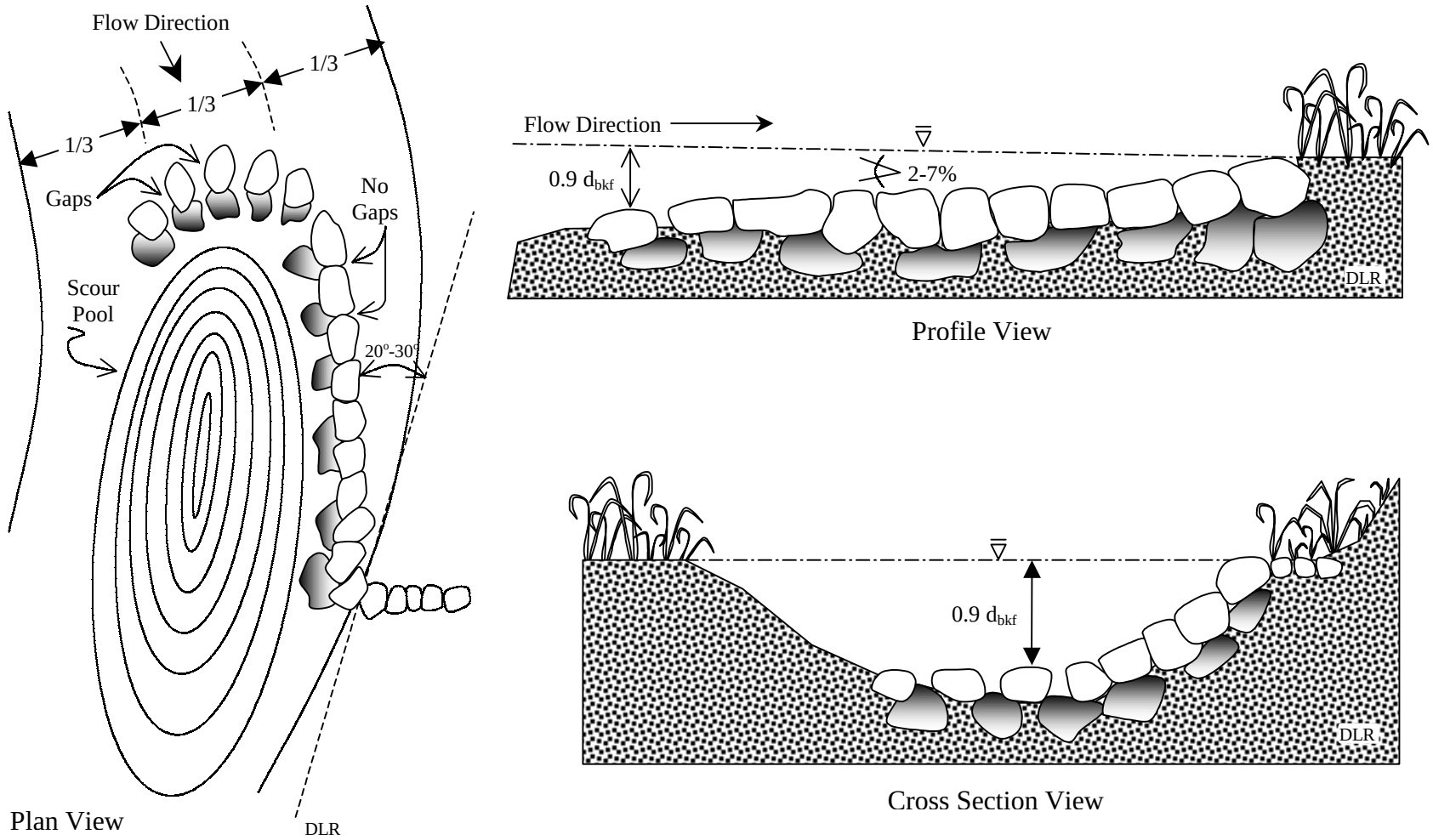

Figure 6. Plan, profile, and section view of the J-Hook Vane

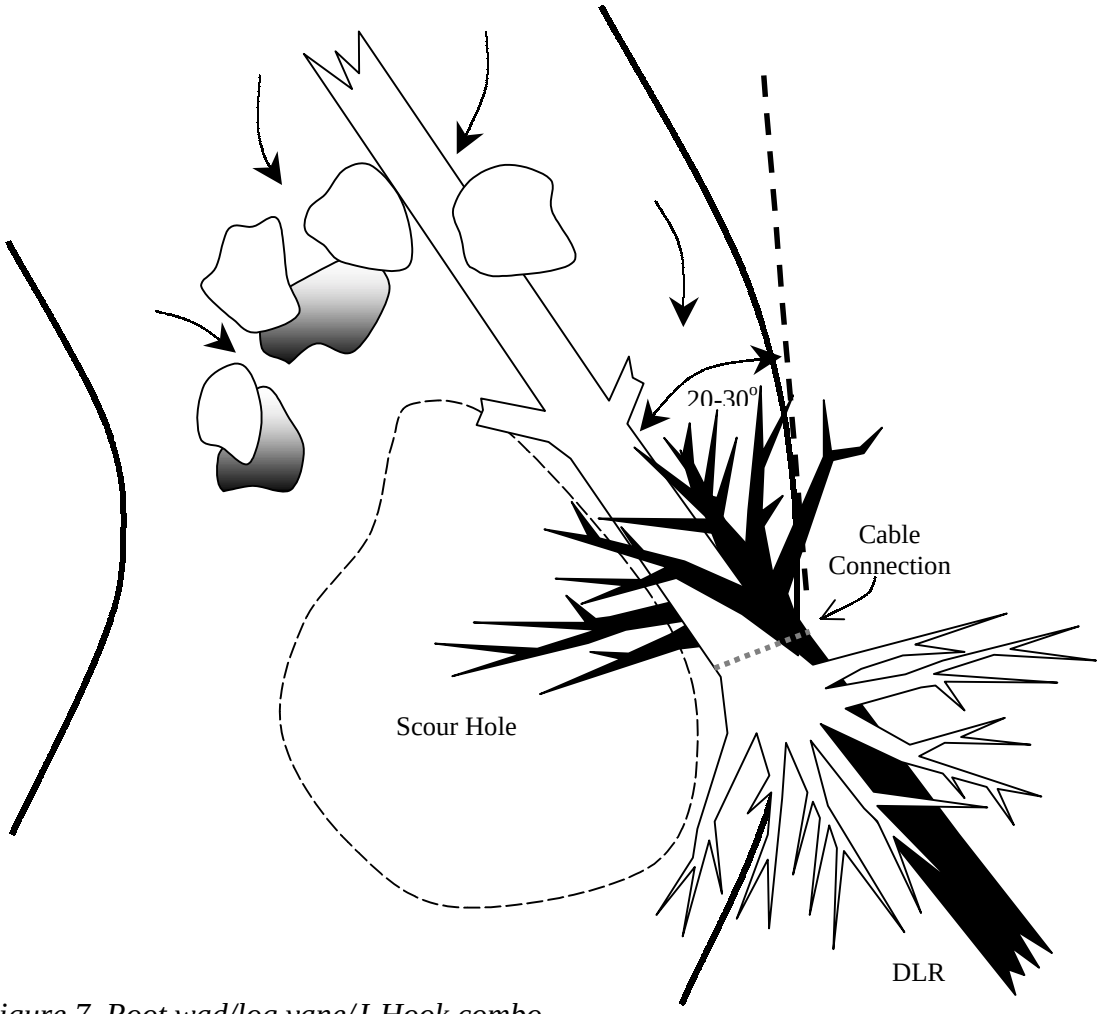

Figure 7. Root wad/log vane/J-Hook combo streambank stabilization and fish habitat structure

increases the "center-channel" shear stress. The center of the channel associated with the hook is efficient at transporting sediment, debris and improving channel capacity and sediment competence. The "shooting flow" associated with the hook portion of the structure provides for recreational boating in moderate to larger sized rivers. Width/depth ratios are maintained by decreasing bank erosion rate and increasing bankfull channel depth, even following major floods.

Design Specifications

Cross-Vanes, W-Weirs and J-Hook Vanes

Vane angle. The vane arm portion of all three structures is generally 20-30 degrees measured upstream from the tangent line where the vane intercepts the bank. The 20-degree angle provides the longest vane length and protects the greatest length of streambank. Variation from 20 to 30 degrees is often utilized in offset Cross-Vanes and/or W-Weirs whose asymmetry disproportionately shift more water to one side of the structure often used for irrigation

diversions. The flatter and smaller vane angle arm will extend farther upstream to intercept proportionately more water and increase the length of bank protected.

Vane slope. The slope of the vane extending from the bankfull stage bank should vary between 2-7 percent. Vane slope is defined by the ratio of bank height/vane length. For installation in meander bends, ratios of J-Hook Vane length/bankfull width is calculated as a function of the ratio of radius of curvature/bankfull width and departure angle (Table 1). Equations for predicting ratios of J-Hook Vane spacing/bankfull width on meander bends based on ratio of radius of curvature/bankfull width and departure angle is shown in Table 2. Vane length is the distance measured from the bankfull bank to the intercept with the invert elevation of the streambed at 1/3 of the bankfull channel width for either Cross-Vanes or J-Hook Vanes. For very large rivers, where it is impractical to extend the vane length to 1/3 of the bankfull width, vane slope is calculated based on the specified angle of departure and the ratio of bank height/vane length where the vane arm intercepts the proposed invert of the structure.

Table 1. Equations for predicting ratio of vane length/bankfull width (V_L) as a function of ratio of radius of curvature/width and departure angle, where W = bankfull width. (SI units)

Rc/W	Departure Angle (degrees)	Equation
3	20	$V_L = 0.0057\ W + 0.9462$
3	30	$V_L = 0.0089\ W + 0.5933$
5	20	$V_L = 0.0057\ W + 1.0462$
5	30	$V_L = 0.0057\ W + 0.8462$

Table 2. Equations for predicting ratio of vane spacing/width (Vs) as a function of ratio of radius of curvature/width and departure angle, where W = bankfull width (SI units)

Rc/W	Departure angle (degrees)	Equation
3	20	$Vs = -0.006\ W + 2.4781$
3	30	$Vs = -0.0114\ W + 1.9077$
5	20	$Vs = -0.0057\ W + 2.5538$
5	30	$Vs = -0.0089\ W + 2.2067$

The spacing of J-Hook Vanes can be increased by 0.40W if there exists a low bank erosion hazard rating (BEHI) of less than 30 (Rosgen, 1996, 2001).

Bank height. The structure should only extend to the bankfull stage elevation. If the bank is higher, a bankfull bench is constructed adjacent to the higher bank and the structure is integrated into the bench. The use of a Cross-Vane is shown in Figure 8 where a bankfull bench is created adjacent to a terrace bank.

Footers. The minimum footer depth at the invert for cobble and gravel bed streams is associated with a ratio of 3 times the protrusion height of the invert rock. This is applicable to all three structures and is shown in Figure 9 for a J-Hook Vane. For sand bed streams, the minimum depth is doubled due to the deeper scour depths that occur. All rocks for all three structures require footers. If spaces are left between the invert rocks for Cross-Vane and W Weirs, then the top of the footer rocks becomes the invert elevation for grade control. If no gaps are left, then the top of the surface rock becomes the base level of the stream.

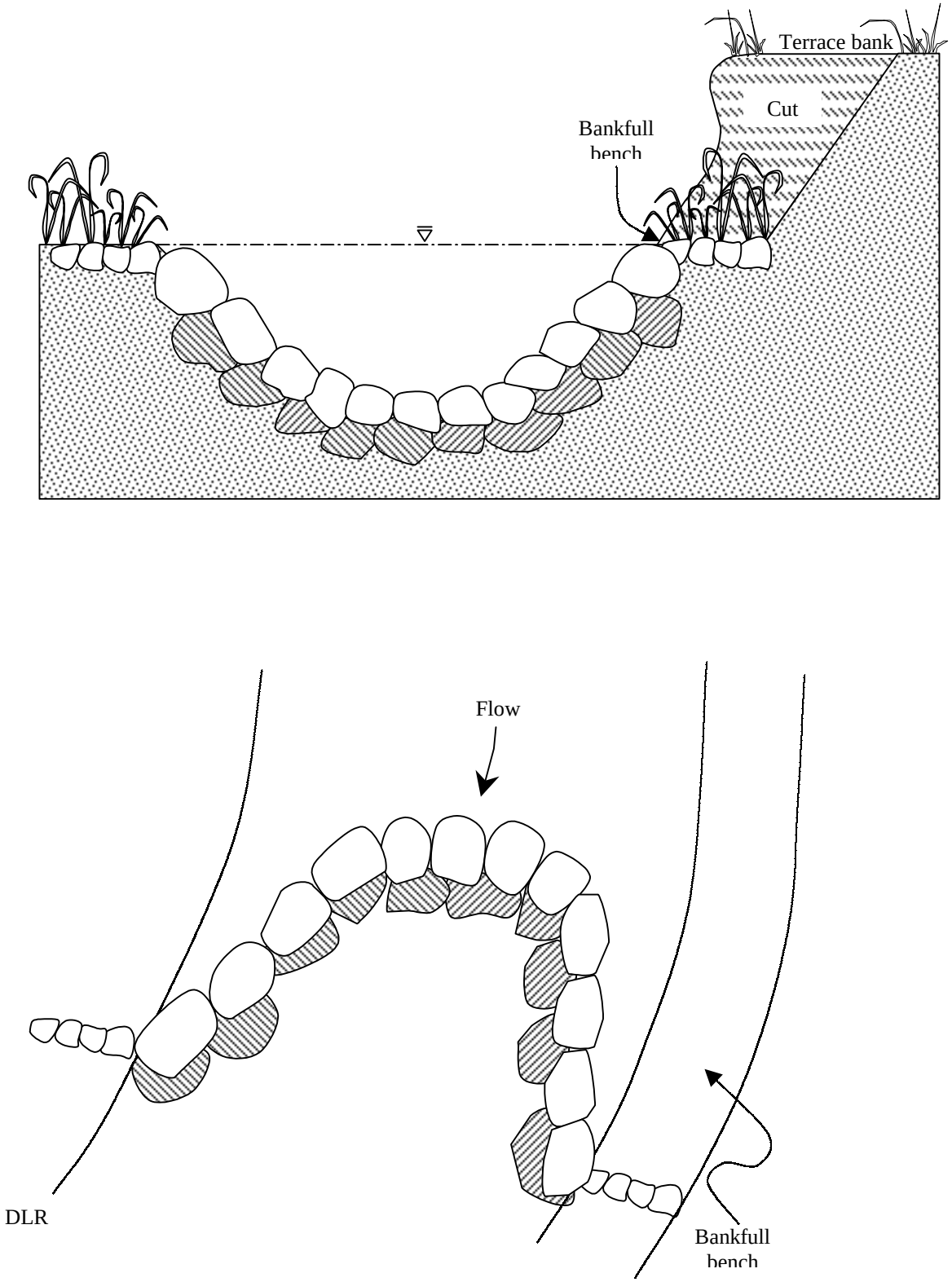

Figure 8. Example of a boulder Cross-Vane and constructed bankfull bench

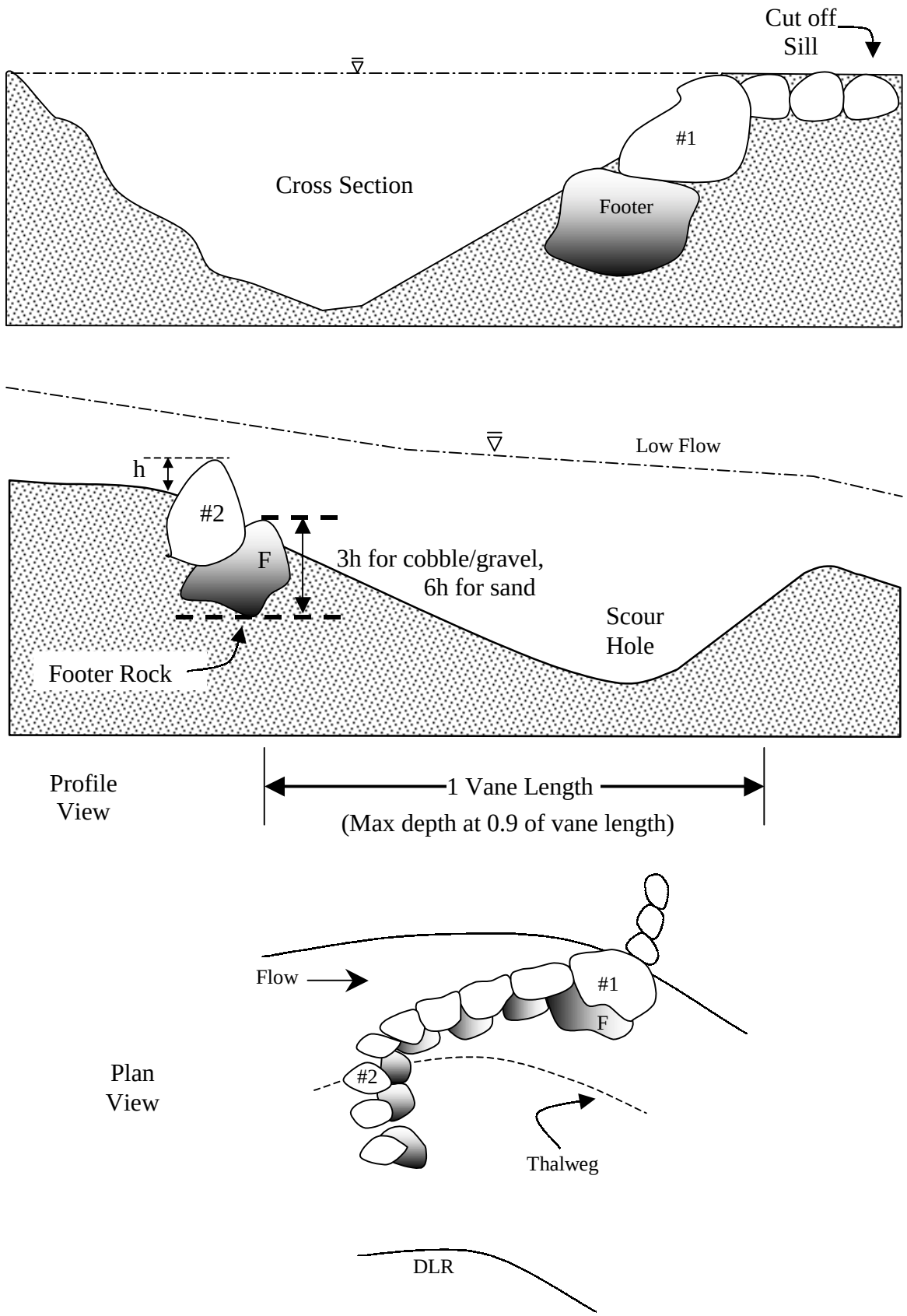

Figure 9. Locations/positions of rocks and footers in relation to channel shape and depths

Rock size. The relationship of bankfull shear stress to minimum rock size used for all three structures is shown in Figure 10. The application of this empirical relation is limited to size of rivers whose bankfull discharge varies from 0.56 cms (20 cfs) to 113.3 cms (4,000 cfs). For example, appropriate minimum rock sizes for values of bankfull shear stress less than 1.7 kg/m^2 (0.35lbs/ft^2) are associated only with stream channel bankfull depths from 0.26 - 1.5m (2 - 5 ft). This relation would *not* be appropriate for applications outside the limits of the data for a river slope of 0.0003 and a mean depth of 6.1m, even though a similar shear stress results as in the example presented.

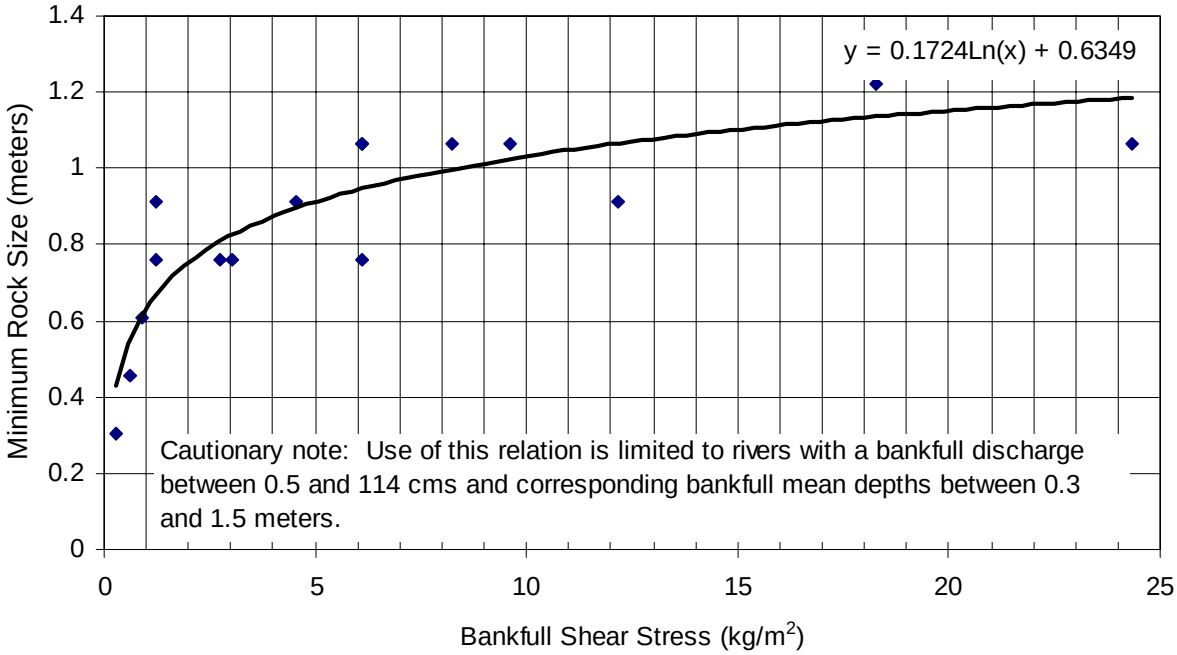

Figure 10. Minimum rock size as a function of bankfull shear stress

Materials. The Cross-Vane can be constructed with boulders, logs and a combination of both. A geotextile fabric is required to prevent scour under the structure when logs are used or when rocks are used in sand or silt/clay bed channels. The design using logs only and a duckbill anchor system is shown in Figure 11. Large flat rocks can be substituted for the duckbill anchor and cable to keep the logs in place.

Hydraulics. The center cell of Cross-Vane and J-Hook Vane structures generally contain 0.80 of the bankfull discharge. The left and right 1/3 cells of the structure each generally contain 0.3 of the mean velocity, 0.02 of the shear stress and 0.01 of the stream power of the entire bankfull channel. A velocity isovel showing the distribution of velocity over a J-Hook Vane on Turkey Creek, Colorado is shown in Figure 12. The Cross-Vane isovels are similar to those of the J-Hook Vane, as they distribute the velocity from the near-bank region to the center of the channel.

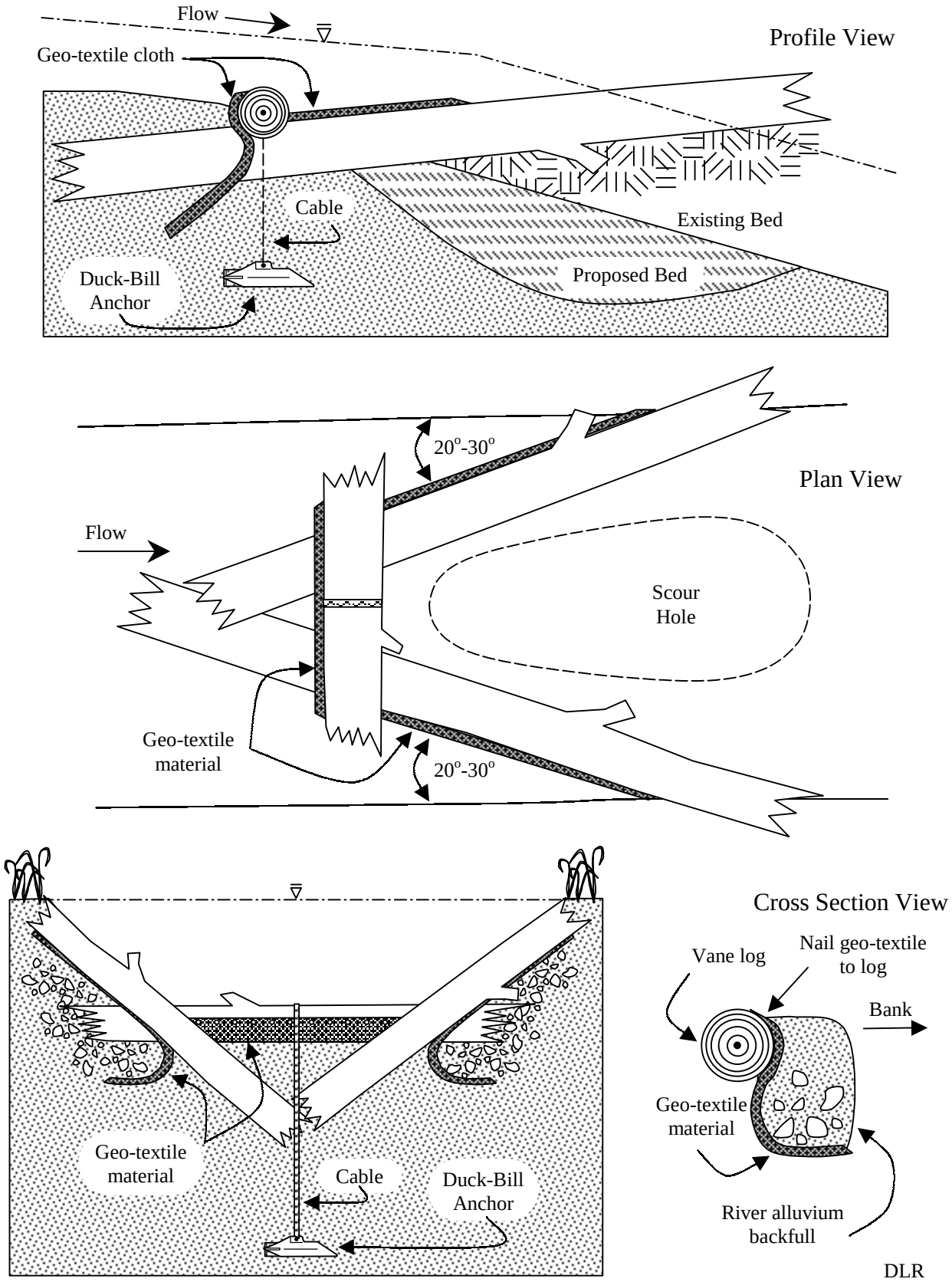

Figure 11. Cross-Vane using logs and a duck-bill anchor

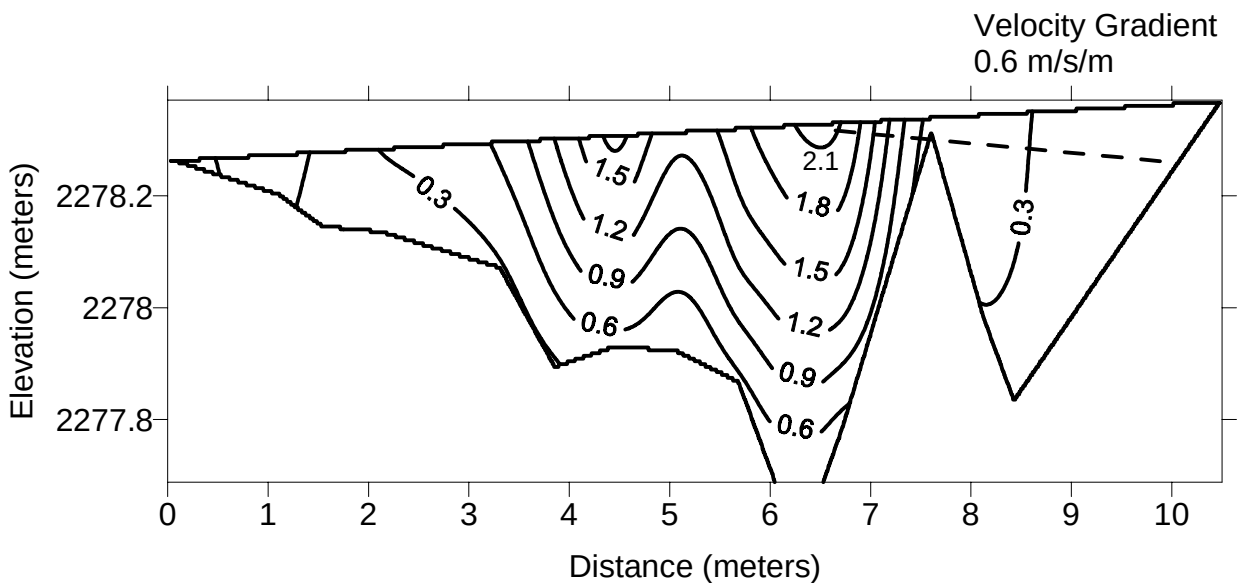

Figure 12. Velocity isovels of a J-Hook at Turkey Creek, CO (Velocity in meters/second)

Applications

Irrigation diversions. The use of a Cross-Vane for an irrigation diversion is shown in Figure 13. Cross-Vanes and W-Weirs have both been used successfully for irrigation structures. Both the Cross-Vane and W-Weir create a differential head in the near-bank region due to the flat slope of the vane leading to the bank. This condition provides the head to deliver water to the head gate at very low flows so that it is not necessary to construct sacrificial dams at low flows. When the head gate is closed during high flows, fine sediments often accumulate. To prevent the sediment deposition at the head gate and in the irrigation canal, a sediment sluice gate is installed so that the sediment is delivered back to the channel during normal high flows (Figure 13).

Grade control. The Cross-Vane is used to maintain base level in both riffle/pool channels, rapids-dominated stream types and in step-pool channels (Figure 14). One aspect of river restoration is associated with the conversion of incised rivers G and F stream types to B stream types (Rosgen, 1994,1996, and 1997). The Cross-Vane, as used for grade control, maintains the new width/depth ratio, entrenchment ratio, reduces bank erosion, dissipates energy and improves fish habitat. Spacing of the structures is based on a negative power function relationship of the ratio of pool spacing / bankfull width as a function of slope.

$$P_s = 8.2513\ S^{-0.9799}$$

Where P_s = the ratio of pool to pool spacing/bankfull width

S = channel slope in percent

This relationship was developed from natural channels and has a correlation coefficient (R^2) of 0.92 and is shown in Figure 15.

Bridge protection. Bridges constructed on a skew to the channel and/or placed on an outside bend often experience abutment scour and embankment erosion. This problem can be reduced by the placement of an offset Cross-Vane in the upstream reach. The vane on the outer bank in the bend has a flatter slope and smaller angle (20°), while the vane arm on the inside bank has a steeper slope and a larger angle (30°) (Figure 16). W-Weirs are particularly useful for reducing

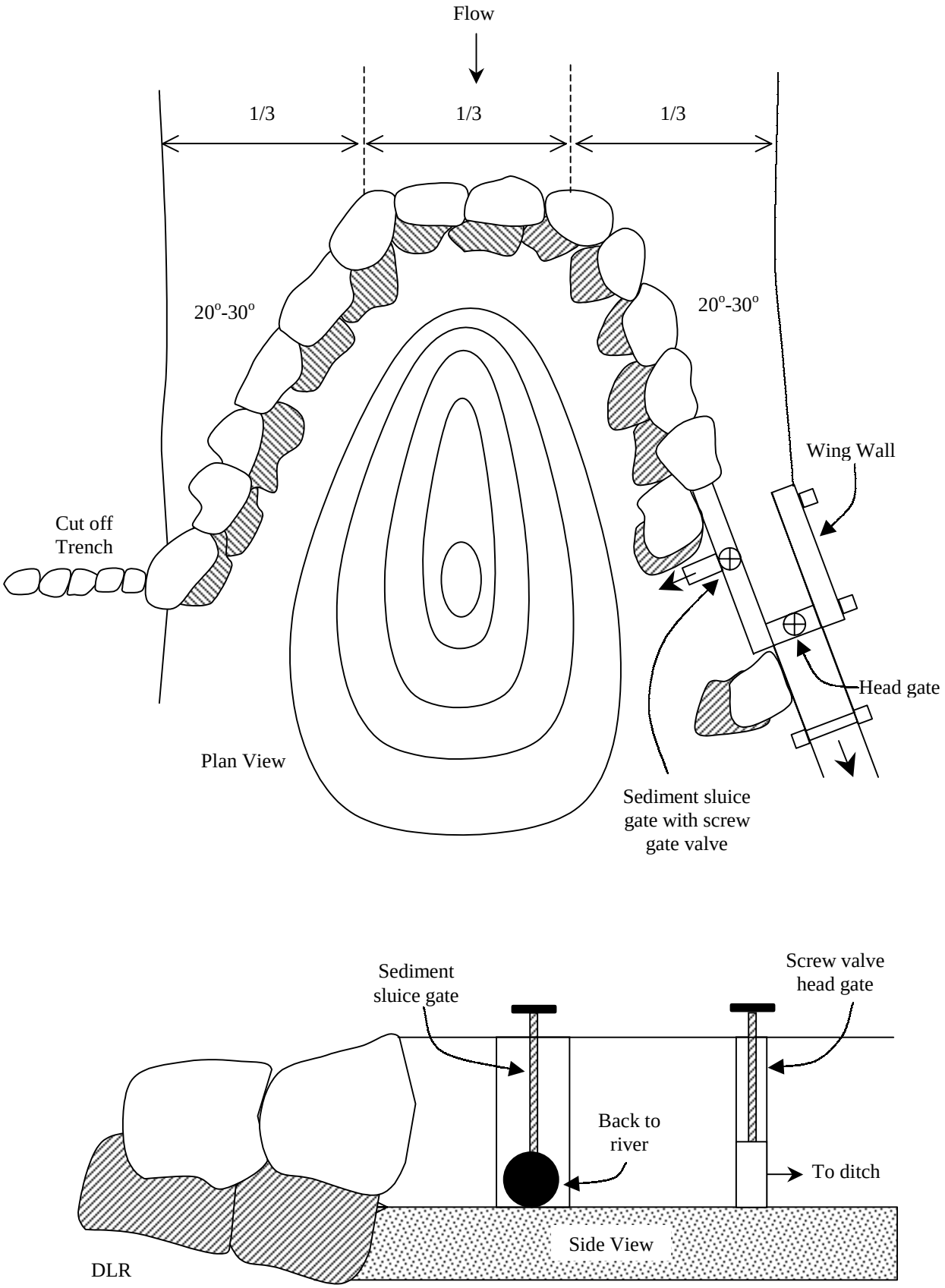

Figure 13. Example of a Cross-Vane/irrigation head gate-sediment sluice

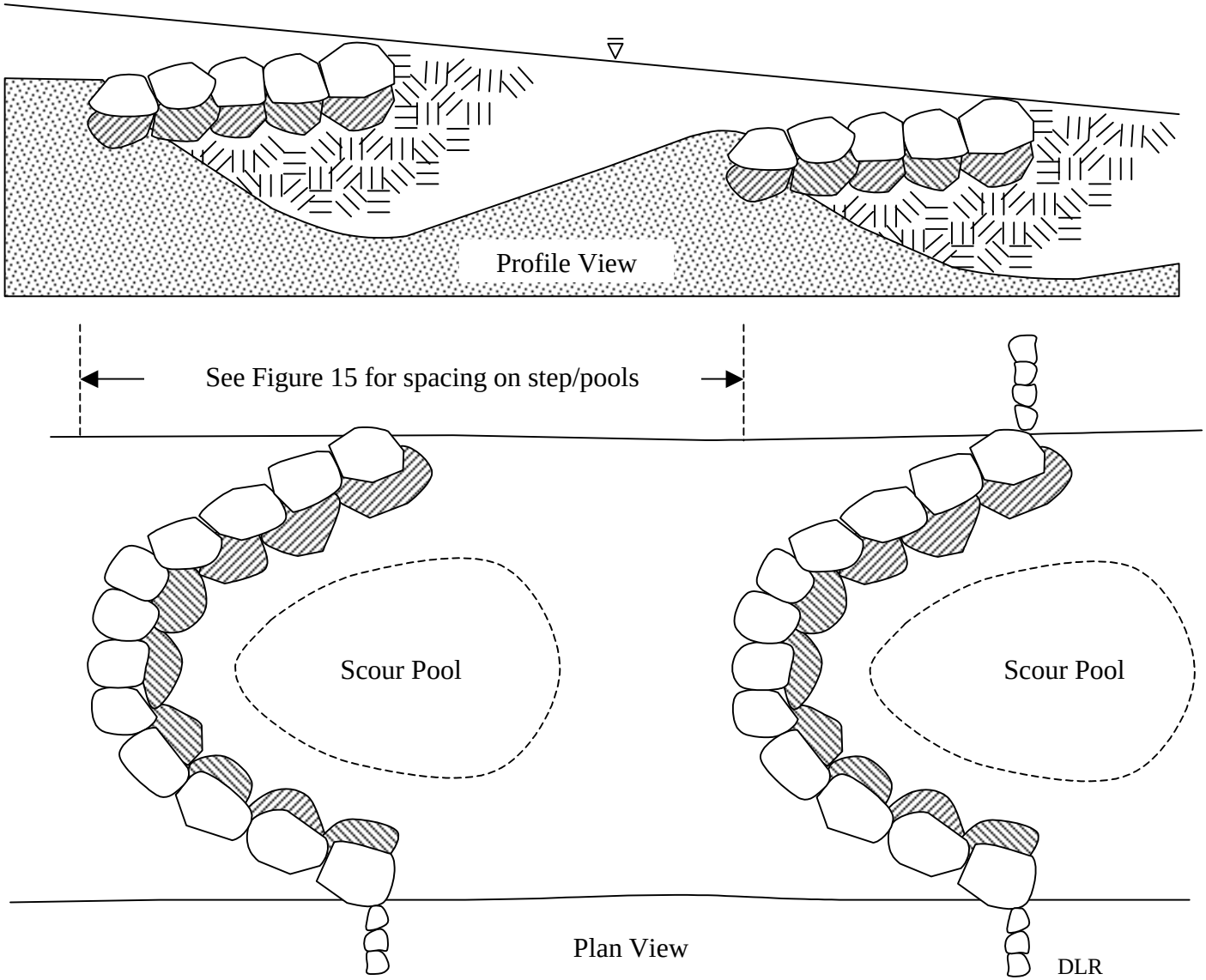

Figure 14. Use of Cross-Vane for step/pool restoration

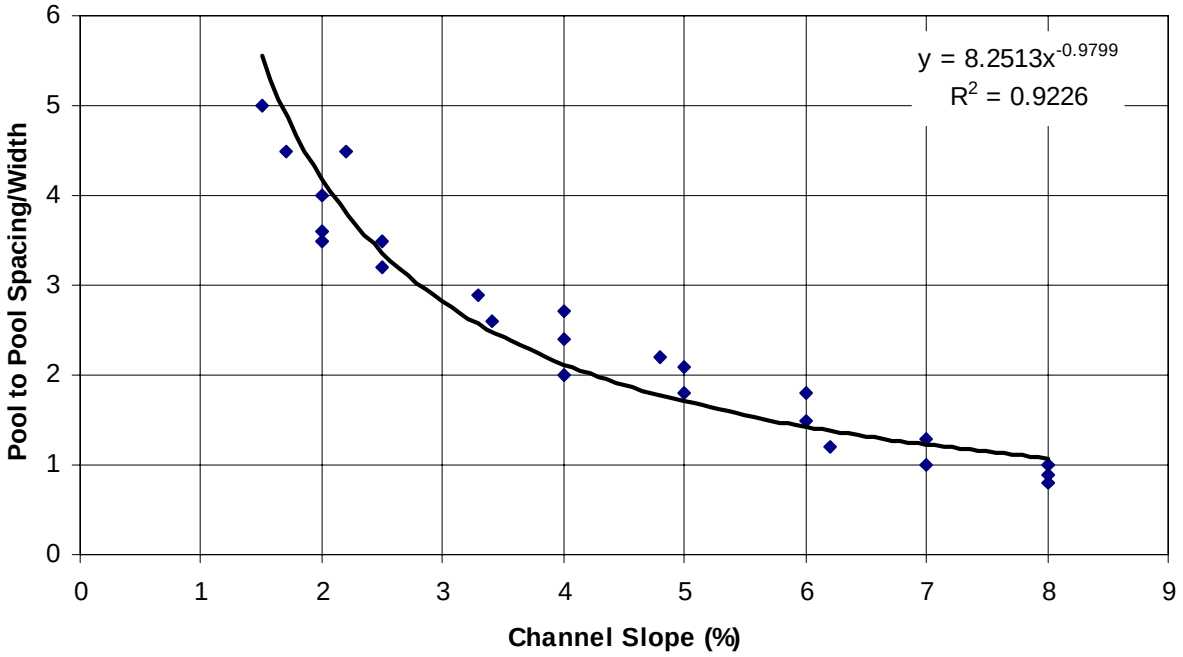

Figure 15. Ratio of pool spacing to bankfull width as a function of channel slope

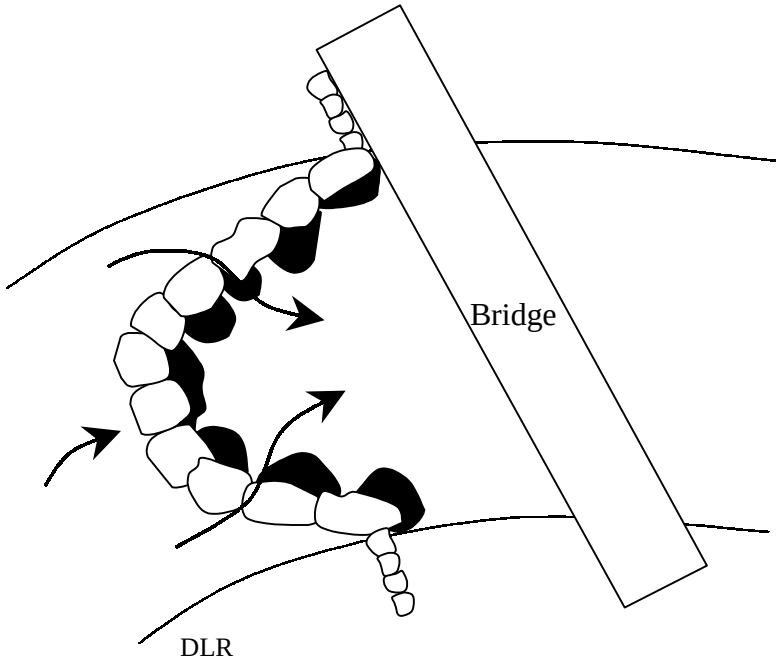

Figure 16. Application of a Cross-Vane for bridge and channel stability.

center pier scour. Both the Cross-Vane and W-Weir can provide grade control, prevent lateral migration of channels, eliminate fish migration barriers, increase sediment transport capacity and competence and reduce footer scour. J-Hook Vanes can reduce bank erosion on outside banks both for the approach and downstream reaches of the bridge.

Streambank stabilization. The J-Hook Vane is designed to reduce accelerated streambank erosion on the outside bend of meanders. As a minimum, the amount of bank protected is 2 times the vane length, while maximum spacing provides approximately 3 times the bank protection to vane length. If both banks are eroding due to confinement (lateral containment) and entrenchment (vertical containment), then the Cross-Vane decreases the stream power and shear stress concurrently on both banks. This avoids lining or hardening both banks through a reach to provide protection.

Summary

The Cross-Vane, W-Weir and J-Hook Vane are structures that can be implemented to maintain or enhance river stability and function to facilitate multiple objectives. These structures have been successfully applied in natural channel design for river restoration, bank stabilization, grade control, irrigation diversions, fish habitat enhancement, bridge protection, and recreational boating. Continued monitoring will provide the information necessary to improve the designs to further their application to meet the ever-increasing demand for environmentally "softer" structures that meet multiple objectives.

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