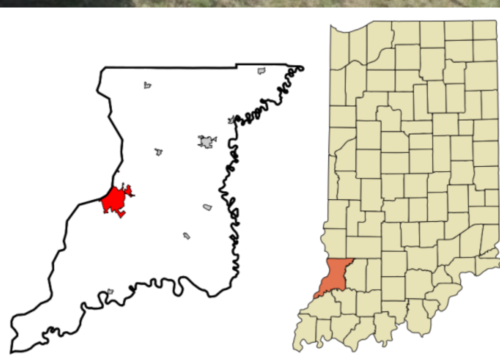
LEVEE SYSTEM EVALUATION REPORT

VINCENNES, INDIANA

LOUISVILLE DISTRICT CORPS OF ENGINEERS

US Army Corps of Engineers



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May 2014

INDEPENDENT TECHNICAL REVIEW CERTIFICATION

LEVEE SYSTEM EVALUATION REPORT
VINCENNES, INDIANA
LOUISVILLE DISTRICT
MAY 2014

The District Quality Control Review for the subject document has been completed and all comments have been resolved in the enclosed report. The following DQC team members certify completion of the review and satisfactory resolution of all comments. This document is provided to the Local Sponsor, the City of Vincennes.

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ACRONYMS

ACES	Automated Coastal Engineering System
AE	Architectural Engineering
bpf	Blows per foot
CASE	Computer Aided Structural Engineering
CCTV	Closed Circuit Television
CEDAS	Coastal Engineering Design and Analysis System
cfs	Cubic feet per second
CFR	Code of Federal Regulations
CMP	Corrugated Metal Pipe
COE	Corps of Engineers
CU	Consolidated Undrained
CWALSHT	Design/Analysis of Sheet-Pile Walls by Classical Methods
CY	Cubic yard
DM	Design Memorandum
DS	Downstream
DQC	District Quality Control
EAP	Emergency Action Plan
EC	Engineer Circular
ED-D-S	Engineering Division, Design Branch, Structures Section
ED-D-M	Engineering Division, Design Branch, Mechanical Section
ED-T-G	Engineering Division, Civil Branch, Geotechnical and Dam Safety Section
ED-T-H	Engineering Division, Civil Branch, Hydraulics and Hydrology Section
EL	Elevation
EM	Engineer Manual
EP	Engineer Pamphlet
ER	Engineer Regulation
ETL	Engineer Technical Letter
ERNS	Emergency Response Notification System
FDA	Flood Damage Analysis
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
FS	Factor of Safety
ft.	Feet
FWEEP	Flood Warning and Emergency Evacuation Plan
GPM	Gallons per minute
GPS	Global Positioning System
GRC	George Rogers Clark
GW	Gate Well
HEC-FDA	Hydrological Engineering Center, Flood Damage Analysis
HEC-HMS	Hydrological Engineering Center, Hydrological Modeling System
HEC-RAS	Hydrological Engineering Center, River Analysis System
ICW	Inspection of Completed Works
IDOT	Indiana Department of Transportation
IFH	Interior Flood Hydrology

ACRONYMS (continued)

IHNC	Inner Harbor Navigation Canal
ISGS	Indiana State Geological Survey
lf	Linear feet
LOI	Letter of Intent
LRD	Lakes and Rivers Division
LRFD	Load and Resistance Factor Design
LRL	Lakes River Louisville (Louisville District)
LS	Landside
LSE	Levee System Evaluation
MCC	Motor Control Center
MDE	Maximum Design Earthquake
MDF	Maximum Design Flood
MOA	Memorandum of Agreement
NASSCO	National Association of Sewer Service Companies
NAVD	North American Vertical Datum
NFIP	National Flood Insurance Program
NFPA	National Fire Protection Association
NGVD	National Geodetic Vertical Datum
NLD	National Levee Database
NOAA	National Oceanic and Atmospheric Administration
OHW	Ordinary High Water
OSHA	Occupational Safety and Health Administration
O&M	Operation and Maintenance
PACP	Pipeline Assessment Certification Program
pcf	pounds per cubic foot
PGA	Peak Ground Acceleration
PI	Periodic Inspection
PMF	Probable Maximum Flood
PPE	Personal Protective Equipment
PS	Pump Station
psf	pounds per square foot
psi	pounds per square inch
QCP	Quality Control Plan
RS	Riverside
RTS	Regional Technical Specialist
R&U	Risk and Uncertainty
SA	Support Agreement
SCADA	Supervisory Control and Data Acquisition
SCS	Soil Conservation Service
SFHA	Special Flood Hazard Area
SME	Subject Matter Expert
SOP	Standard Operating Procedure
SPT	Standard Penetration Test
STA.	Station
TOW	Top of Wall

ACRONYMS (continued)

UFGS	Unified Facilities Guide Specifications
US	Upstream
USACE	United States Army Corps of Engineers
U.S.E.D.	United States Engineering Datum
USGS	United States Geological Survey
VWU	Vincennes Water Utilities

DEFINITIONS

Type I I-Wall – A simple concrete gravity wall.

Type II I-Wall – A concrete wall overlying sheet-piling driven to a depth necessary for structural stability and sometimes to prevent seepage from going under the levee.

Levee Embankment – A soil embankment with the primary purpose of furnishing flood reduction for seasonal high water loading periods lasting from days to weeks.

System – A flood damage reduction system is made up of one or more flood damage reduction segments which collectively provide flood damage reduction to a defined area. Failure of one segment within a system constitutes failure of the entire system. Failure of one system does not affect another system.

Segment – A flood damage reduction segment is defined as a discrete portion of a flood damage reduction project or flood damage reduction system that is operated and maintained by a single entity. A flood damage reduction segment can be made up of one or more features (levee, floodwall, pump plant, etc.).

Closure – A gap in the levee system that remains open for pedestrian or vehicular traffic but can be closed in the event of high water.

Slide/Sluice Gate – A gate structure which operates vertically through a drainage structure used to control flows through the line of protection to prevent backwater interior flooding.

Pumping Plant/Station – A structure used to pump interior drainage water from the interior side of a levee system to the river side.

Relief Well – A seepage control feature consisting of a vertical pipe installed landside of the levee with a slotted section below grade designed to intercept and relieve seepage pressures to the surface.

1. INTRODUCTION

1.1. Preface

Unlike the other levee systems within the Louisville District, the Brevoort-Vincennes Levee system is comprised of two segments; the Vincennes Segment and the Brevoort Segment. Typically, an entire levee system (includes all segments if applicable) is required to meet the standards associated with an Accredited Levee System for the National Flood Insurance Program (NFIP). However, only a portion of the Brevoort Segment plus the entire Vincennes Segment (not the entire levee system) are considered as structurally sound to provide flood risk reduction for NFIP purposes to the City of Vincennes, Indiana. This LSE study utilized FEMA guidance found in *Analysis and Mapping Procedures for Non-Accredited Levee Systems* dated July 2013.

A portion of the Brevoort Segment is included in this study. This portion was found to be a sound reach, while the other portions of the Brevoort Segment were either not evaluated or structurally insufficient. This sound reach of the Brevoort Segment is included with the Vincennes Segment to provide flood risk reduction for the majority of the City of Vincennes. The complete Vincennes Segment and the sound reach portion of the Brevoort Segment are herein referred to as the Vincennes Sound Reach. Figure 1.1-1 shows the entire Brevoort-Vincennes Levee System and a highlighted length of levee representing the Vincennes Sound Reach.

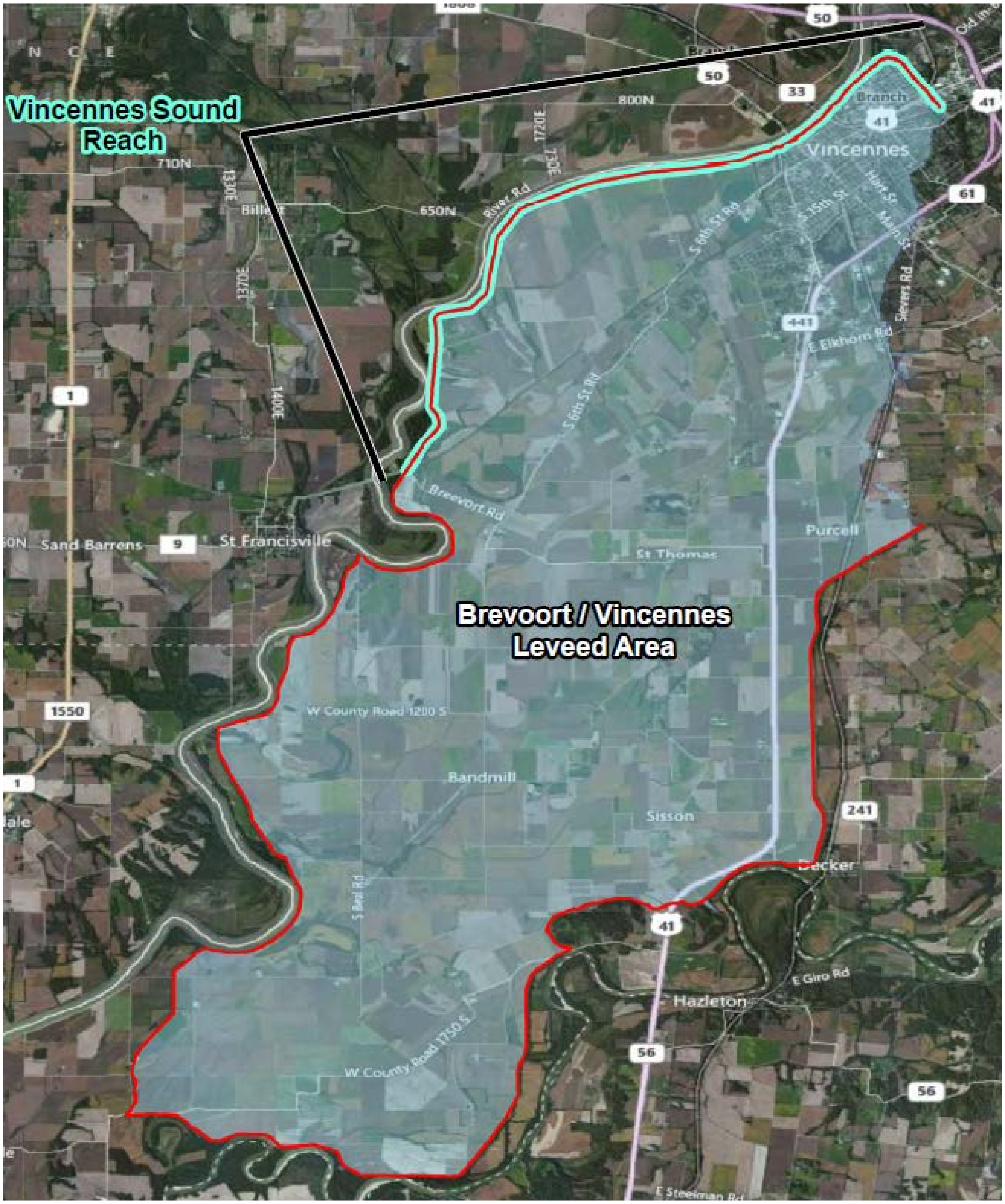

Figure 1.1-1 Brevoort-Vincennes Levee System with Vincennes Sound Reach Shown

1.2. Executive Summary

The Louisville District of the U.S. Army Corps of Engineers, at the request of the Local Sponsor (City of Vincennes, Indiana), has performed a Levee System Evaluation study for the City of Vincennes for the purposes of providing an assessment of the levee's ability to satisfactorily perform as required by the Federal Emergency Management Agency as part of the National Flood Insurance Program. This system evaluation study was accomplished in accordance with 44 CFR 65.10, *Mapping of Areas Protected by Levee Systems*, dated 1 October 2002, Engineering Circular EC 1110-2-6067, *USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation,* dated 30 July 2009, and *Analysis and Mapping Procedures for Non-Accredited Levee Systems*, *New Approach*, dated July 2013. The system evaluation study included a thorough review of project historical documentation, a field inspection to review the condition of the project; including proper operation and maintenance, analysis of the system components, a hydrology and hydraulic analysis, review of the pipeline inspection video and report of the gravity lines through the line of protection, stability analyses of the structures, seepage analyses, megger testing of the pumping stations' wiring, etc. The components of the project were evaluated with respect to the 1% annual chance (100-year) flood elevation with 95% chance assurance.

A new hydraulic profile utilizing HEC-RAS computer modeling was determined as part of this LSE. This new 1% annual chance (100 year) profile was used in the system evaluation. This new profile differs from the 1984 Flood Insurance Study profile. The new profile results in a decrease of approximately 2.4 ft from the 1984 FEMA Profile. The computed risk and uncertainty with 95% chance assurance is 2.4 ft.

Based upon the hydrology and hydraulic analysis, the City of Vincennes relies upon an upstream section of the Brevoort Levee to provide reduced flood risk to the city. At approximately 8 miles downstream on the Brevoort Levee, there are seepage issues which cause the upstream section of Brevoort to be a "Sound Reach", and downstream from this location would fall under the "Structural Based Inundation Procedure". The "Structural-Based Inundation Procedure" involves modeling breaches at various locations along the levee. To determine the Special Flood Hazard Area (SFHA), possible locations of system breach, geometry and failure duration were considered. The previous 2011 USACE Hydraulic and Hydrologic Analysis study of the Brevoort-Vincennes levee system was utilized to determine the appropriate breach parameters to assume for this current modeling effort. The former study utilized a HEC-RAS model (to develop a breach hydrograph) and a FLO-2D model (for interior flood modeling) to simulate a variety of levee breach scenarios at given locations along the Brevoort Segment. Model results were used as a visual aid to qualify how susceptible Vincennes would be to flooding given overtopping and/or levee failure of the Brevoort Segment at a given location.

Results of the breach scenarios indicated that a small low lying portion of the City is susceptible to backwater conditions from different breach scenarios along the Brevoort Segment. In Figure 1.2-1, the shading depicts the area which would be inundated by the

1% chance (100-year) flood elevation if the subject project were not in place. Figure 1.2-2, in contrast, shows the lesser potential inundated area with the levee system in place.

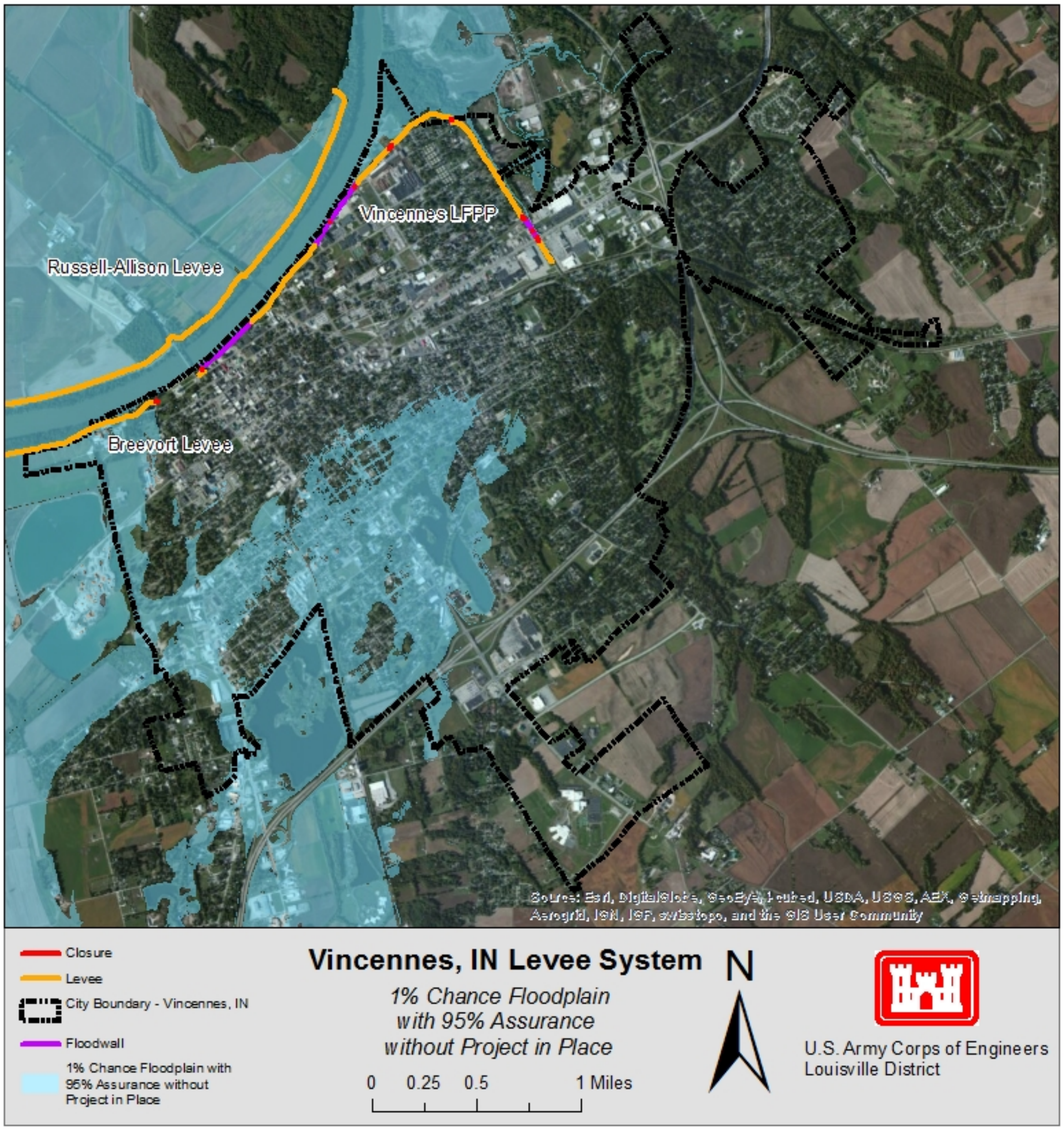

Figure 1.2-1: Vincennes, Indiana Inundation by 1% Chance (100-year) Floodplain With 95% Assurance Without Levee System in Place

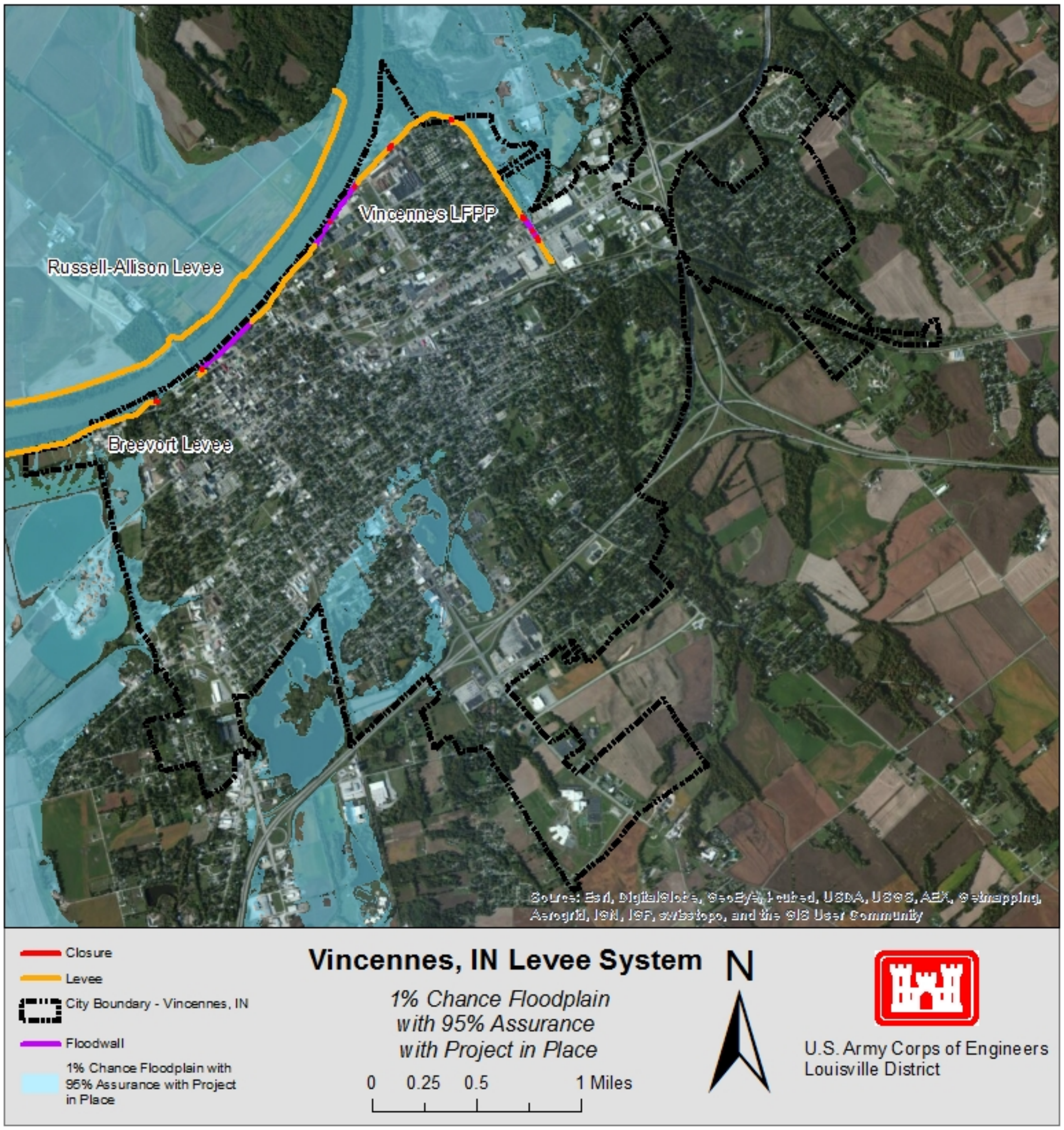

Figure 1.2-2: Vincennes, Indiana Inundation by 1% Chance (100-year) Floodplain With 95% Assurance With Levee System in Place

2. SYSTEM DESCRIPTION

2.1. Location, Authorization, and Local Sponsor

The Vincennes Levee is located in Knox County, Indiana, along the left bank of the Wabash River approximately 128 miles above the confluence of the Wabash and Ohio Rivers. The subject project, in conjunction with the Brevoort Levee, reduces flood risk to residents and businesses within the City of Vincennes and southwest Knox County. The Vincennes Segment and the Brevoort Segment of Levee combine to create the Brevoort-Vincennes Levee System.

The project was initially divided into 5 sections identified as Section “A” Part 1, Section “A” Part 2, Section “B” Part 1, Section B Part 2, and Section “B” Part 2b. Section “B” Part 2 and Part 2b were not constructed and were de-authorized by Public Law 99-662 (Nov. 1986). This was due to the Brevoort Levee Segment which was considered to provide flood risk reduction beyond the downstream end of the Vincennes Segment. Due to this de-authorization, a portion of the Brevoort Segment was evaluated to be included in the LSE to ensure the elevation of a 0.01 ACE (100 yr) event with 95% assurance is met. Construction of Section “A” Parts 1 and 2 and Section “B” Part 1 started in May 1952, were completed in 1962, and were assigned to local interests in 1960. Construction of the Brevoort Segment began in 1938, was completed in 1947, and assigned to local interests in January 1949.

The Vincennes Levee Segment was designed to have a crest elevation of 431.0 ft upstream to 429.3 ft downstream National Geodetic Vertical Datum (NGVD-1929), which corresponds to the current elevation datum of 430.57 ft upstream to 428.87 ft downstream North American Vertical Datum (NAVD-1988), a difference of 0.43 feet. The Brevoort Levee Segment has an elevation of 428.0 ft (NGVD 1929) at the upstream end, or 427.57 ft (NAVD 1988).

Table 2.1-1: Conversion of Original Project Vertical Datum to the Current Vertical Datum

Datum	N.G.V.D. (1929)	N.A.V.D. (1988)
Top of Levee Elevation	431.0-429.3	430.57-428.87
1% Event (95% assurance)	427.63-426.63	426.8-426.3

2.2. Main Features

The Vincennes Segment is composed of earthen embankment and I-wall, as well as seven closures. The portion of the Brevoort segment evaluated for this project consists of earthen embankment and two earthen closures. Six pumping stations exist in the Vincennes Segment, with an additional station located on the Brevoort Segment sound reach. There is approximately 9,222 ft of earthen levee on the Vincennes Segment, and 4,199 ft of I-wall divided into three sections. The first section from Station 212+00 to 230+70 is composed of Type I I-wall. The second section from Station 250+70 to 288+39 is Type II I-wall, and the third section from Station 337+65 to 344+12 is Type I.

The sound reach of the Brevoort Segment consists of approximately 8 miles of earthen levee.

2.2.1. Levee Features

The earthen levee consists of six separate sections (seven if you count the Brevoort segment), separated by floodwalls, closures, and high ground. The levee has a crest width of 12 feet with embankment slopes constructed to 2.5H:1V throughout the Vincennes Segment. The Brevoort Segment has a crest width of 8 ft with embankment slopes of 3H:1V throughout.

Photo 2.2-1. I-Wall from Sta. 212+00 to 230+70

The concrete flood wall from Station 212+00 to 230+70 is composed of Type I I-wall with a typical embedment depth of 5.5 ft with a stickup height of 4 ft. The second section from Station 255+91 to 275+06 is Type II I-wall with a typical section consisting of 13'-9" Z-27 sheet piling driven to grade with a concrete cap beginning 4 ft below grade and a stickup of 10 feet (14 ft total). The concrete cap is typically 23” wide at the base tapering to 15” wide at the top and is reinforced with rebar. A small section of wall associated with the Oliphant Closure exists from Station 306+16 to 307+29 and is Type II I-wall with various embedment and stickup lengths. The third section from Station 337+65 to 344+12 is Type I I-wall with a typical embedment depth of 5.5 ft with a stickup height of 4 ft.

2.2.2. Closures

A total of nine closures currently exist on the Vincennes Sound Reach to date, including two earthen fill closures from the Brevoort Segment. Two closures from the original construction have since been abandoned due to elevation improvements along the Vincennes Segment. A summary of the closures are listed in Table 2.2-1.

Table 2.2-1. Closure Summary

Location	Station	Closure Type
6th Street	344+54.6	Movable Post (abandoned)
Nursery on Niblack Blvd	342+18.34	Movable Post
2nd St and Railroad	338+21.37	Movable Post
Oliphant Drive	306+59.92	Movable Truss
Kimmel Park	287+67.54	Movable Post
Portland Ave	274+03.16	Movable Post
Service Opening	263+15	Bulkhead (LNO issued for permanent closure)
B&O Railroad	238+47.75	Sandbag (abandoned)
B&O Railroad – Main St	212+94.34	Movable Post
Clark Memorial	1134+85 (Brevoort) to Clark Memorial Structure	Earthen Fill
B&O Railroad/Willow St	198+11 1134+85 (Brevoort)	Earthen Fill

The two earthen fill closures located on the Brevoort Segment have been evaluated for slope stability and seepage. The evaluation calculations are included in Appendix H. Based on the evaluation, the B&O Railroad/Willow St closure does not pass stability evaluations under the current installation method. This item is considered an LSE issue and a modification to the operating plan or proper abandonment of this closure will be required. An operating plan is also needed for the George Rogers Clark Memorial which should include the fill volume, time to install, compaction requirements, material source, as well as documentation from the local sponsor indicating the capacity to perform installation of the closures as stated in the operating plans.

2.2.3. Pumping Stations

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A total of six pumping stations exist on the Vincennes Sound Reach. Originally there were five, and the Sixth St Pump Station was added when INDOT revised 6th St in 1996. The City Ditch Station located on the Brevoort Segment also works with the system to remove interior water from the city. Table 2.2-2 provides a summary of the pumping plants associated with the Vincennes Sound Reach.

Table 2.2-2: Pumping Plants of the Vincennes Sound Reach

Pump Station	Stationing	# of Pumps	Discharge capacity (CFS)
Perry Street	227+55	4	20,000 x 3, 3000 x 1
Hickman/College St	249+00	3	3800 x 3
St. Clair Ave	270+20	4	23,000 x 3, 8000 x 1
Highland St	314+20	3	9250 x 3
2nd and Niblack	337+59	2	6180 x 2
Sixth St	344+00	3	Unknown
City Ditch	659+00 (Brevoort)	2	50,000 x 2

2.2.4. Pipe Penetrations

When the project was turned over to the city of Vincennes there were 17 gravity pipe penetrations through the levee. Some penetrations have been abandoned, and others are scheduled for abandonment as they are no longer in use. Table 2.2-3 lists the current gravity penetrations through the Vincennes Sound Reach.

Table 2.2-3: Gravity Drain Pipe Penetrations Through Vincennes Sound Reach

Station	Pipe Diameter and Type	Description	Closure Method
344+70	66” RCP	Sixth St Pump Station gravity discharge (GW 1 has been ABANDONED)	Flap gate, sluice gate
337+96	24” VCP	GW 2 to MH-1C	Flap gate, sluice gate
313+90	48” x 40” concrete box culvert	GW 3, Highland St PS discharge	Flap gate, sluice gate
270+18	66” RCP	GW 4, St Clair PS discharge	Flap gate, sluice gate
269+70	16” VCP	GW 5 located in I-wall	Flap gate, sluice gate
260+26	12” VCP	GW 6 located in I-wall	Flap gate, sluice gate
249+05	30” CMP	GW 7, College/Hickman St PS discharge	Flap gate, sluice gate
241+17	30” CMP	GW 8	Flap gate, sluice gate
239+21	12” steel	GW 9	Flap gate, sluice gate
239+16	12” RCP	GW 10	Flap gate, sluice gate
239+10	24” VCP	GW 11	Flap gate, sluice gate
238+05	42” CMP	GW 12	Flap gate, sluice gate
237+60	6” cast iron	GW 13	Flap gate, sluice gate
237+45	10” steel	GW 14 (water intake)	Valve in GW
227+55	60” CMP	MH 18, Perry St PS discharge	Flap gate, sluice gate
224+09	48” RCP	GW 15	Flap gate, sluice gate
211+46	12” CMP	GW 16	Flap gate, sluice gate
200+75	24” CMP	Willow St, Downstream of GRC memorial	Flap gate, sluice gate
1118+54	48” CMP	WWTP effluent (Brevoort)	Flap gate, sluice gate
891+80	48” CMP	Brookhaven Rd (Brevoort)	Flap gate
833+20	36” CMP	(Brevoort)	Flap gate
814+57	36” CMP	(Brevoort)	Flap gate
799+68	30” CMP	(Brevoort)	Flap gate
731+81	30” CMP	(Brevoort)-abandoned	Flap gate
659+26	Three 90” metal w/ 4 seep rings each	City Ditch (Brevoort Section)	Sluice gates

3. REFERENCES

The following is a discipline specific list of references. This report also makes many references to information found only in the appendix sections. Refer to the List of Appendices at the introduction of this report for the location of available information.

3.1. General

1. Engineering Circular EC 1110-2-6067, *USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation*, dated 31 August 2010.

2. 44 CFR 65.10, Mapping of Areas Protected by Levee Systems, dated 1 October 2002

3. *Analysis and Mapping Procedures for Non-Accredited Levee Systems, New Approach*, FEMA, dated July 2013.

4. EP 500-1-1, *Emergency Employment of Army and Other Resources Civil Emergency Management Program – Procedures*, dated 30 September 2001

5. USACE As-Built Drawings, Vincennes Levee and Brevoort Levee

6. Vincennes Levee Project Routine Inspection Reports, dated from 1988 to 2012.

7. Vincennes Levee Periodic Inspections No. 1, dated March 1976, No. 2, dated October 1980, and No. 3, dated April 2011.

8. Operation and Maintenance Manual, Flood Protection Works, Vincennes, Indiana, dated 1961, revised 1983.

9. Definite Project Report on Local Flood Protection Vincennes, Indiana, U.S. Army Corps of Engineers, dated December 1951

3.2. Hydrology & Hydraulics

1. Flood Insurance Study City of Vincennes, Knox County, Indiana, Community Number 180120, Federal Emergency Management Agency, June 1984.

2. HEC-RAS River Analysis System User’s Manual, US Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA

3. HEC-FDA Flood Damage Reduction Analysis User’s Manual, US Army Corps of Engineering Center, Davis, CA

4. HEC-HMS Hydrologic Modeling System User’s Manual, Hydrologic Engineering Center, Davis, CA

5. NOAA Atlas 14, National Oceanic & Atmospheric Administration, National Weather Service, Silver Spring, MA

6. Director of Civil Works Memorandum titled "Guidance on Levee Certifications for the National Flood Insurance Program", dated 10 April 1997

7. EM 1110-2-1413, Hydrologic Analysis of Interior Areas, U.S. Army Corps of Engineers, dated 15 January 1987

8. EM 1110-2-1000, Coastal Engineering Manual, U.S. Army Corps of Engineers, dated 30 April 2002

9. EC 1110-2-6067, USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation, U.S. Army Corps of Engineers, dated 31 August 2010

3.3. Structural

1. EM 1110-2-2105, *Design for Hydraulic Steel Structures,* dated 31 May 1994

2. EM 1110-2-2705, *Structural Design of Closure Structures for LFPP*, dated 31 March 1994

3. EM 1110-2-2502, *Retaining and Flood Walls*, dated 29 September 1989

4. RAM Elements V8i Structural Software, Release 10.0.2, Copyright 2009, Bentley Systems, Inc.

5. CWALSHT, Program #X0031, Version 2007/11/9, Computer Aided Structural Engineering.

6. ETL 1110-2-575, *Evaluation of I-Walls* dated 1 September 2011

7. ERDC TR-07-15, "Fitness-for-Purpose Evaluation of Hydraulic Steel Structures", published in November 2007

3.4. Geotechnical

1. EM 1110-2-1913, *Design and Construction of Levees*, dated 30 April 2000

2. ETL 1110-2-569, *Design Guidance for Levee Underseepage*, dated 1 May 2005

3. EM 1110-2-1902, *Slope Stability*, dated 31 October 2003

4. EM 1110-1-1804, *Geotechnical Investigations, ENG 1836, ENG 1836A*, dated 1 January 2001

5. EM 1110-2-1901, *Seepage Analysis and Control for Dams,* dated 30 April 1993

6. GeoStudio 2012 Software Products: SLOPE/W and SEEP/W, GEO-SLOPE International Ltd. Version 8.05

7. *Saline water at the base of the glacial-outwash aquifer near Vincennes, Knox County, Indiana*. 1980, Shedlock, Robert J. USGS Water-Resources Investigations Report: 80-65

8. EM 1110-2-1601 *Hydraulic Design of Flood Control Channels,* dated 30 June 1994

9. EM 1110-2-1914 *Design, Construction, and Manintenance of Relief Wells*, dated 29 May 1992.

3.5. Mechanical

1. EM 1110-2-3102, *General Principles of Pumping Station Design and Layout*, dated 28 February 1995

2. EM 1110-2-3105, *Mechanical and Electrical Design of Pumping Stations*, dated 30 November 1999

3. IRD MECHANALYSIS, INC., General Machinery Vibration Severity Chart, Copyright 1964

4. Hydraulic Institute Standards, Copyright 2000

4. LEVEE SYSTEM EVALUATION TEAM MEMBERS

The following is a list of the Louisville District, Engineering Division team members involved in the evaluation and the preparation of the Levee System Evaluation Report for the City of Vincennes, Indiana.

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Adam M. Connelly, P.E.
Jessica Fox, E.I.T.

Structural:
Terry M. Sullivan, P.E. (SME)
Neil Cash, P.E.
Kate Brandner, E.I.T.

Mechanical:
Brian D. Smith, P.E.
Mark Robertson, P.E.

Electrical:
Jeffrey W. Timbas, P.E.
Chas Krish

5. PREVIOUS CERTIFICATION INFORMATION

A Flood Insurance Study report, dated June 18, 1984 was conducted for the City of Vincennes, Indiana by FEMA. The purpose of this study was to produce the Flood Insurance Rate Map for the city of Vincennes. This study utilized a physical model to develop the 100-year, 50-year, and 10-year flood profiles.

6. LETTER OF INTENT (LOI), MEMORANDUM OF AGREEMENT (MOA), SUPPORT AGREEMENT (SA), AND QUALITY CONTROL PLAN (QCP) BETWEEN DISTRICT AND SPONSOR

The LOI was provided to LRL on 27 August 2009. The MOA was signed, executed and provided to LRL on 5 October 2009. The SA was signed between LRL and the Sponsor on 8 February 2010. See Appendix A for a copy of these agreements.

7. OVERALL PROJECT HISTORY AND OPERATION AND MAINTENANCE

7.1. O&M Responsibilities

The city of Vincennes has been responsible for the operation and maintenance of the system since 1960, when the project was turned over to the local sponsor.

7.1.1. History of Project Permit Actions

The following list of permitted actions was obtained from the archived project files at the Louisville District office in Louisville, Kentucky.

Table 7.1-1: Permit Actions of the Vincennes Sound Reach

Vincennes Segment Permits			
Date issued	Permit #	Station	Description of Change
10-Nov-1959		274+00	Run exposed water line through Portland Avenue Closure
13-Nov-1973		333+30	Levee crossing with a 12" MJDI water main near Niblack Boulevard & Day Street
8-Jul-1977		312+20	Install a 2" plastic water line over levee (3' below surface). Shut off valve located ~100' landside of levee
15-Sep-1981		345+50	Place galvanized conduit over levee ~ 2' below surface (6th Street and Niblack Boulevard)
12-Feb-1982		288+30	Cross line of protection (over levee ~2.5' below surface) with 4" steel force main sewer line for Kimmell Park
10-Sep-1986		337+85	Install 5" pipe sleeve through the closure sill at Second and Niblack Boulevard for fiber optics cable.
4-Dec-1987		310+50	Install fiber optic cable over levee (2' below surface) at Old Terre Haute Road and Niblack Boulevard
14-Aug-1991		near 351+55 (in easement)	Install a 36" drainage structure at SE corner of the Johnson Controls, Inc. property to provide interior drainage from the plant area into Kelso Creek (crosses beneath Niblack Blvd)
17-Dec-2002	2002112628.VIN	310+00	16" welded water main to be placed in 30" steel casing to be bored under levee
21-Mar-2006	200419.VIN	290+00 to 351+00	Construction of walking trail and access ramp along the levee
16-Apr-2007	200626.VIN	Section A, Parts 1 & 2; Section B, Part 1	Construction of a riverwalk between George Rogers Clark Memorial and Kimmel Park
7-Jun-2007	200614.VIN	239+00	Construction of a ramp over the levee to move equipment under the CSX Railroad
Not permitted	200627.VIN	340+00 to 343+00	Construction of new 36' wide opening in the concrete floodwall
8-Aug-2007	200718.VIN	Throughout project	Concrete repairs and sealing
25-Feb-2010, not yet performed	200942.VIN	210+00 to 245+00	Construct Heritage Trail

13-Apr-2010	201018.VIN	188+13	2" HDPE sanitary force main replacement	
Not yet performed	2011030.VIN	338+00	Second and Niblack closure sill improvement	Project cancelled and included in upcoming INDOT project
24-Oct-2011	2012001.VIN	274+00 to 241+00	Construction of temporary access road for debris removal at RR bridge piers	
5-Dec-2011 not yet performed	2011039.VIN	213+45, 269+82, 270+75, 270+94, 342+74, 342+94	Repair/installation of external waterstops at joints	
5-Dec-2011, not yet performed	2011040.VIN	263+15	Abandoning existing bulkhead closure and replacing with reinforced concrete panel	
9-Jan-2012, not yet performed	2011031.VIN	215+00, 220+54, 224+10, 337+94, 338+00	Slipline 5 pipes	
17-Jan-2012, not yet performed	2011032.VIN	260+14	Drainage line replacement and abandon gatewell #6	
17-Jan-2012, not yet performed	2011033.VIN	241+18	Drainage pipe replacements and repairs	
18-Jan-2012	2011034.VIN	13 locations between 213+59 to 230+62	Repair and reconstruction of the floodwall at 13 locations	
7/17/2012 Only 198+40 completed to date	2011035.VIN	198+40, 224+10, 227+56, 237+47 to 239+21, 270+11	Pipe replacement & repair	
Not yet performed	2012020.VIN	212+94	ABANDON B&O CLOSURE	
11/7/2012, Not yet performed	2012024.VIN	gatewell 15, perry st pump sta grav line, gw 8, college ave ps ww, gw 7, gw 5, st clair st ps ww, gw 4, gw 3, gw 2, mh 1c	GATEWELL REPAIRS	
12/13/2013 completed	2012075.vin	241+00 – 274+00	Permanent Riverside access Rd CSX	
Not yet performed	2013006.vin	211+46	Slipline 12” CMP	
Not yet performed	2013027.VIN	306+60	Oliphant closure Sill Rehab	
Brevoort Segment Permits (Wabash River Section STA 710+00 to 1134+65)				
Date	**Permit #**	**Stationing**	**Description of Change**	
4-Nov-1963		1125+00	Construction of ramp over levee for access to river	
15-May-1977		1134+00	Observation wells installed in this area by U.S. Geological Survey	

3-May-1988		1110+00-1137+00	Placement of fiber optic cables along NW right-of-way of River Road
6/2013	2012010.BRE	1122+56, 1126+59	Repair of pipe joints for two existing sanitary manholes along toe of levee
completed	2011044.BRE	1135+00-1120+00	Abandonment of sanitary line in levee toe
completed	200613.BRE	891+80	Pipe sliplined
completed	201047.BRE	1116+98	Close drain at STA 1116+98 that used to provide drainage to the water treatment plant that no longer exists.
Not yet performed	2012021.BRE	1116+80, 1118+54	Sluice gate replacement and sliplining of WWTP outfall
completed	2012071.bre	814+57	Sliplining of 36” CMP
completed	2013045.bre	731+81	Abandonment of 30” CMP

7.1.2. Issues, Repairs and Alterations associated with the Vincennes Sound Reach

Since completion of the project in July 1962, there have been minimal repairs or alterations to the project beyond normal maintenance.

- 197? – B&O Railroad sandbag closure abandoned, sta. 238+40
- 1996 - GW-1 abandoned, 6th St PS installed, 6th St Closure abandoned
- 2006 - Slipline of pipe at station 891+80 (Brevoort)
- 2007 - Surficial repairs were made to the I-wall concrete and joint sealant of random sections of I-wall from Sta. 212+00 to 230+70.
- 2012 - replacement of 25 lf of pipe with RCP and new headwall, Station 198+40 (Brevoort)
- 2013- Two monoliths of floodwall replaced to grade and other monoliths repaired with epoxy and membrane treatment, Sta. 213+59 – 230+62
- 2013-Sliplining of 36” CMP at Sta. 814+57 (Brevoort)
- 2013-Abandonment of 30 inch CMP at Sta. 731+81 (Brevoort)

7.2. Review of Levee Routine Inspections

Routine inspections have been conducted on the Vincennes Segment and on the Brevoort Segment since 1988. A more standardized format for recording observations was adopted in 2003 with changes made in the Inspection of Completed Works (ICW) program, and only those results have been included in Table 7.2-1. Individual levee items are evaluated and the overall project segments are rated as either ‘Acceptable’, ‘Minimally Acceptable’, or ‘Unacceptable’. A project rating of ‘Unacceptable’ means there are one or more deficient conditions that may prevent the project from functioning as designed and require corrective action for the project to remain eligible for rehabilitation assistance under Public Law 84-99. The most recent routine inspection report for the Vincennes Segment was conducted in February 2012 in conjunction with the LSE inspection. The most recent Brevoort Segment routine inspection was conducted November 2012. Both reports cited an overall project rating of Minimally Acceptable.

Table 7.2-1: Findings of Routine Inspections Since 2003

Date of Inspection	Comments and Deficiencies
03 Oct 2003	**Items noted as minimally acceptable:** • The concrete wall is cracking and spalling throughout its length and should be repaired as necessary. • There has been some settling in some areas of the concrete wall in the past which appears to have stabilized. • Animal control, burrows • Trees and brush at the floodwall, riverside toe, and rip rap areas. • Monolith joints in need of repair • Pump station sumps • Corrugated metal pipes • Roadway cover plates damaged **Items noted as unacceptable: none**
24Sept 2004	**Items noted as minimally acceptable:** • Tree and brush on the riverside toe and slope, rip rap areas, and floodwall • Settling of concrete wall that appears to have stabilized • Monolith joints in need of repair • Animal control, burrows • Concrete wall is cracking and spalling throughout its length • Corrugated metal pipes • Gatewell concrete surfaces **Items noted as unacceptable: none**
11 Aug 2005	**Items noted as minimally acceptable:** • Tree and brush on the riverside toe and slope, rip rap areas, and floodwall • Animal control, burrows • Settling of concrete wall that appears to have stabilized • Monolith joints in need of repair • Concrete wall is cracking and spalling throughout its length • Corrugated metal pipes • Gatewell concrete surfaces • Gate operators • Pump station sumps **Items noted as unacceptable:** • Pumps- one or more pumps is not operational-City Ditch P.S.

6 Feb 2012 (The inspection format significantly changed from the prior inspection)	**Items noted as minimally acceptable:** • Sod cover, railroad bridge • Encroachments, utility poles, vehicular traffic • Settlement- sta. 299+27 • Rip rap displaced • Relief wells, inadequate inspection records • Fencing and gates are corroded • Gatewell concrete surfaces • Gatewell cover plates corroded • Riprap/revetments of discharge areas • No P.S. safety inspection reports • Pumps: Sump pumps inoperable • P.S. Power source • Electrical panels- minor corrosion • Intake and discharge pipelines: minor corrosion • P.S. access hatches corroded **Items noted as unacceptable:** • Vegetation growth • Closure Structures: Oliphant storage vault, Kimmel Park Closure sill, B and O closure ponds water, 2nd and Niblack Closure railroad issue, Oliphant closure sill deteriorated, trial erections not performed. • Animal control; burrows • Culverts/discharge pipes; several pipes need to be repaired • Relief Wells; several well standpipes damaged, some missing • I-wall Concrete surfaces • Monolith joints • Sluice gates; 2nd St P.S. discharge, GW#2 gate, MH1 gate inoperable • Flap Gate; GW#6-flapgate removed at time of inspection • P.S. inspection records • O&M Manuals not present in P.S. • Plant Buildings • Motors-Highland St P.S. circuit breaker • Electrical Systems

7.3. Overall Performance of Brevoort-Vincennes Levee System

The Brevoort-Vincennes Levee System has been subjected to four significant events during the past 7 years, as shown in the below Table 7.3-1. Data from the 2005, 2008, 2011, and 2013 events is well documented. However, these events did not significantly load the system. The top of levee elevation at the Memorial Bridge where the gauge is located is approximately 429 ft NAVD, leaving roughly 7.5 feet of freeboard for the 2008 and 2011 events, and 7.3 feet of freeboard for the 2013 event. Photo 7.3-1 below shows the water height just reaching the base of the I-wall during the 2013 event.

Table 7.3-1. Historical Crests for Wabash River at Vincennes (NWS website)

Gauge Height, Date*	Elevation, (NAVD 88)
(1) 29.33 ft on 05/23/1943	423.33 ft
(2) 29.04 ft on 01/18/1950	423.04 ft
(3) 27.68 ft on 4/27/2013	421.68 ft
(4) 27.50 ft on 06/10/2008	421.50 ft
(5) 27.48 ft on 05/03/2011	421.48 ft
(6) 27.25 ft on 03/02/1985	421.25 ft
(7) 27.15 ft on 01/18/2005	421.15 ft
(8) 27.11 ft on 06/21/1958	421.11 ft
(9) 26.50 ft on 01/06/1991	420.50 ft
(10) 26.30 ft on 03/29/1913	420.30 ft
(11) 26.28 ft on 02/05/1969	420.28 ft
(12) 25.65 ft on 02/17/1959	419.65 ft
(13) 25.45 ft on 05/17/2002	419.45 ft
(14) 25.27 ft on 03/28/1978	419.27 ft
(15) 25.26 ft on 01/29/1974	419.26 ft
(16) 25.00 ft on 03/22/1982	419.00 ft

*gauge height is 394.43 ft NGVD 29, 394.00 ft NAVD 88

Photo 7.3-1. Levee I-wall during 2013 Flood Event, sta. 260+00

January 2005 Event- Along the Vincennes Segment, city officials noted seepage of water under the floodgate (Station 274+03.16) at Portland Ave and also through the earthen levee immediately northeast of this floodgate. This area was observed during the 2008 event at the seepage area and floodgate and noted no seepage at the time.

June 2008 Event- Along the Vincennes Segment, clear seepage water was observed south of the Kimmel Park Closure at approximate station 280+00. Due to uneven pavement, there was moderate water coming under the Kimmel Park Closure. Sandbags were placed to help control the volume. The Relief wells within Chicago Park (sta. 310+00 to 334+00) were inspected and none were discharging any water.

May 2011 Event- Along the Brevoort Segment, clear seepage water was apparent along much of the River Rd stretch. Shortly after the river crested, two subsidence areas were observed along River Rd upstream of the water treatment plant at station 1125+69. This was later found to be due to infiltration into a manhole around improperly sealed pipe joints and an abandoned pipe. These pipe joints were repaired in November 2011. Along the Vincennes Segment, heavy, yet clear seepage water was observed along the levee toe upstream and downstream of the Oliphant closure, near station 304+00 to 309+00. There is a gravel relief trench in this area, which is intended to release seepage pressures at the levee toe. It was assumed this seepage may have been excessive in the field.

April 2013 Event- Along the Brevoort Segment, the pipe issues observed in 2011 did not resurface. General seepage occurred on the Brevoort segment from Station 950+00 south along the River Rd stretch again. Data was obtained from the 8 piezometers installed in the Brevoort embankment and were used in seepage analyses for this report. A group of 4 small sandboils was noted approximately 100 feet from the Brevoort Segment near Station 790+00. Several other significant sandboil areas exist downstream of the Wabash Cannonball Bridge (Station 717+00). There were only minor issues along the Vincennes Segment such as a leaky Gatewell 6 and Kimmel Park Closure.

The HEC-FDA computer program estimates project performance over the long-term period as shown in Table 7.3-2 for existing condition levees/floodwalls. As shown on this table, there is only a 0.1% chance that this flood protection project will be overtopped in the next 10 years and a 0.5% chance it will be overtopped during the next 50 years. The HEC-FDA program also estimates the project performance for non-exceedance by flood event as shown in Table 7.3-3. This table shows that if a 4% chance flood occurred, there is a 99.98% chance this top of protection will not be overtopped. If a 1% chance flood occurred, there is a 99.71 % chance it also will not be overtopped.

It should be noted that these probabilities apply to the Vincennes Sound Reach. Several locations along the Wabash River portion of the Vincennes-Brevoort levee system were analyzed. This analysis shows that nearly the entire levee reach along the Wabash River, including the entire Brevoort Segment, provides greater than 95% certainty that the levee will not be overtopped with the 1% chance event.

Table 7.3-2: Expected Annual Performance and Equivalent Long-Term Risk

Levee Plan	Annual Chance of Project Being Exceeded	Equivalent Long-term Risk Chance of Exceedance during		
		10 Years	**30 Years**	**50 Years**
Existing Levee	0.0001	0.001	0.003	0.005

Table 7.3-3: Levee Performance for Specified Events

	Levee Performance as % Chance of Non-exceedance for Specified Events				
Levee Plan	**10% Chance Flood**	**4% Chance Flood**	**2% Chance Flood**	**1% Chance Flood**	**0.2% Chance Flood**
Existing Levee	1.000	0.9998	0.9984	0.9971	0.9949

8. ENGINEERING STUDIES, INVESTIGATIONS AND ANALYSES

8.1. Site Visit Summary

The initial and most comprehensive site visit for the report was conducted by thirteen team members on 6-10 February 2012; reference Chapter 4 of this report for a list of the primary study team members and their discipline. Items noted as requiring attention or repair were placed into one of two categories, LSE issues (unacceptable deficiencies) that would prevent the project from receiving a positive evaluation report, and O&M issues that require attention but would not prevent the project from being considered eligible to be in the FEMA program. Initially, a total of 16 items were documented as LSE issues as shown in Table 8.1-1.

Table 8.1-1: Initial LSE Issues Documented During the Field Inspection

Discipline	Item of Deficiency	Report Reference
Geotechnical	Animal Burrows throughout both Vincennes and Brevoort embankments	8.4.5.1
Geotechnical	No relief well performance testing or maintenance records	8.4.5
Geotechnical	Willow St Closure does not pass stability evaluation	2.2.2
Electrical	Highland St Pump Station; repair to motor #3 circuit breaker is required	8.6.1, 8.6.3
Mechanical	2nd St. Pump Station; Sluice gate located in discharge well was inoperable at time of inspection, repair as required.	8.5.1.1
Mechanical	Gatewells #5 and #6; gatewells are inoperable and were indicated in inspection to be abandoned: should be properly abandoned	8.5.1.8
Mechanical	The sluice gate in Manhole 1C is inoperable and needs to be replaced.	8.5.1.8
Mechanical	Highland St P.S. discharge flap gate is cracked and requires repair	8.5.1.3
Mechanical	Gatewell #2 in 2nd St. is inoperable and should be repaired. Access to the gatewell should be restored.	8.5.1.1
Mechanical	Gatewell #7 sluice gate stem should be repaired, misaligned flap gate should be repaired.	8.5.1.2
Mechanical	Treatment Plant Effluent gatewell (Brevoort Sta.	8.5.1.8

	1118+54) is inoperable and needs to be replaced.	
Mechanical	Perry St. P.S.; repair replace new bolts/nuts missing from pump discharge flapgates.	8.5.1.4
Mechanical	Pump start/stop elevations should be verified as current with O&M procedures.	8.5
Structural	Kimmel Park closure is required to be trial erected with USACE team member present. –Accomplished 17 December 2012 with no issues	8.3.2.3
Structural	Pipes receiving a PACP structural grade of 4 or 5 have not yet been remediated.	8.3.6
Structural	Manway closure at Sta. 263+15 is improperly installed (upside down) – corrected by Sponsor in September 2013	8.3.2.2

8.1.1. Additions to Initial List of Levee System Evaluation Issues

Based on modeling and analysis of project features and conditions, some items were added to the list of LSE issues, given in Table 8.1-2 below.

Table 8.1-2. Additions to LSE Issues List

Geotechnical	Toe Drain Inspection, Sta 214+34 to 241+00; Seepage models indicate this toe drain is required to achieve adequate factor of safety, video inspection of this line is required.	8.4.4
Geotechnical	Brevoort Levee Embankment; Levee does not meet seepage criteria during the flood event at a specific location downstream (Sta. 710+00). The levee downstream of this location cannot be included as a Sound Reach.	8.4.4
Geotechnical	Relief wells along the Wabash River are required to be inspected, and selective wells pump tested to determine their flow capacity. This capacity will then be used to verify their adequacy.	8.4.4
Hydraulics	In conjunction with the Vincennes Levee Segment, a portion of the Brevoort Levee Segment is relied upon for providing flood reduction for the City. Select areas of Vincennes are shown to be vulnerable to a backwater condition from a breach downstream of the Sound Reach. Measures to address this backwater flooding may be required in order to receive a positive Levee System Evaluation for these impacted areas, or these areas could be delineated as within the floodplain on inundation mapping.	8.2

8.2. Hydrology and Hydraulics Evaluation

8.2.1. Summary of Available Information

The flood of record along the Wabash River at Vincennes, Indiana occurred in March 1913 with a flow rate of about 255,000 cfs. This high flow produced a corresponding flood elevation of about 421 feet on the Wabash River at the Vincennes USGS gaging station. This flood easily surpassed all other damaging floods along the Wabash River including much of Central Indiana and Illinois during recorded times. This flood was caused by rainfall that began on 23 March 1913 and continued through 27 March with up to 10 inches falling in some locations and over 8 inches in most locations with up to 5 to 6 inches falling on the 25th. It was stated for this flood that over 600 people lost their lives, a quarter million people were left homeless, and damages were estimated in the hundreds of millions, making it at that time one of the worst natural disasters the United States had witnessed. As a result, there was a national outcry for state and federal governments to reevaluate their roles in flood control. Even though construction of Brevoort Segment and Vincennes Segment did not begin until July 1938 and May 1952, this event and other flood events such as January 1937 precipitated construction of these levees as well as many others along the Ohio and Wabash Rivers. As just stated, construction of the Vincennes Segment began in May 1952 and was completed in June 1962. In addition to this flood reduction measure, Corps reservoirs were constructed throughout the Ohio River basin, including four Corps reservoirs upstream of Vincennes, to further reduce the impact of flooding on the receiving streams of these reservoirs including the Wabash and Ohio Rivers. Since the time of construction of the Vincennes Segment, the largest flood per peak flow that has occurred for this area happened in March 1985 with a peak flow of 104,000 cfs and a corresponding flood frequency of about a 2% chance, 50-year flood.

The Vincennes Segment begins at the upstream end of Vincennes near mile 129.4 on the Wabash River tying into high ground at Station 351+55 on Section A Part 1 at about elevation 430.5 feet NAVD and continues downstream to about mile 128.5 or Station 210+36 on Section B Part 1 at the Vincennes downstream city limits with a top of levee elevation of about 428.8 feet NAVD. This location is the end of the Vincennes Segment. From this point the attached Brevoort Segment begins at Station 1137+57 continuing downstream to the confluence with the White River at mile 95.5 and thence continues upstream along the White River.

The Vincennes Segment was initially designed to provide 4.0 feet of freeboard above a 15-year flood per a 1951 Definite Project Report. However, based upon present flow frequency criteria and flow reductions from upstream COE reservoirs, the Vincennes Segment presently provides >1% chance of exceedance (without consideration freeboard requirements or potential structural inadequacy). The Brevoort Segment was initially designed to give protection to a flood expected to occur 7 times per 100 years. However, since levee grades are higher than the as-built drawings, frequency relations have been revised, and considering the effects of upstream reservoirs, the existing Brevoort Segment also provides equal to or greater than the 1% chance exceedance, (100-year) flood level elevation with 1.5 feet of freeboard per a 1983 COE report.

Although the Wabash River reach of the Brevoort-Vincennes levee system is hydrologically adequate for nearly its entire reach, the levee is structurally inadequate beginning approximately 8 miles downstream of the most upstream end of the Wabash River Brevoort Segment (just downstream of the Wabash Cannonball Bridge). Should the levee fail anywhere downstream of this location (or anywhere along the White River reach of the Brevoort Segment) during a major flood, there is potential for the interior area to fill-up to an elevation slightly greater than the minimum top of levee elevation at the downstream end. A portion of the City of Vincennes may be subject to backwater flooding through the storm sewer system with outlets at City Ditch and Mantle Ditch. Construction of sluice gates and necessary pumping capabilities for local inflow could prevent such flooding. This area is defined as the inundated areas of Figure 1.2-2 within the city boundary.

Frequency discharges for the length of the Wabash River were based upon an updated hydrologic analysis. Former discharge frequency relationships for the Wabash River were based on coordinated discharge estimates dated April 1980 with Indiana Department of Natural Resources (IDNR). This updated analysis was based upon added USGS annual peak flows from 1980 to present and shows reductions in frequency flood flows, including those at Vincennes. For instance, the 1% chance flow at Vincennes is shown to be 114,000 cfs with the updated analysis, but the coordinated discharge estimate for the same frequency was 150,000 cfs. See Table 8.2-1 for the full range of frequencies that were used for the hydraulic analysis.

It should be noted that all elevations listed in this report are based upon the North American Vertical Datum (NAVD) of 1988. Backup data used for this report include elevations based upon the National Geodetic Vertical Datum (NGVD) of 1929. To obtain NAVD elevations at Vincennes, subtract 0.4 feet from NGVD elevations.

Table 8.2-1 Summary of Discharges

Flooding Source & Location	Drainage Area (Sq Miles)	Chance Exceedance Peak Discharge (CFS)							
		99%	50%	20%	10%	4%	2%	1%	0.20%
Wabash River @ Vincennes	13,706	51,000	62,000	76,000	87,000	96,000	107,000	114,000	130,000

8.2.2. Characterization of the Flood Hazard

Frequency flood profiles for the Wabash River for this Levee System Evaluation study were based upon HEC-RAS River Analysis Systems computer modeling utilizing the discharges in Table 8.2-1. From the HEC-RAS model, one percent chance flood elevations were computed which varied from about 423.9 feet NAVD at the upstream end of the Vincennes Segment at mile 129.4 continuing downstream to the city limits of Vincennes at mile 128.5 with a 1% chance flood elevation of 422.8 feet NAVD. Continuing along the Brevoort Segment to mile 118.9, the 1% chance elevation equals about 416.2 feet NAVD.

The Louisville District COE performed risk based analysis of the Wabash River at Vincennes using the HEC-FDA (Flood Damage Analysis) computer program for this evaluation. Use of risk based analysis by the COE has been accepted by FEMA as shown in the Memorandum "Guidance on Levee Certification for the National Flood Insurance Program", dated 10 April 1997. Ninety five percent assurance of containing the 1% chance flood was developed using this risk based analysis. The frequency discharge relationship for Vincennes was used in the FDA analysis with a period of record of 43 years based upon completion and operation of the four flood control lakes located upstream of this project. A standard deviation of error in elevation of 1.2 feet was also used. Based upon this analysis, the elevations providing 95% chance assurance of the Vincennes Sound Reach not being overtopped were 426.3 feet NAVD at the upstream end of the Vincennes Segment, 425.2 feet NAVD at the upstream end of the Brevoort Segment, and elevation 418.6 feet NAVD 9.0 river miles downstream of the upstream end of the Brevoort Levee reach. Comparisons between the 95% chance elevations and the top of protection show differences of about 4.2, 3.6, and 2.4 feet respectively which meets FEMA guidelines relating to the NFIP.

8.2.3. Wave Overtopping

Wave overtopping analysis for this report is based upon the new Corps of Engineers publication EC 1110-2-6067, *USACE Process for the National Flood Insurance Program Levee System Evaluation,* dated 30 July 2009 and EM 1110-2-1100, Coastal Engineering Manual, dated 30 April 2002. In the EC, it is stated that the maximum required freeboard will be the larger of the 1% chance flood elevation with 95% assurance, or the required freeboard based upon wave analysis added to the 1% chance flood still-water elevation. For this wave overtopping analysis, the deterministic approach outlined the in the EC was applied.

Wind speed data was not available for the City of Vincennes, so an extreme fastest mile wind speed dataset for Evansville, IN, located to the south of Vincennes, for the time period of 1941-1984 was downloaded from the Information Technology Laboratory at the National Institute of Standards and Technology (NIST). A Type I Gumbel Distribution was performed on this data set following directions from NIST. The 100-year fastest mile wind speed determined from this distribution was approximately 67 mph. Using conversion factors from EM 1110-2-1100 Part II Chapter 8 Table II-8-7, the fastest mile wind speed was converted to the 100-year 1-hour average wind speed of roughly 53mph.

A map of the area was then created using ArcGIS, showing contours, the location of the levee, and the 1% annual chance floodplain. A point near the center of the levee was chosen and fetch radials were drawn from the levee to the 1% annual chance flood elevation at intervals of 5 degrees.

The Automated Coastal Engineering System (ACES) program, part of the Coastal Engineering Design and Analysis System (CEDAS) 4.0 suite of programs, was utilized to determine the significant wave height, H_s. Significant wave heights for several combinations of wind durations and directions were calculated. Ultimately, a 30-minute duration and wind direction of 30 degrees resulted in the highest significant wave height of 2.26 feet with a wave period, T_p, of 2.78 seconds.

Using the results from ACES, parameters for EM 1110-2-1100 Equation VI-5-24 were then calculated and the equation was solved for required freeboard for several different overtopping rates. These results are presented in Table 8.2-2 below. According to EC 1110-2-6067, the maximum acceptable value of average wave overtopping for an unarmored earthen levee is 0.1 cfs/ft. However, emerging data suggests that this value is extremely conservative. The true value may be as high as 1.0 cfs/ft or more. For an overtopping rate of 0.1 cfs/ft, 1.9 feet of freeboard is required on the Vincennes Sound Reach. This level of freeboard is available along the length of the levee in the vicinity of the City of Vincennes.

Table 8.2-2 Required Freeboard by Overtopping Rate

Overtopping Rate, Q (cfs/ft)	**Required Freeboard (ft)**
1.0	0.6
0.1	1.9
0.01	3.2
0.001	4.5

8.2.4. Interior Drainage

Drainage of storm water from the floodplains within the leveed area is impeded by the presence of the levees and floodwalls along the Vincennes Sound Reach. Flooding that occurs from the drainage impeded water was analyzed for this study with the resulting impacted floodplain included on the digital mapping. Above ground ponding was only a concern at the City Ditch Pump Station in this study. Coincident Frequency Analysis was deemed unnecessary at the City Ditch outlet because its location is so far removed from the City of Vincennes that ponding at the outlet should not threaten the city. For the City Ditch outfall of the Vincennes, Indiana flood protection system a single rainfall event was modeled. This event, a 1% annual chance exceedance 24-hour duration storm, was considered during low river stage when the gravity outlets were open (gravity conditions) and during high river stage when the gravity outlets were closed (blocked conditions). The performance of the pump at this location was not considered.

The computer program HEC-HMS (Hydrologic Modeling System) developed by HEC (Hydrologic Engineering Center) was used for this analysis. Several types of data were required for the analysis. A storage-area curve was needed for the HMS model. A relationship between storage and area for Vincennes was taken from a 1985 historical flood. Two data points were added to this data by linearly interpolating beyond the highest values in the dataset. Hypothetical frequency rainfall was obtained from NOAA Atlas 14 for Vincennes, Indiana. This rainfall was used to generate runoff hydrographs for the subbasins throughout the City Ditch drainage area. The drainage area was separated into 4 subbasins ranging in size from 1800 acres to 4700 acres. Runoff was determined using SCS Curve Number method and was routed through each subbasin and through the gravity outlet at the levee. Interior ponding within the City Ditch drainage area was based upon 2-ft contours. Gravity outlet data such as pipe size, material, and invert elevations were obtained from as-built drawings. The highest ponding elevation was 404.2 ft. This occurred when the outlet was blocked. The ponding elevation with an open outlet was 402.1 ft. Ponding at these elevations remained in agricultural areas and did not threaten the City of Vincennes.

All storm drainage through the levee in the immediate vicinity of the City of Vincennes is underground. The storm sewer outlets that were in place prior to the installation of the flood protection project were found to be inadequate to convey the runoff from a 10% chance (10-year) storm without surcharging. The Definite Project Report for the Vincennes Segment states that pumping plants for the project were designed to provide adequate capacity at maximum head for runoff from the 1-hour rainfall depth of 0.40 inch. If the sewer was not adequate to deliver this flow to the pumping plant under maximum surcharge conditions, the surcharge capacity based on the gradient beginning at the point of diversion to the pumping plant was used. Since the sewers are not capable of delivering runoff from a maximum rainfall having 30-year frequency of occurrence coincident with selected pump starting river elevation, the pumping capacity to be provided at minimum head was determined separately for each pumping station.

The Definite Project Report for the Vincennes Segment provided drainage areas, times of concentration, sewer profiles, and calculated pumping capacities for pumping stations at Highland Street, Second Street, Hickman Street, and Perry Street. To verify these capacities, they were recalculated using updated data and computer modeling. The City of Vincennes provided GIS data of the current storm sewer system, including pipe sizes. Inverts were assumed to have remained the same and were taken from Sanitary and Storm Sewer Plans from 1946. The flows at each sewer inlet were calculated from times of concentration and regression equations given in the Definite Project Report. The computer program, StormCAD, was used to model the sewer systems draining to each pump station. The resulting flows confirmed the pump capacities for those four stations.

Data for the St. Clair Street Pumping Station was not included in the Definite Project Report and the Sixth Street Pumping Plant was constructed well after the original project. Pumping capacities for these two stations were verified in a similar fashion as the other four using StormCAD, GIS data provided by the City of Vincennes, storm sewer plans from 1946, and As-Built drawings. Areas and times of concentration were calculated manually. Rainfall intensities were derived from NOAA Atlas 14.

Interior ponding does not appear to be an issue for the City of Vincennes. These analyses show that should interior flooding occur, it would most likely be a result of inadequate storm sewer sizing, not the presence of the levee or pumping capacities.

Table 8.2-3 Vincennes, IN 1% Chance Exceedance Interior Ponding Elevations

Pump Plant Location	Interior Ponding Elevation
Second Street	NA *
Highland Street	NA *
St. Clair Avenue	NA *
College Avenue	NA *
Perry Street	NA *
Sixth Street	NA *
City Ditch	404.2

* No above ground ponding. All storage within pump plants and storm sewers.

8.2.5. Hydrology and Hydraulic Conclusions

For the Levee System Evaluation related to the Hydrology & Hydraulic analysis, there are certain requirements that must be met. These requirements include freeboard, closure, embankment protection, interior drainage, and operational plan analysis as described in EC 1110-2-6067 and 44 CFR 65.10. Based upon the H&H analysis, the Vincennes Sound Reach meets all FEMA criteria for NFIP purposes with slight modifications and would yield a positive finding.

8.3. Structural Evaluation

8.3.1. General Description of Project and Structures

The Vincennes Levee Segment is comprised of the following structures:

- Reinforced Concrete Floodwalls: There is a total of 4,275 l.f. of concrete floodwall. The floodwalls are almost entirely composed of I-Wall excluding a small section of L-Wall.
- Closures: There are seven removable roadway and railroad closures and one service opening on the Vincennes Segment. In order to meet a positive evaluation, the evaluation included the upstream 8 miles of the Brevoort levee; this portion includes two fill and sandbag closures.
- Cast-in-Place Concrete Gatewells: There are 16 concrete gatewells in the Vincennes Segment and one concrete gatewell in the Brevoort Segment of the project.
- Concrete Pump Plants: There are five active pump plants on the Vincennes levee segment and one pump plant from the Brevoort segment.

8.3.2. Closure Devices

8.3.2.1. Introduction and General Description

- Closure Structures: There are seven roadway and railway closure structures on the project. Each structure is either a truss or post and panel closure. The truss closures are comprised of sheeting panels which bear on purlins, and the purlins span across trusses or abutments. Post and panel closures generally have steel members slotted into vertical positions to allow panels to span across each post and/or abutment. The two types of closures systems used on the Vincennes levee system are shown in Figures 8.3-1 and 8.3-2 below from the project O&M Manual. Floodwater loads are transmitted from the sheeting panels to the purlins/posts and then are transmitted to the trusses, the abutments, and/or the concrete sill.
- There is one service closure that is comprised of a one piece bulkhead.
- There is one fill closure and one sandbag closure in the Brevoort portion of the levee system.
- Closure storage vaults: Each of the above listed movable closures are constructed adjacent or near a reinforced concrete vault where the movable closure parts are stored.

Figure 8.3-1 Typical Truss System (Oliphant Drive and B&O Railroad Closures)

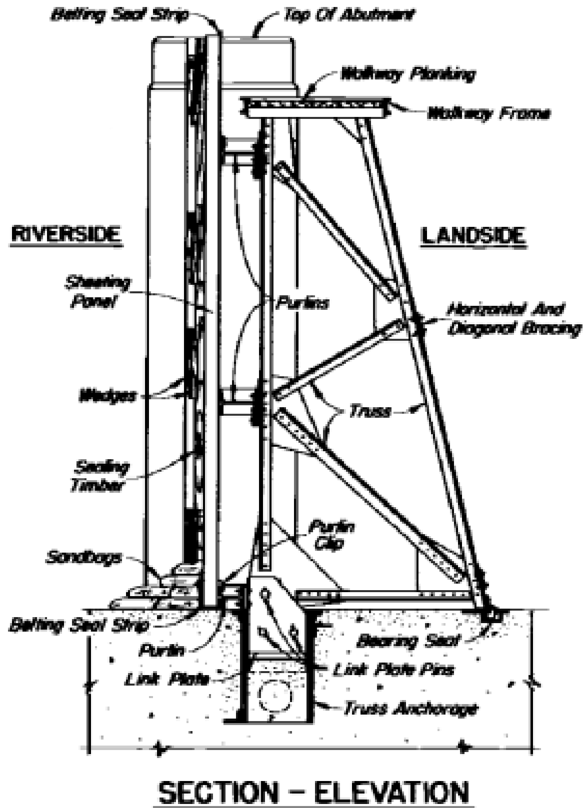
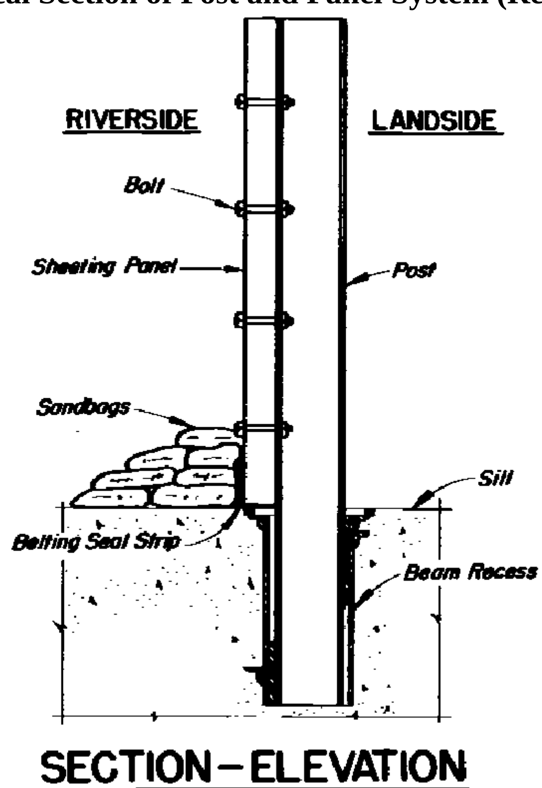


Figure 8.3-2 Typical Section of Post and Panel System (Remaining Closures)



8.3.2.2. Field Inspections of Closures

A detailed site inspection was performed for this evaluation by a team of structural engineers in February 2012. Several follow up inspections have been made to check on the status of items discovered during the original inspection, but most observations were made in February. During the original inspection, the condition of the concrete abutments and sills for each of the floodwall closures was observed and recorded. The storage vaults were also inspected at this time. Detailed discussion of the inspection results are provided in the next sections.

8.3.2.2.1. Sills and Abutments

Flood loads are transferred into the concrete sills and abutments at a floodwall closure. A careful inspection was therefore performed to document the condition of each of these important components of the levee system. During the field inspection, all of the closure abutments were found to be in overall good condition excluding the Second and Niblack Closure. This closure showed evidence of a vehicular impact at the panel slot in the northern abutment (see Photo 8.3-1). Although this would create a complication during installation of the closure, it does not negatively affect the Levee System Evaluation (LSE) since the closure sill is above the 1% chance (100-year) flood elevation with 95% assurance. The defect is considered an O&M item.

The closure sills are generally in fair to good condition with the exception of the Oliphant Drive Closure. The sill was found to be highly deteriorated and is in need of repair (see Photo 8.3-2). A separate site visit was made in December of 2012 to discuss repair options with the sponsor of the Vincennes Segment. Details of the site visit can be found in Appendix M. During the visit, the anchorage recesses were inspected and found to be in good condition (see Photo 8.3-3). Due to the good condition of the recesses, the sill is considered an O&M issue and does not negatively impact the LSE. Other closures and sills with noteworthy O&M Items along with previously mentioned items are listed here:

- The panel slot in the north abutment of the Second and Niblack Closure is in need of repair.
- The closure sill of the Oliphant Drive Closure is in need of rehabilitation.
- The B&O Railroad Closure sill at Station 213+00 has some issues with interior drainage which causes ponding water (see Photo 8.3-4). However, the sponsor has been issued a Letter of No Objection (LNO) under Permit 2012020 to permanently close this closure. Until construction is complete, this is an O&M issue.
- The Portland Avenue, Oliphant Drive, Kimmell Park, and Dollar General Closures are in need of minor repair to the cover plates of the recesses. There are some instances where the bolt heads have broken off and/or the cover plates are missing sections of plate (see Photo 8.3-5).
- The Dollar General Closure at Station 342+16 has some moderate spalling in the sill that is in need of rehabilitation (see Photo 8.3-6).

- The Second and Niblack Closure has a long standing issue which was a result of the railroad company, CSX, raising the railroad tracks and ballast in the closure sill. Due to its current state, the closure is not capable of being properly installed per the O&M Manual. As mentioned previously, the sill elevation is above the 1% chance (100-year) flood with 95% assurance, but the issue needs to be resolved (see Photo 8.3-7).
- The bulkhead in the service opening at Station 263+15 is currently installed until construction commences to permanently close the closure under Permit 2011040. However, during the February 2012 inspection, the bulkhead was installed upside down and was missing several J-bolts. This has since been addressed by the sponsor in September of 2013 and is no longer an issue (see Photo 8.3-8).

There are two non structural closures in the Vincennes Sound Reach, Willow Street and George Rogers Clark Park. The Willow Street closure and the George Rogers Clark Park closure are earthen fill closures. Explanations of both closures and their impact on the LSE are detailed in Section 8.4 of this report.

Photo 8.3-1 Traffic damage at Second and Niblack north abutment

Photo 8.3-2 Severely deteriorated closure sill at Oliphant Drive

Photo 8.3-3 Typical Condition of Truss Anchorage at Oliphant Dr Closure

Photo 8.3-4 Standing Water at B&O Railroad Closure Sill

Photo 8.3-5 Missing Cover Plate Bold Heads, Portland Ave Closure

Photo 8.3-6. Spalling in Dollar General sill and missing Section from Cover Plate

Photo 8.3-7 Sill Condition at Second and Niblack Closure

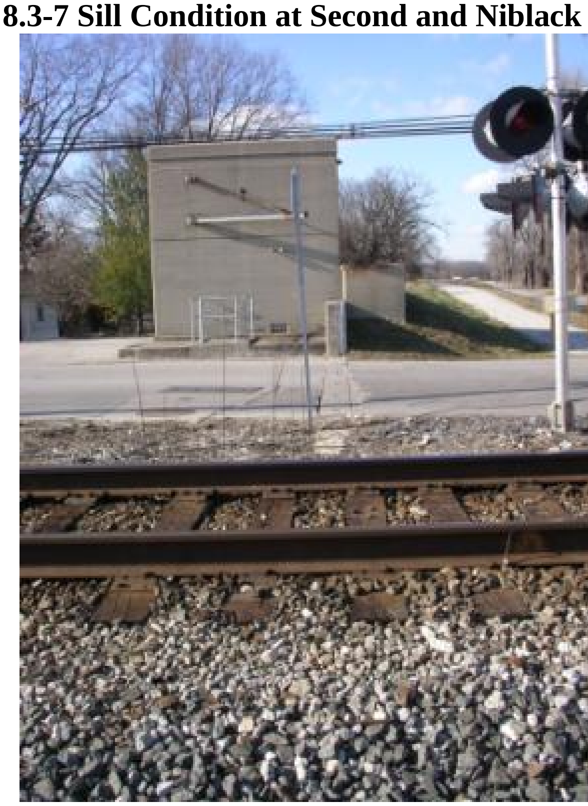


Photo 8.3-8 Service Opening bulkhead at Station 263+15 installed upside down (left), corrected in September of 2013 (right)

8.3.2.2.2. Field Inspections of Storage Vaults

During the detailed on-site inspection, the condition of the closure vaults and closure parts for each of the floodwall closures was observed. Although there were no issues discovered during the inspection that affect a positive LSE finding, there were a few O&M issues concerning the storage vaults that need to be addressed. These issues are summarized below:

- The storage vault roof drainage is inefficient at the B&O Closure (Station 213+00) and has resulted in ponding water. The grading of the roof needs to be investigated and remediated to allow for proper drainage (see Photo 8.3-11).
- Ponding water was observed on the Oliphant Drive Closure vault roof during the February 2012 inspection. During the December 2012 site visit, the roof drainage was shown to have been remediated and is now performing well; see Appendix M for more information. Prior to the remediation, the ponding water was so extensive that the vault floor also had standing water. The closure components, specifically the purlins, have corrosion in the top and bottom flanges and need to be sand blasted and painted per USACE SOP's (see Photo 8.3-12).
- The corrosion in the lintels is causing the brick façade to crack at the Kimmell Park Closure vault. Corrosion and cracks need to be repaired (see Photo 8.3-13).
- The Second Street Pump Station roof, which also houses the Second and Niblack Closure components, is in contact with overhanging telephone lines located on the

roof parapet. Suggest rerouting lines so they are no longer in contact with the roof as a safety precaution (see Photo 8.3-14).

Photo 8.3-9 Typical interior of closure vault

Photo 8.3-10 Typical roof condition of closure vault

Photo 8.3-11 Ponding Water on B&O Closure Vault Roof

Photo 8.3-12 Corrosion in purlins at Oliphant Drive Closure vault

Photo 8.3-13 Cracks in brick façade from lintel corrosion at Kimmell Park Closure vault

Photo 8.3-14 Overhanging lines near Second Street Pump Station roof

8.3.2.3. Closure Installation Exercises

During the 2011 April and 2013 April Floods, numerous closure installations were performed by the sponsor in response to the flood waters as dictated in the Project O&M Manual (including the Willow Street Earthen Fill Closure of the Brevoort Segment). The only closures that were not installed were the Second Street, Dollar General, and George Rogers Clark Park Closures; the river gage did not reach the action stage for these closures. USACE staff were present during the flood event and visually inspected all installed closures (see field notes in Appendix M). Although the O&M Manual required the closures to be installed, only the Oliphant Closure had any flood load on the structure (approximately 10-inches of water). The Oliphant Closure performed as expected with typical leakage and no problems noted. See Table 8.3-1 to see the history of all closure installations and reasoning for assembly. USACE staff required the sponsor to perform a trial installation of the Kimmell Park Closure for LSE purposes. This was due to the fact that during the 2011 Event, the Kimmell Park Closure was only partially installed because of its difficulty and complexity. The Second Street and Dollar General Closure sills are above the 100 year flood elevation.

The local sponsor performed the trial installation of the Kimmell Park Closure on 17 December 2012. On site USACE staff documented the event with pictures and reports from the installation. The detailed reports are included in Appendix M of this report. In summary, all installations demonstrated that the local sponsor has a work force that was able to install these large and complex assemblies in an acceptable manner. These efforts demonstrated the local sponsor's competence, diligence, and high level of interest in preparation for flood events.

During the trial installation of the Kimmell Park Closure, the paint system on the closure components were assessed. The original lead paint primer is in good condition, but it is recommended that the posts be given a new superficial protective paint coating. A paint consultant should be asked for a recommendation as to what product would be best suited to cover the primer and provide a robust protective coating. The selected paint system will then need to be submitted to USACE for approval. Seal installation could also be taken into consideration to reduce potential leakage. Refer to the report in Appendix M for more details.

The Second Street Closure requires some consideration due the situation the railroad company has imposed on the City of Vincennes. CSX Railroad Company made a modification to the closure which caused the railroad tracks and ballast to be raised several feet. As a result, the Second and Niblack closure is no longer able to be installed properly. Because the closure's sill elevation is higher than the 1% chance (100-year) flood elevation with 95% chance assurance, this is considered an O&M item for the time being. However, the sponsor has started the permit process to get the issue resolved.

Table 8.3-1 Closure Installations

Station	Project Section	Closure	Type of Gate	Last Assembly	Remarks
212+94	B1	B&O Railroad "Main Street"	Truss	Apr-11	In response to Flood Event
263+15	A2	Special Monolith 38	Bulkhead	Installed	Permanently in place
274+03	A2	Portland Avenue	Post and Panel	Apr-11	In response to Flood Event
287+68	A1	Kimmel Park	Post and Panel	Dec-12	Installed at the request of USACE for the LSE
306+60	A1	Oliphant Drive	Truss	Apr-11	In response to Flood Event
338+21	A1	Second Street "2nd and Niblack"	Post and Panel	Jun-10	Partially installed due to railroad interference
342+16	A1	"Dollar General"	Post and Panel	-	-
344+50	A1	Sixth Street	N/A	N/A	Sill Raised, Closure Eliminated
1137+57	Brevoort	George Rogers Clark	Sandbag	-	-
1134+85	Brevoort	B&O Railroad "Willow Street"	Fill	Apr-11	In response to Flood Event

8.3.2.4. Flood Performance

Many high-water events have occurred since the completion of the Vincennes Segment in June 1962 and the Brevoort Segment in September 1947, including the most recent event in the spring of 2013. The City of Vincennes officials were not aware of any closure problems that occurred during these events and the USACE staff did not note any issues in the most recent event. For more information on past events, see Section 7.2 of this report.

8.3.2.5. Analysis of Closures

Table 8.3-2 below lists all of the roadway and railway closures on the project. A records search did not reveal any design calculations for any of the closures. For this study, the closures with sills below the 1% chance (100-year) flood elevation with 95% chance assurance were required to be structurally evaluated for that flood loading. The elevation used for the analysis varied by closure, but ranged from 426.21 to 426.81 feet NAVD88. Closure structures were evaluated per the steel design methods of EM 1110-2-2105, *Engineering and Design of Hydraulic Steel Structures*. More detailed analysis results can be found in Appendix H.

A total of seven closures on the Vincennes Sound Reach have sill elevations below the threshold elevation. One closure is a service opening, two closures are either fill or sandbag closures (analysis results in Section 8.4), and the remaining four are for roadways or railroads. These four closures in addition to the service opening were evaluated using the structural software RAM Elements; see Appendix H. For loading associated with the 1% chance (100-year) flood elevation with 95% chance assurance, all of the evaluated closures met the requirements for EM 1110-2-2105 *Engineering and Design—Design of Hydraulic Steel Structures* and EM 1110-2-2705 *Structural Design of Closure Structures for Flood Control Projects*.

Table 8.3-2 Closure Structure Analysis

Station	Project Section	Closure	Opening Length (ft)	Type of Gate	Sill Elev. (ft) NAVD	100-yr Flood Elev., % Conf.	Need to Analyze	Remarks
212+94	B1	B&O Railroad "Main Street"	33.83	Truss	420.50	426.24	Yes	Meets USACE Requirements
263+15	A2	Special Monolith 38	6.00	Bulkhead	421.60	426.30	Yes	Meets USACE Requirements
274+03	A2	Portland Avenue	18.00	Post and Panel	421.80	426.64	Yes	Meets USACE Requirements
287+68	A1	Kimmel Park	107.00	Post and Panel	423.00	426.75	Yes	Meets USACE Requirements
306+60	A1	Oliphant Drive	43.83	Truss	421.00	426.81	Yes	Meets USACE Requirements
338+21	A1	Second Street "2nd and Niblack"	80.41	Post and Panel	426.83	426.81	No	N/A
342+16	A1	"Dollar General"	23.83	Post and Panel	427.00	426.81	No	N/A
344+50	A1	Sixth Street	85.50	N/A	N/A	426.81	No	Sill Raised Closure Eliminated
1137+57	Brevoort	George Rogers Clark	N/A	Sandbag	423.93	426.24	Yes	See Geotechnical Section 8.4
1134+85	Brevoort	B&O Railroad "Willow Street"	16.00	Fill	419.93	426.21	Yes	See Geotechnical Section 8.4

8.3.2.6. Flood Closures Conclusions

The four closures and one service opening that would experience flood loading during a 1% chance (100-year) flood elevation with 95% chance assurance are judged to be performing well and the evaluation team has a high level of confidence that the City of Vincennes would be at very low risk from flooding as a result of any closure issue. The conclusion is based on: 1) An evaluation of the structural drawings for the closures; 2) the results of the structural analyses discussed above; 3) Observations of the installation; and 4) Field inspections of gate sills, abutments, and gate components.

8.3.3. Floodwalls

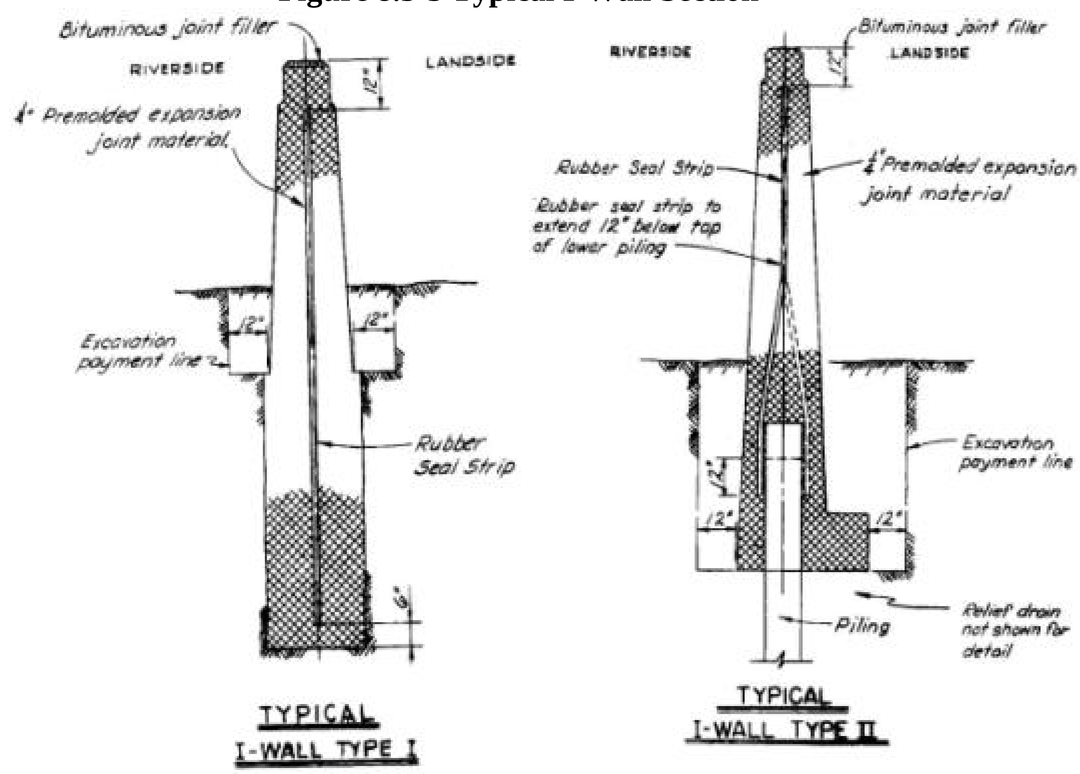
8.3.3.1. Introduction and General Description

The Vincennes Segment has a total of approximately 4,275 l.f. of concrete floodwall. Excluding 40 l.f. of L-Wall, the project is nearly entirely composed of I-Wall. This includes 130-feet of "transitional" I-Walls, which are constructed to transition from a full height floodwall or closure abutment to either high ground or a high levee section. Transitional I-Walls do not have a consistent height and may be stepped below finished grade.

There are three kinds of I-Walls on the project: Type 1, Type 2, and Modified Type 2 (see Figure 8.3-3 below). All Type 2 I-Walls are founded on sheet piling. USACE does not consider Type I walls to be "I-Walls' but rather considers them gravity structures. The method of analysis and assessment for Type 1 I-Walls is therefore different from Type 2 I-Walls.

- Reinforced Concrete Floodwalls: There is a total of 4,275 l.f. of concrete wall.
- Reinforced Concrete Sheet Pile I-Walls: There is approximately 4,200 l.f. of I-Wall on the Vincennes Segment, including; 2,310 l.f. of Type 1 I-Wall in Section A, Part 1 and in Section B, Part 1. In Section A, Part 2, there is approximately 1,890 l.f. of Type 2 I-Wall. In Section A, Part 1 there are 22 monoliths at approximately 20-feet length each, ranging from 3.5-feet to 5.5-feet in height. Section A, Part 2 has 99 monoliths approximately 19.5-feet in length, ranging from 9 to 10-feet in height. Section B, Part 1 includes 86 monoliths at 20-feet lengths ranging from 3.5 to 5-feet in height.

Figure 8.3-3 Typical I-Wall Section



- Reinforced Concrete L-Walls: There is a total of 41 l.f. of L-Wall at the Kimmell Park Closure (two monoliths). These walls measure approximately 8-feet from the lower sill elevation to the top of wall and tie into the levee on either end.

8.3.3.2. Field Inspections of Floodwalls

This project has three sections of floodwalls; Section A, Parts 1 and 2 and Section B, Part 1. All components of the concrete floodwalls in the project had their conditions assessed during the inspections that took place in February 2012. In general, the floodwall was observed to be in good to very good condition in Section A, Parts 1 and 2 (see Photos 8.3-15 and 8.3-19). None of the monoliths are tilted or rotated and no monoliths show any signs of lateral movement. A detailed “arms length” inspection was made of the top of wall using a manlift. Cracking, efflorescence, and discoloration were observed at many locations similar to other USACE floodwall projects. Many monoliths also have extensive cracking at the top (see Photo 8.3-20). Certainly freeze-thaw damage is already occurring in many locations. It is recommended that all cracks greater than 0.02-inches in width are crack injected per USACE SOP and a waterproof sealant be applied on the top of the wall to help prevent further damage from occurring. However, the cracking and damage observed was limited to the upper portions of the taller wall monoliths and thus does not negatively impact the LSE. A few O&M issues were noted that specifically applies to Section A, Parts 1 and 2, and are listed below along with previously mentioned items:

- Recommend applying a waterproof sealant on top of walls to prevent further freeze-thaw damage from occurring. General spalling/delamination/crack repairs should be made in accordance with standard USACE SOP’s throughout the project
- Encroachments: In Section A, Part 1 there is a stockpile of material stored on the landside of the floodwall at approximate Station 339+25 that needs to be removed to allow access in a flood event (see Photo 8.3-17). Utility poles are located on both sides of the floodwall at approximate Station 343+75; the poles could provide a seepage path if the soil profile below has a layer of free draining soil. Refer to Section 8.4 to see if utility poles require relocation. In Section A, Part 2 a utility line goes up and over the floodwall near the downstream abutment of the Portland Avenue Closure (see Photo 8.3-21). However, this was found to be a permitted item in the permit records, no action is necessary.
- Vegetation: In Section A, Part 2 there is heavy plant growth on the landside of the floodwall (see Photo 8.3-22). Vegetation is growing in the joints to the full height of the wall as well as near the bottom of the wall in several areas. On the riverside of the wall, there was evidence that the sponsor has made attempts to control the vegetation as indicated by the numerous tree stumps that were found in various locations (see Photo 8.3-23). Vegetation needs to be cleared out to allow for visual inspections during major events and stumps are recommended to be removed to ensure that the root system will not interfere with the floodwall foundation.
- Animal Burrows: Animal burrows were found in several areas on both sides of the floodwall in Section A, Part 2 (see Photo 8.3-24). The infestation in this area needs to be controlled to prevent a burrow from creating a seepage path below the floodwall; some burrows were directly adjacent to the floodwall, exposing the

wall up to 1.5 feet deep. Existing burrows are required to be repaired by approved USACE methods.

- The upstream abutment at the Portland Avenue Closure is missing a pedestrian barrier at the top of the wall where the wall transitions into the levee (see Photo 8.3-25). This needs to be replaced to prevent pedestrian access to the wall and to avoid any injury.

The condition of the floodwalls in Section B, Part 1 in February 2012 was quite different in comparison to the remaining project. It is suspected that during construction, a poor aggregate choice was made that resulted in significant deterioration of the concrete and caused numerous cracks, major spalls, and exposed reinforcement (see Photos 8.3-26 thru 8.3-28). The sponsor has made attempts to repair a few monoliths in the past with crack injections (see Photo 8.3-29). The repair prototypes were performed by F.E. Gates and are generally performing well. In July of 2013, a permitted repair commenced on the problematic I-Walls identified by Banning Engineering (Permit 2011034). The existing concrete was removed to sound concrete and then cast up to the original top of wall elevation (see Photo 8.3-30). Given the difficulty of construction, it was decided that the original method of repair would be more cost beneficial. The remaining walls were crack injected and sealed in October of 2013 (see Photo 8.3-31). Section B, Part 1 also had an animal burrow problem which frequently occurred on the riverside of the floodwall. Burrows are required to be repaired by approved USACE methods. Similar to the other sections of floodwall, Section B, Part 1 also has a few noteworthy encroachments. A preexisting monument base occurs at approximate Station 214+00 (Photo 8.3-26), utility poles were found on the landside of the floodwall, and a few pedestrian overlooks were installed by the previous mayor (see Photo 8.3-32). These overlooks could hinder some access during an event and the utility poles could provide a seepage path depending on the soil conditions below (see Section 8.4). The monument base appears in the project's As-Builts and has therefore been accounted for in the original design and is not of any concern for this inspection.

One other O&M issue to note is that the joint filler material and exterior joint sealant is deteriorating throughout the project and even missing in some instances (see Photo 8.3-18). It is no longer serving its original purpose and therefore needs to be replaced throughout the project. Any program to accomplish this work should utilize means, methods, and materials approved by USACE LRL.

A unique feature about the Vincennes Segment is the pre-existing floodwall prior to federal construction of the Vincennes Segment. The existing floodwall borders the river banks on the riverside of the floodwall in Section B, Part 1 and the landside levee toe of Section A, Part 2. In Section A, Part 2 it begins at the Portland Avenue Closure and follows the road towards the Kimmell Park Closure and then ends at the Oliphant Drive Closure. The existing floodwall in Section A, Part 2 is not of concern due to its relatively good condition and location in relation to the Vincennes levee system. However, Section B, Part 1 warranted an inspection because of a concern that failure in the wall could impact the project floodwall. The river bank existing floodwall was constructed as a retaining wall and is in poor to fair condition. In many locations there were spalls with exposed reinforcement and cracks. Many pilaster caps also exhibited the same deterioration of concrete (see Photo 8.3-33). No significant rotation was noted in the wall, but the minor amount of rotation observed should be monitored. After the inspection, a slope stability analysis was performed on the riverside floodwall and confirmed that failure of the river wall could impact the Vincennes Segment floodwall. It is recommended that the riverside existing floodwall be inspected on a routine basis in conjunction with the Periodic Inspection every five years. Defects should be monitored and repaired if they worsen.

Photo 8.3-15 Typical good condition of floodwall in Section A, Part 1

Photo 8.3-16 Minor surface damage on floodwall in Section A, Part 1

Photo 8.3-17 Fill encroachments on landside of wall in Section A, Part 1

Photo 8.3-18 Missing joint filler in floodwall in Section A, Part 1

Photo 8.3-19 Typical Wall Condition in Section A, Part 2

Photo 8.3-20 Localized crack in top of wall in Section A, Part 2

Photo 8.3-21 Utility encroachments on floodwall in Section A, Part 2 (Permitted)

Photo 8.3-22 Typical vegetation in joints of floodwall in Section A, Part 2

Photo 8.3-23 Typical tree stumps on riverside of floodwall in Section A, Part 2

Photo 8.3-24 Numerous animal burrows on riverside of Section A, Part 2 floodwall

Photo 8.3-25 Missing pedestrian barrier near Portland Avenue Closure

Photo 8.3-26 Poor condition of floodwall monolith in Section B, Part 1

Photo 8.3-27 Poor condition of floodwall monolith in Section B, Part 1

Photo 8.3-28 Severe spalling causing exposure of reinforcement in Section B, Part 1

Photo 8.3-29 Monolith repair performing well in Section B, Part 1

Photo 8.3-30 I-Wall repair in Section B, Part 1, remove and replace method

Photo 8.3-31 Completed I-Wall repair in Section B, Part 1, crack injection

Photo 8.3-32 Pedestrian overlook on landside of floodwall in Section B, Part 1

Photo 8.3-33 Typical condition of riverside floodwall in Section B, Part 1

8.3.3.3. Stability and Strength Requirements

The criteria used to analyze the flood wall are the same criteria that would be used to design them.

The criteria for analysis of the L-wall portions of the project are based on EM 1110-2-2502, *Retaining and Flood Walls* and EM 1110-2-2100, *Stability Analysis of Concrete Structures*. The flood wall sections are considered critical structures and the 100-year flood case is, by definition, an unusual load condition and the soil information was considered to be ordinary. The following table shows the requirements.

Table 8.3-3 L-Wall Criteria

Failure Mode	Requirement
Overturning	Minimum 75% of Base in Compression
Sliding (taken over entire width)	Factor of Safety ≥ 1.50
Flotation	Factor of Safety ≥ 1.20
Bearing Capacity	Factor of Safety ≥ 3.00
Strength Design of Concrete	Applicable Code Requirements

I-walls were evaluated using the USACE ETL 1110-2-575, *Evaluation of I-Walls*. The walls were analyzed using the 1% chance (100-year) flood elevation with 95% chance assurance criteria for rotational stability and deformation control dependent on the soil information.

Soil information for the Vincennes Segment was obtained through borings performed by the sponsor for evaluation of the Type II I-Walls. The borings supported analysis of three different profile sections for the analysis of the Section A, Part 2 floodwalls. A predominantly clay section, a clay and sand mix, and a sand section was used for the analysis. An average cohesion (c) value for the undrained condition and average effective angle of internal friction (φ’) for the drained condition were evaluated from the soil information. Conservative values were used in the analyses. See Table 8.4-6 and Table 8.4-7 for the soil values used in this analysis.

Alternatively an evaluation can be performed to determine if the structural elements are “Fit for Purpose,” similar to the methodology proposed in ERDC TR-07-15, "Fitness-for-Purpose Evaluation of Hydraulic Steel Structures", published in November 2007. The basis for a Fitness for Purpose analysis is that hydraulic structures may have fabrication defects that, while not allowed based on stringent interpretation of the project specifications, may not in fact be harmful to the structure. Similarly while a structural flood wall element that was not designed and constructed strictly in accordance with current standards may not be expected to meet all of those standards, shortcomings in regard to those standards may not actually be harmful to the performance of the structure during a flood event. The analysis considers a particular structural component to be adequate as long as the conditions which would lead to failure are not reached. The method of this analysis is ultimately left to the judgment of the Engineer.

8.3.3.4. Structural Analysis

8.3.3.4.1. I-Walls

There is approximately 2,310 l.f. of Type 1 I-Wall in Section A, Part 1 and in Section B, Part 1. These walls range in height from 3.5-feet to 5.5-feet. In Section A, Part 2, there is approximately 1,890 l.f. of Type 2 I-Wall ranging in height from 9 to 10-feet. Type 1 I-Walls are considered gravity structures and were analyzed with the same criteria as L-Walls. Type 2 I-Walls were analyzed using soil-structure interaction software, CWALSHT, to evaluate whether or not they meet all the criteria mentioned in ETL 1110-2-575. All of the monoliths analyzed meet all applicable stability and structural criteria for the imposed flood loads. A summary of these results can be found below in Table 8.3-4 and a more detailed analysis can be found in Appendix I.

Table 8.3-4 Type 2 I-Wall Analysis

Station	Height	Ground Height	100-Year Flood Elevation	As-Built Sheet Pile Embedment	Drained Conditions		Undrained Conditions	
					Req'd Embed	FS	Req'd Embed	FS
258+50	8.97	421.0	426.7	15.0	13.88	1.62	3.19	7.05
262+20	9.00	421.0	426.7	15.0	13.10	1.72	4.67	4.82
271+75	9.23	421.0	426.7	15.0	11.93	1.89	-	-

8.3.3.4.2. L-Walls

There are 41 l.f. of L-Wall (two monoliths) with a height of approximately 8-feet. These monoliths are transitional monoliths and transition the levee system from levee to the Kimmell Park Closure. The L-Walls were analyzed using criteria from EM 1110-2-2502 and EM 1110-2-2100. One monolith was chosen for analysis given the symmetric similarities of the two. The analysis revealed that the monolith meets all applicable stability and structural criteria for the imposed flood loads (see Table 8.3-3 for criteria). The detailed L-Wall analysis can be found in Appendix I.

8.3.3.5. Floodwall Conclusions

The evaluation team has a high level of confidence that the City of Vincennes would be at very low risk from flooding as a result of any floodwall stability or structural issue. The conclusion is based on: 1) An evaluation of the structural drawings for the I-Walls and L-Walls; 2) the results of the structural analyses discussed above; 3) the performance of these monoliths during various floods; 4) Field inspections of the entirety of the project's floodwalls; and 5) the adequate level of maintenance observed during the February 2012 inspections. To maintain the low risk from flooding, it is recommended that the existing riverside retaining wall be inspected on a routine basis in conjunction with the Periodic Inspection.

8.3.4. Gate Structures

There are 16 cast-in-place concrete gate structures and sluice gates on the Vincennes Segment and a gatewell and sluice gate at the sanitary treatment plant in the Brevoort Segment that were inspected for LSE purposes. These structures are discussed in detail below.

The gatewell structures were inspected to observe the condition of the concrete. The majority of the concrete on the gatewells are in good condition, with minimal cracking or spalling (see Photo 8.3-34). The exceptions are Gatewells #9, #10, #13, and #14 at approximate stations 239+16, 239+21, 237+60, and 237+45, respectively. These gatewells have significant deterioration in the upper portion of the concrete structure (see Photos 8.3-35 and 8.3-36). In some cases the deterioration has potentially affected the cover plate recesses, especially in Gatewells #3, #10, and #13 (see Photo 8.3-37). However, these issues will not negatively affect the LSE as the overall stability of the structure is not compromised and the integrity of the gates is not in danger. These issues are considered O&M items and are recommended for repair in compliance with USACE guidelines and standard operating procedures.

During the flood event in 2011, Gatewell #5 was noted to have been left open with the operator removed. This configuration caused backwater flooding in 2005 and 2008 and was recommended for remediation in the after action flood report. The gatewell has been properly decommissioned under Permit Number 2012024 and should no longer cause any problems.

All of the sluice gates were operated and checked to ensure a proper seal and positive closure. Details of this portion of the inspection can be found in Section 8.5.

For this LSE, no structural analysis was performed for the gate structures or sluice gates. The gate structures and sluice gates are judged to be well performing and the evaluation team has a high level of confidence that the City of Vincennes would be at very low risk from flooding as a result of any sluice gate issue. The conclusion is based on: 1) An evaluation of the structural drawings for the gate structures; 2) performance during past flood events; 3) the operability demonstrated during the 2012 inspection.

Photo 8.3-34 Gatewell #11 exhibiting typical good condition of concrete

Photo 8.3-35 Gatewell #9 exhibiting poor condition of concrete, condition is similar in Gatewells #10 and #13

Photo 8.3-36 Gatewell #14 showing cracks and loose concrete near top of structure

Photo 8.3-37 Deterioration has affected the cover plate recesses in Gatewell #10

8.3.5. Pump Plants

There are six active concrete pump stations on the Vincennes Segment – Perry Street, College Street, St. Clair Avenue, Highland Street, Second Street, and Sixth Street, as well as the City Ditch Pump Station on the Brevoort Segment were assessed for LSE purposes. The Perry Street, Second Street, Sixth Street, and City Ditch Pump Plants are designed and constructed to be integral parts of the floodwall or levee.

8.3.5.1. Field Inspection of Pump Plants

All seven pump plants were inspected as part of the site inspection in February 2012 and a follow up inspection was performed on the Perry Street Pump Plant in December 2012. Discussions of those inspections, including a detailed discussion of the condition of some of the plants' components, are found in the sections below.

8.3.5.1.1. Perry Street Pump Plant

The Perry Street Pump Plant is located at Station 227+56. The February 2012 field inspection found this pump plant to have the worst concrete condition out of all pump plants on the project. The concrete at the operating level of the building was severely deteriorated in several areas (see Photos 8.3-40 and 8.3-41). Most concern came from the loss of concrete near the anchorages of several handrails, which would have been considered a life safety issue (see Photo 8.3-39). Fortunately, the sponsor performed extensive repairs on the concrete during the interim prior to the December 2012 inspection, and the condition of the concrete has vastly improved (see Photos 8.3-38, 8.3-39, 8.3-40, 8.3-41). The concrete condition is no longer considered an issue, but two other O&M items still remain:

- Corrosion was observed in the lintel over the doorway and is recommended to be cleaned and painted to prevent the condition from worsening and affecting the brick façade (see Photo 8.3-42).
- Brick façade failures were noted below the parapet and should be monitored (see Photo 8.3-43).

These issues are strictly considered O&M in nature and do not negatively impact the LSE as they do not affect the operation of the pump plant.

During the February 2012 field inspection, the pump plant roofs were inspected by means of an available man lift. The recently replaced roof of the Perry Street Pump Plant is performing well with no noteworthy issues.

Photo 8.3-38 Concrete around Perry Street foundation and stairs, before and after

Photo 8.3-39 Severe spalls at Perry Street handrail anchorages, before and after

Photo 8.3-40 Operating floor concrete condition from below, before and after

Photo 8.3-41 Concrete condition of Perry Street operating floor, before and after

Photo 8.3-42 Corrosion of lintel over doorway at Perry Street Pump Plant

Photo 8.3-43 Brick façade failure below parapet of Perry Street Pump Plant

8.3.5.1.2. College Street Pump Plant

The College Street Pump Plant is also known as the Hickman Street Pump Plant and is located at Station 294+03. The February 2012 field inspection of this pump plant found three O&M items to take into consideration, but do not prevent a positive LSE finding at this time.

- Corrosion of the lintel over the doorway is causing the brick veneer to crack. The lintel can be cleaned and painted to further corrosion (see Photo 8.3-44).
- Settlement of the building has caused cracks in the building corners at the foundation level and in the joints of the brick veneer. Cracks should be monitored.
- Paint failures in the interior paint system throughout the building are causing a thin layer of brick and paint to peel off. If paint chips continue to be a nuisance, the paint could be removed and the wall repainted (see Photo 8.3-45).

Photo 8.3-44 Corrosion of lintel over the doorway at the College Street Pump Plant

Photo 8.3-45 Typical paint failures on interior brick walls of College Street Pump Plant

8.3.5.1.3. St. Clair Avenue Pump Plant

The St. Clair Avenue Pump Plant is located at Station 270+00. The February 2012 field inspection of this pump plant found a few O&M issues that are recommended for repair, but does not affect the LSE at this time.

- The roof drains appear to be clogged as noted by the vegetation growing inside. Vegetation is recommended to be cleared to allow for proper drainage. Also, the roof membrane has begun to fail and should be considered for replacement in the future (see Photo 8.3-46).

Photo 8.3-46 St. Clair Avenue roof drain and membrane in early stages of failure

8.3.5.1.4. Highland Street Pump Plant

The Highland Street Pump Plant is located at Station 314+00. The February 2012 field inspection of this pump plant found four O&M issues that require attention, but do not negatively affect the LSE at this time.

- A few interior cracks were observed at the corners of a roof opening in the Highland Street Pump Plant (see Photo 8.3-47). These cracks could potentially allow water to enter the pump plant. If desired, the cracks could be repaired using pressure injected concrete to fill in the cracks and prevent leakage. Any program to accomplish this work should utilize means, methods, and material approved by USACE LRL.
- Corrosion was observed in the lintel over the doorway and is recommended to be cleaned and painted to prevent the condition from worsening and affecting the brick façade (see Photo 8.3-48).
- A large section of brick veneer is loose near the bottom of the door frame (see Photo 8.3-49). Recommend securing loose portion of brick.
- The roof membrane has begun to fail and should be considered for replacement in the near future (see Photo 8.3-50).

Photo 8.3-47 Cracks in Highland Street Pump Plant roof at opening

Photo 8.3-48 Corrosion of lintel over Highland Street Pump Plant doorway

Photo 8.3-49 Loose brick section near bottom of Highland Street Pump Plant doorway

Photo 8.3-50 Highland Street Pump Plant roof membrane has begun to fail

8.3.5.1.5. Second Street Pump Plant

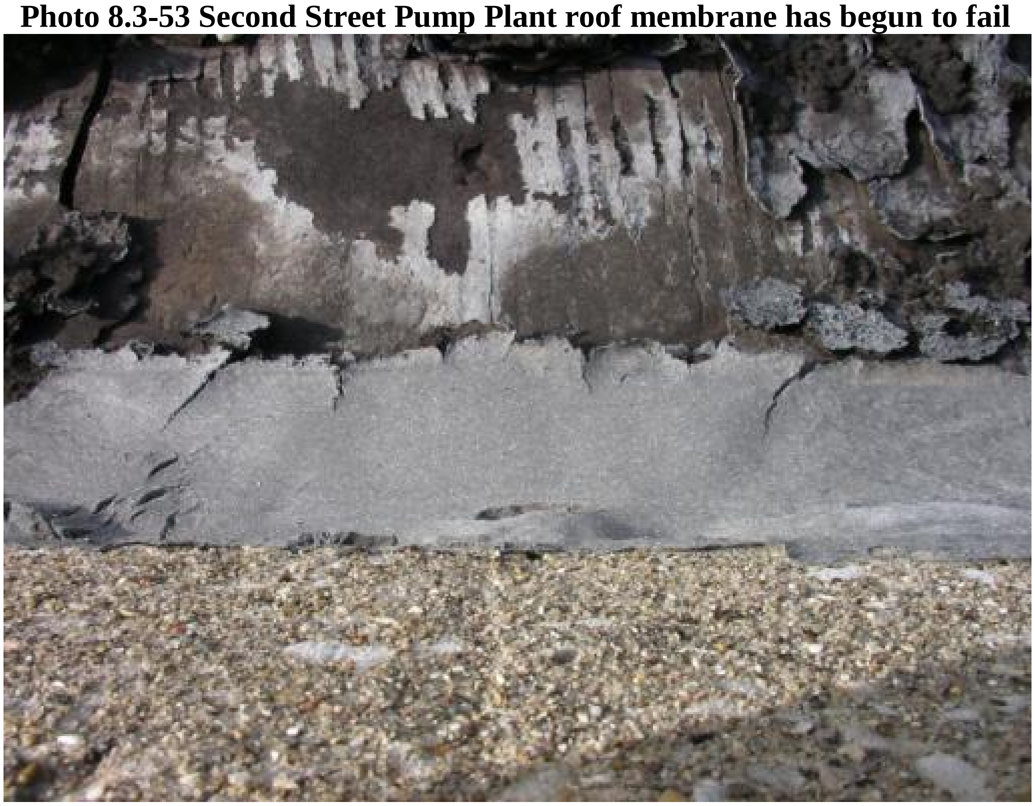
The Second Street Pump Plant is located at Station 337+59. The February 2012 field inspection of this pump plant found three O&M issues that require attention, but do not prevent a positive LSE finding at this time.

- A crack was found at the midspan of the crane corbel (see Photo 8.3-51). The crack is recommended for repair using pressure injected concrete to fill the crack. Any program to accomplish this work should utilize means, methods, and material approved by USACE LRL.
- Third party overhanging lines are in contact with the parapet on the Second Street Pump Plant (see Photo 8.3-52). Recommend rerouting the lines to avoid contact and to prevent any potential safety issues.
- The roof membrane has begun to fail and should be considered for replacement in the near future (see Photo 8.3-53).

Photo 8.3-51 The interior corbel for the overhanging crane has a crack at the midspan

Photo 8.3-52 Overhanging lines in contact with the Second Street Pump Plant parapet

Photo 8.3-53 Second Street Pump Plant roof membrane has begun to fail



8.3.5.1.6. Sixth Street Pump Plant

The Sixth Street Pump Plant is a submersible pump station located at Station 314+00. The February 2012 field inspection of this pump plant did not find any noteworthy structural issues. For more information, see Section 8.5 for details regarding the pump plant operation.

8.3.5.1.7. City Ditch Pump Plant

The City Ditch Pump Plant is located in the Brevoort Segment, but an inspection was performed for LSE purposes. The February 2012 field inspection of this pump plant found three O&M issues that require attention, but do not affect the LSE at this time.

- The pump plant is located in a remote location and is prone to vandalism. Evidence of persons vandalizing and damaging the structure was observed (see Photo 8.3-54). If possible, recommend taking measures to prevent access to the public.
- The corners of the building have cracks at the foundation. Settlement cracks should be monitored in future inspections. Also monitor the minor cracks observed in the wingwalls of the discharge pipes.
- The platform above the trash rack has had its handrails removed for ease of debris removal from the racks (see Photo 8.3-55). Recommend installing a safety chain to prevent falling and to avoid hindering maintenance efficiency.

Photo 8.3-54 Damage on City Ditch Pump Plant exterior wall caused by trespassers

Photo 8.3-55 Missing handrail on City Ditch platform above trash rack

8.3.5.2. Stability Analysis of Pump Plants

The Perry Street, Second Street, Sixth Street, and City Ditch Pump Plants are structures designed as integral parts of the levee system. Therefore, the stability of these plants was analyzed with respect to global stability of the structure.

The criteria used to analyze pump plant stability are the same criteria that would be used to design it today. Alternatively, an evaluation could have been performed to determine if the structure is "Fit for Purpose," similar to that described in the floodwall portion of this report.

The stability of these stations was analyzed in accordance with EM 1100-2-2100, *Stability Analysis of Concrete Structures*, dated 01 December 2005. This document provides guidance for the evaluation of many types of structures and includes specific guidance in regards to pumping plants. The safety factors provided in the referenced manual are based on the assumption that for critical and normal structures, the strength of the materials in the foundation and structure has been conservatively established through explorations and testing (see Table 8.3-5). When the stability of an existing structure is in question, a phased, systematic approach to evaluating stability should be performed before any remedial actions are taken to improve stability.

Table 8.3-5 Pump Plant Analysis Criteria

Failure Mode	Requirement
Overturning	Minimum 75% of Base in Compression
Sliding	Factor of Safety ≥ 1.50
Flotation	Factor of Safety ≥ 1.20
Bearing Capacity	Factor of Safety ≥ 3.00
Strength Design of Concrete	Applicable Code Requirements

The pump plants in question met or exceeded the requirements for sliding, floatation, overturning, and bearing capacity as shown in Table 8.3-6. A more detailed analysis can also be found in Appendix L.

Table 8.3-6 Pump Plant Analysis Results

Pump Plant	Overturning	Sliding	Flotation	Bearing
Perry Street	100%	1.62	1.38	>> 3.0
Second Street	100%	>> 1.50	1.24	>> 3.0
Sixth Street	100%	>> 1.50	1.27	>> 3.0
City Ditch	100%	1.50	1.69	>> 3.0

8.3.5.3. Pump Plant Conclusions

The pump plants are judged to be a well performing component of the Vincennes Sound Reach. The evaluation team has a high level of confidence that the City of Vincennes would be at very low risk from flooding as a result of any structural issue related to the pump plants. The conclusion is based on: 1) An evaluation of the structural drawings for the pump plants; 2) performance of the pump plants during past flood events; 3) the results of the stability analysis performed for this study; and 4) the overall good structural condition of the structures found during the February 2012 inspections.

8.3.6. Condition Assessment of Pipes

The City of Vincennes had condition assessments performed for the storm sewer and sanitary sewer pipes that pass through the levee system in 2008. These assessments were accomplished utilizing Closed Circuit Television (CCTV) tools following the specifications provided by USACE. USACE required that each pipe be coded in accordance with NASSCO's Pipeline Assessment Certification Program (PACP). For pipes that are submerged or partially submerged, sonar technology is required for inspection if dewatering is not possible. Fortunately, the inspection did not encounter a situation where sonar was required. See Appendix K of this report for the inspection notes of the Vincennes Segment condition assessment of pipes. This same appendix includes detailed tables with information about all of the pipes which were rated using the PACP coding system.

USACE conducted a detailed review of the video and the reports of the pipes inspected. The pipes are made of concrete, iron, and vitrified clay. All pipes that crossed through the Vincennes Sound Reach were video inspected and a few issues were found that would affect a positive LSE rating. The sponsor was notified of these issues and remediation was permitted and completed. The defects found are shown below in Table 8.3-7 along with the corresponding permit number for the repair. Since the sponsor is to address all of the issues, the condition of the pipes is not anticipated to hinder a positive LSE rating once repairs are complete.

Table 8.3-7 LSE Items for Pipes

Station	Location/ Description	Diameter	Material	Issue	Action Taken
224+10	MH-64 to Wabash River Outfall	48"	RCP	-Multiple fractures at 16.0 and 20.2 feet into pipe -Longitudinal fracture at 25.9 feet into pipe -Hole with a visible void at 33.9 feet into pipe	Pipe has been sliplined under Permit Number 2011031
227+56	MH-63a	30"	VCP	-Longitudinal fractures at 6.0 and 12.7 feet into pipe -Multiple fractures at 12.7 feet into pipe -Deformation at 12.7 feet into pipe	Pipe has been sliplined under Permit Number 2011035
260+14	Vincennes University	15"	VCP	-Holes with soil visible at 3.2, 12.4, and 26.2 feet into pipe -Multiple fractures at 11.2 feet into pipe -Longitudinal fracture at 12.3 feet into pipe	Pipe and associated gatewell has been abandoned under Permit Number 2011032
270+00	St. Clair GW to Wabash Outfall	66"	RCP	-Hole with soil visible 14.7 feet into pipe	Defective portions of pipe replaced under Permit Number 2011035

The remaining issues found during the assessment of pipes are considered O&M issues because they are either defects that do not affect the structural integrity of the pipes or they are defects outside of the levee system limits. O&M items in nature, do not negatively impact the LSE and most of the identified defects were resolved through sliplining or pipe abandonment. Little action is required by the sponsor for remediation. These defects are summarized in Table 8.3-8 along with the permitted action taken for remediation of the pipes. For pipe report details refer to Appendix K.

8.3.6.1 Pipes Conclusion

The pipes are judged to be well performing and the evaluation team has a high level of confidence that the City of Vincennes would be at very low risk from flooding as a result of any pipe issue. The conclusion is based on: 1) An evaluation of the video inspection of pipes and 2) performance during past flood events.

Table 8.3-8 O&M Items for Pipes

Station	Location/ Description	Diameter	Material	Issue	Action Taken
200+75	MH-66 to Wabash River Outfall	24"	RCP	-Multiple fractures 349.3 feet into pipe	Pipe has been sliplined under Permit Number 2011035
238+78	MH-8 to MH-14	18"	RCP	-Attached deposits from 52.67 to 58.6 feet into pipe	Pipe has been abandoned under Permit Number 2011035
239+12	Wabash Outfall to STR-110	24"	VCP	-Compacted deposits from 6.0 to 32.1 feet into pipe	Pipe has been abandoned under Permit Number 2011035
260+14	Vincennes University to Outfall	15"	VCP	-Root ball at joints from 11.2 to 19.5 feet into pipe	Pipe has been abandoned under Permit Number 2011032
313+90	Highland Station - South Dir	39" x 39"	RCP	-Compacted deposits from 6.0 to 220.5 feet into pipe	-

8.3.7. Structural Conclusion

Once pipe repairs are complete, the Vincennes Sound Reach is expected to meet all Structural requirements for the LSE for the 1% chance (100-year) flood elevation with 95% chance assurance. This conclusion was reached after the USACE LRL Structural Team performed a very detailed assessment of the entire project in close coordination with the local sponsor, the City of Vincennes. This assessment took into account all of the available data, including an assessment of historical records; a study of the sponsor's maintenance and operations practices; observations of emergency flood gate assemblies; a very detailed series of inspections; assessment of the serviceability of the paint systems; structural evaluations; observations of construction operations performed by contractors making repairs to various components of the levee; and a detailed battery of structural stability analyses for the floodwalls. All of the above has been described within this report and its Appendices. The findings of this section are summarized below in Table 8.3-9.

Table 8.3-9 Structural Levee System Evaluation Summary

Closure Devices	All closures meet applicable structural requirements and are well maintained; additionally those that have experienced flood events have records of successful installation and operation. All closure vaults were inspected to assess the condition of the metal closure parts and were found to be in good condition.
Floodwalls	All walls analyzed meet applicable stability and structural criteria and are well maintained; additionally those that have experienced flood events have performed well.
Gate Structures	All gate structures were operated successfully during inspections; additionally the local sponsor provided records demonstrating that they are being well maintained with timely replacement or reconditioning of aged equipment and materials.
Pump Plants	The pump plants that are structurally integral parts of the levee system met or exceeded the requirements for sliding, floatation, overturning, and bearing capacity.
Pipes	Detailed condition assessments have been performed for all pipes crossing the levee system. LSE issues to be remediated through permitted actions.

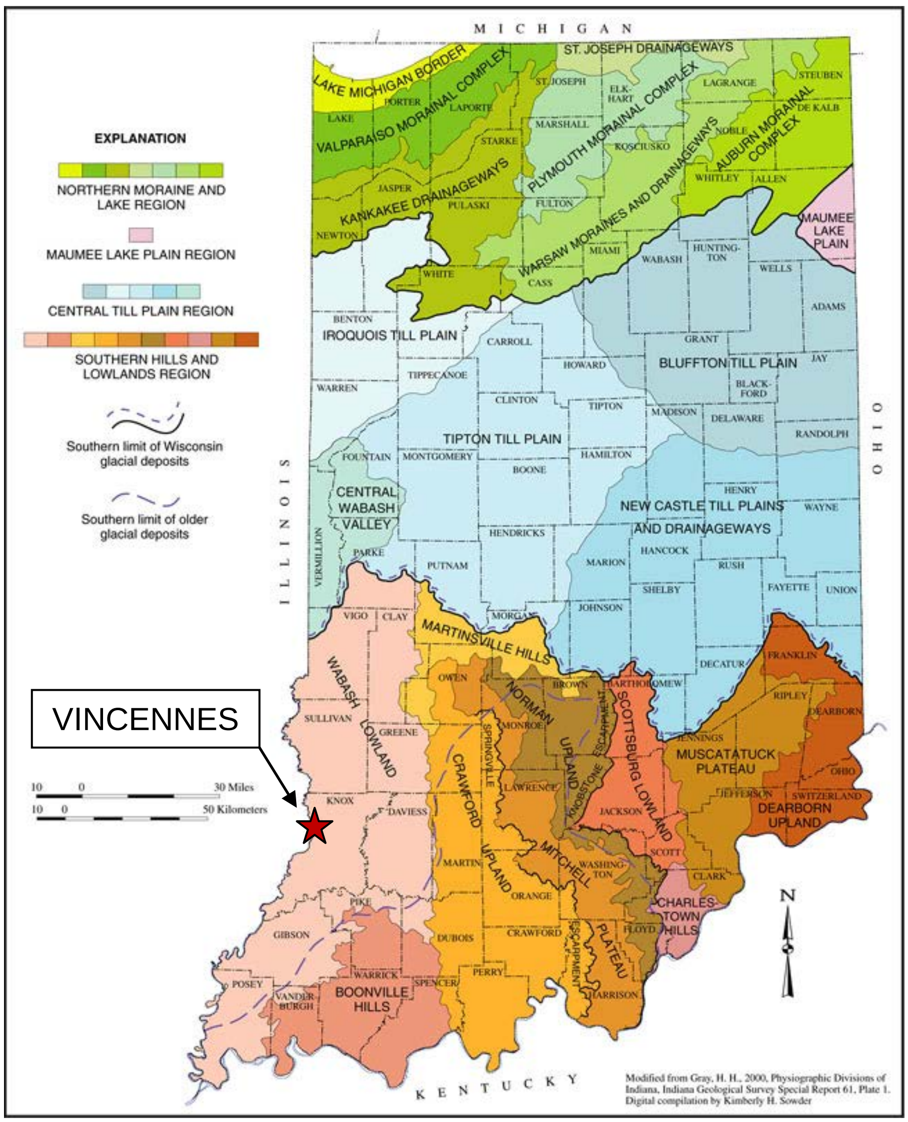
8.4. Geotechnical Evaluation

8.4.1. Geology of Project Area

Physiography

The City of Vincennes is located in the Wabash Lowland Physiographic province. The physiography is controlled by bedrock lithology and topography, although pre-Wisconsinan glacial deposits and Wisconsinan loess are present at the land surface. The overall subdued topography is the result of the underlying fine-grained, clastic Pennsylvanian bedrock composed primarily of shale and sandstone with minor amounts of limestone and coal, as shown in Figure 8.4-1.

Figure 8.4-1. Physiographic Map of Indiana

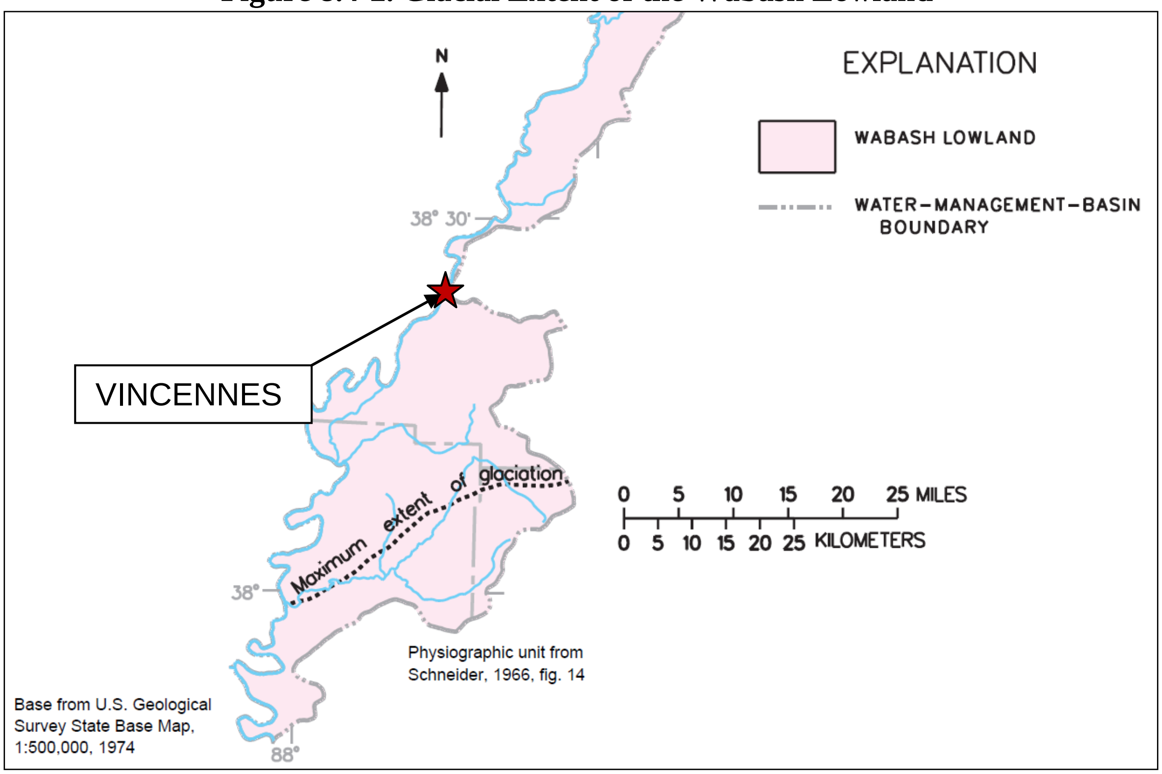


Geologic History

The Vincennes Sound Reach, including the City of Vincennes is in the southwest portion of Indiana in Knox County. Pleistocene glaciation reshaped the landscape through the direct action of glacial ice, and rivers of melt water. The early glacial advances were responsible for reducing Indiana topography through erosion and deposition such as preglacial valleys being filled with outwash sand and gravel, which created the need for underseepage controls along the Vincennes Segment. The extent of pre-Illinoian glaciation is difficult to determine because the majority of these deposits were eroded or buried by the subsequent glaciation known as the Illinoian glacial advance.

The Illinoian glacial advance created many of the landforms found in Knox County. This time of glaciation included the southernmost extent of continental glaciation in North America. The Illinoian glaciers then retreated, leaving behind low-relief rolling ground moraine which over time eroded. Mass wasting under paraglacial/periglacial conditions, and loess deposition during the Wisconsinan glacial advance were the last geologically significant events to modify the area. The Glacial Extent of the Wabash Lowland is shown in Figure 8.4-2.

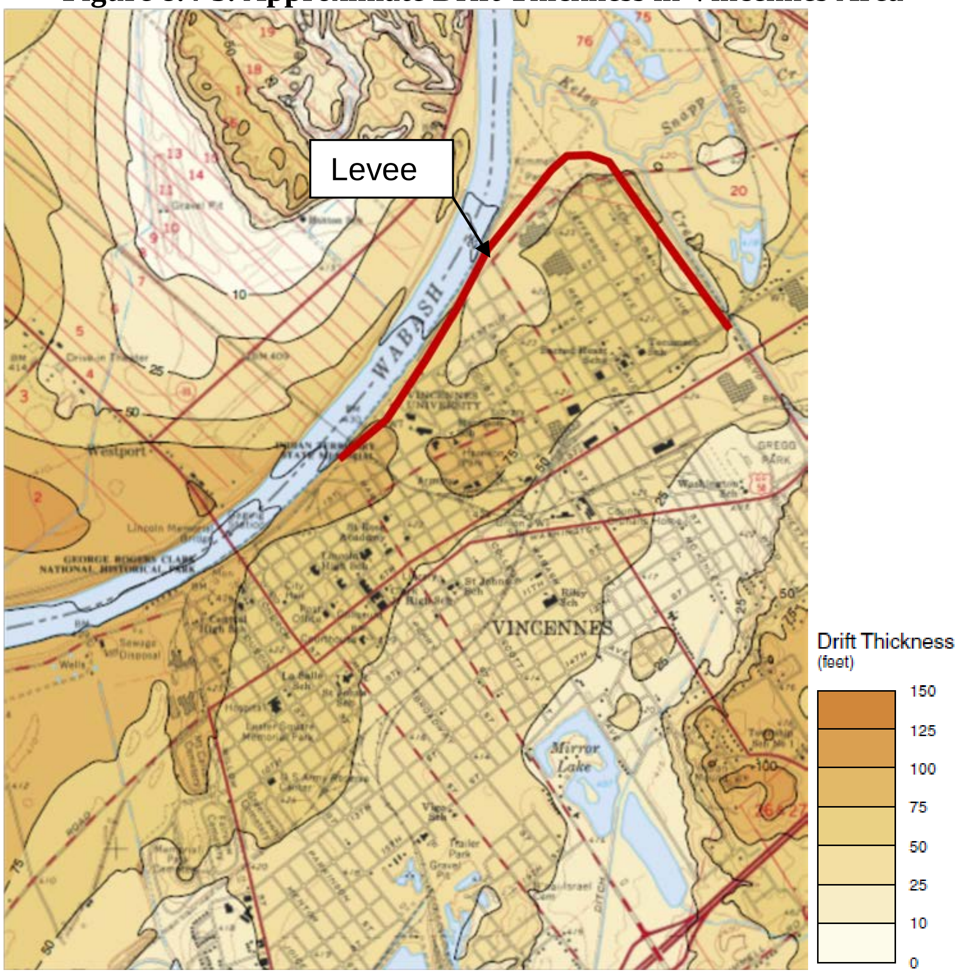
Figure 8.4-2. Glacial Extent of the Wabash Lowland



Structural Setting

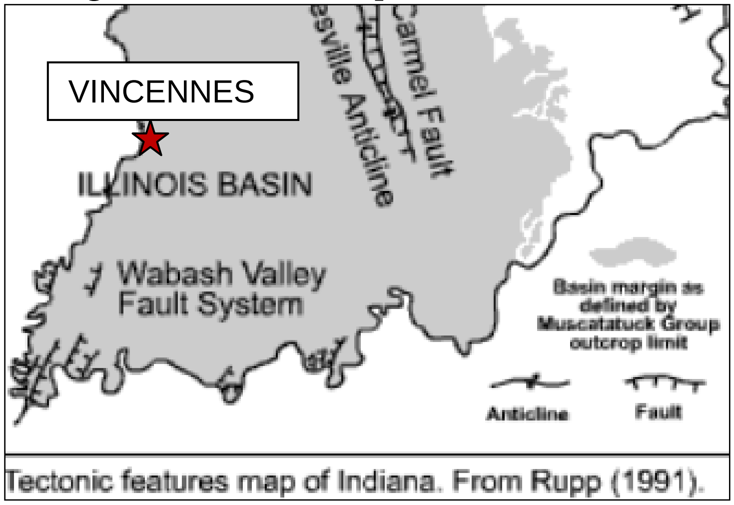
Knox County is located on the east flank of a regional structural feature known as the Illinois Basin, and bedrock dips gently to the west into the basin. The bedrock is not considered to have much effect on the Levee System primarily due to its depth (30 feet around the Kelso Creek portion to 125 feet deep along the Wabash River), and the nature of the overlying unconsolidated deposits, which are largely sand and gravel. The approximate thickness of these deposits is shown in Figure 8.4-3 below.

Figure 8.4-3. Approximate Drift Thickness in Vincennes Area



The Wabash Valley Seismic Zone is another pronounced structural feature of the basin and is approximately 25 miles south of the project, as shown in Figure 8.4-4. Faults as much as 30 miles long, with displacements greater than 400 ft, have been identified although not within the limits of the project. The faults in the Lower Wabash River basin are confined to Posey and Gibson Counties and trend north-northeastward.

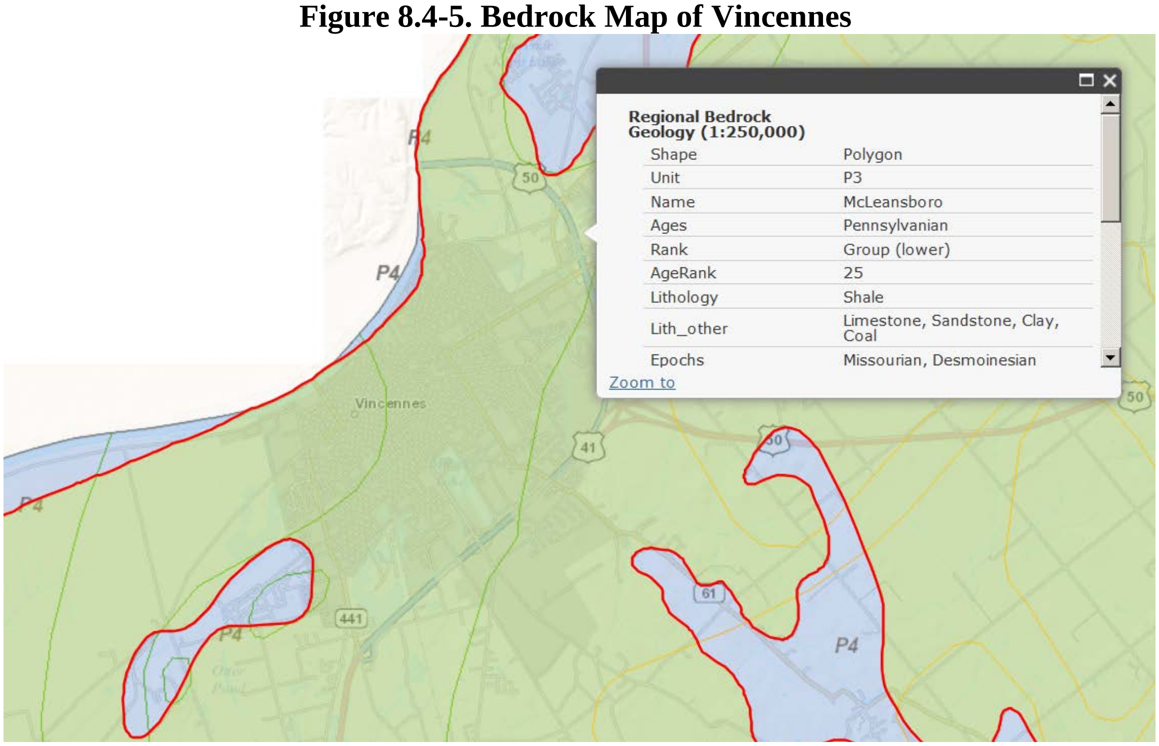
Figure 8.4-4. Fault Map of Southern Indiana



Bedrock

Rocks of Pennsylvanian age are at approximately 30-125 feet below the project. A lithologic sequence of sandstone, shaly sandstone, shale, thin limestone, coal, and underclay comprise the Raccoon Creek, Carbondale, and McLeansboro Groups of Pennsylvanian age (Cable and others, 1971) but have an insignificant role in the performance of the levee system. The regional bedrock geology is shown in Figure 8.4-5 below.

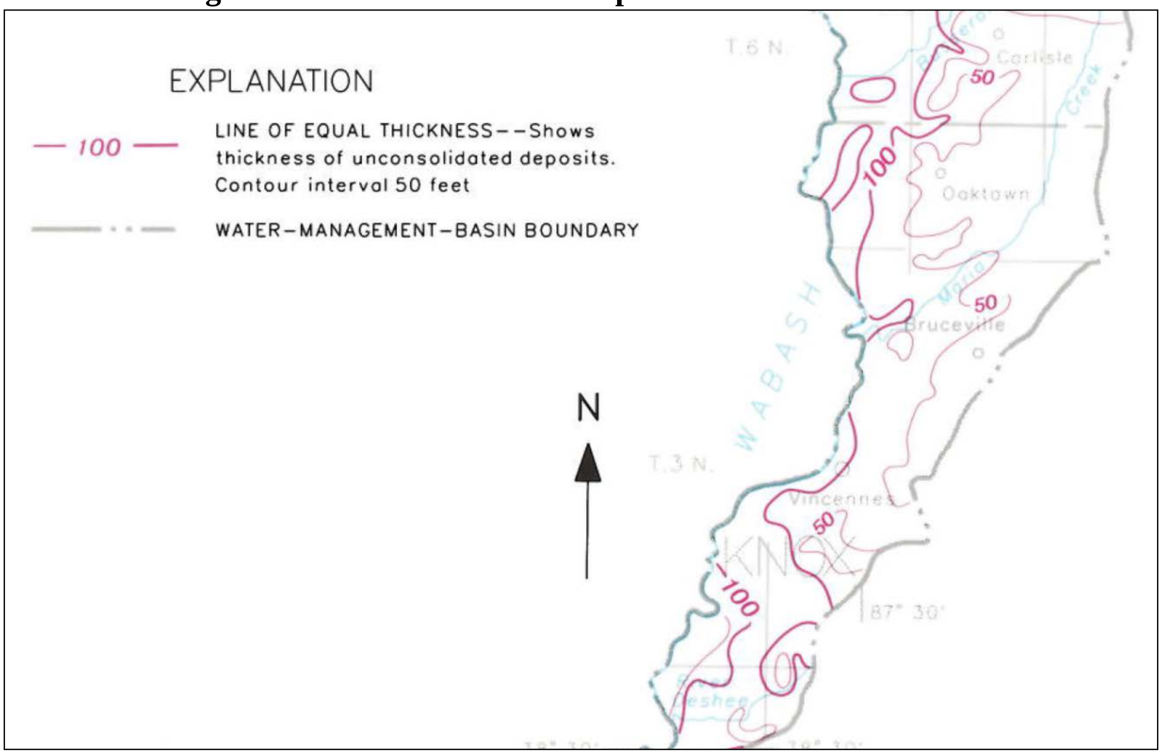
Figure 8.4-5. Bedrock Map of Vincennes



Unconsolidated Deposits

In the aggraded valleys of the Wabash River and major tributaries, the primary unconsolidated deposits consist of alluvium that overlies thick Pleistocene valley-train sand and gravel deposits. Thicknesses of sand and gravel as great as 150 ft have been measured adjacent to the Wabash River (Fidlar, 1948, pl. 3) and along Busseron Creek. In general, the sand and gravel deposits lie directly on the bedrock (Shedlock, 1980). Thickness of unconsolidated deposits decreases to 50 ft in minor tributary valleys and to less than 50 ft in the uplands as shown in Figure 8.4-6 (Gray, 1983). Many oxbow lakes and abandoned meanders are present in the modern Wabash River flood plain. Some of these depressions are filled with gravel and silt carried by floodwaters. Clay and silt beds were deposited in the lake plains along many of the tributary valleys.

Figure 8.4-6. Unconsolidated Deposits of Wabash Lowland



Hydrogeology

Due to the glaciated history of the area, the Brevoort-Vincennes Levee System overlies sand and gravel outwash that has been reworked by the meandering of the Wabash River and Kelso Creek. As previously discussed, the sand and gravel thickness is between 30-125 feet thick directly overlying bedrock. These sediments are capped by a thin layer of clay or silt according to Indiana Department of Natural Resources well logs. Particularly near the levee these low permeability clays and silts are in some cases nonexistent, with a maximum thickness of 2 feet which underscores the importance of the relief well system in controlling underseepage during flood events.

8.4.2. Embankment Erosion Protection

On the Vincennes Segment, there are three areas where rip rap protection is provided along the embankment for erosion protection. The first area is located at Station 305+66 to 307+78 along the riverside slopes on either side of the Oliphant Drive Closure. This riprap is shown as 18 inches of riprap on 9 inch gravel blanket. The stone size estimated in the field appears to be a median (D_{50}) size of approximately 8 inches. The second area is located at the I-wall to embankment transition at Station 255+00, as shown in the below Photo 8.4-1 and Photo 8.4-2. This riprap is shown on the plans as 12 inch riprap on 6 inch gravel blanket. Several large pieces of concrete exist within this rip rap. The third area is along the levee toe from Station 246+00 to the I-wall transition at Station 230+76Photo 8.4-1. Much of this rip rap has been silted in, but is still visible along this stretch. This rip rap is also shown as 12 inch rip rap on 6 inch gravel blanket. No erosion has been noted in these areas following past flood events.

Utilizing the hydraulic modeling, an average velocity for the 100 year flood event was 6 ft/s. An evaluation regarding the adequacy of the rip rap sizing has been performed utilizing EM 1110-2-1601 Hydraulic Design of Flood Control Channels, equation (3-3) as follows;

$$D_{30} = S_f C_s C_v C_t d \left(\left(\frac{\gamma_w}{\gamma_s - \gamma_w} \right)^{0.5} \frac{V}{\sqrt{K_1 g d}} \right)^{2.5}$$

Where:
D_{30}= stone size, feet
S_f = safety factor (1.25)
C_s = stability coefficient for incipient failure (0.3 for angular rock)
C_v = vertical velocity distribution coefficient (1.0 for straight channel)
C_t = thickness coefficient (1.0 for thickness = 1*D_{100}(max))
d = local depth of flow at same location as V, feet (10 ft avg.)
γ_s = unit weight of stone (150 pcf)
γ_w = unit weight of water (62.4 pcf)
V= local depth averaged velocity (6 ft/s)
g = gravity (32.2 ft/s^2)
K_1 = side slope correction factor (1 for bottom rip rap)

This produces a D_{30} size of 0.16 ft, or 1.92 inches. The median D_{50} size in the field of 8 inches, along with past performance history, indicates that the rip rap size present is sufficient.

Photo 8.4-1. Rip Rap at Station 256+00 looking downstream

Photo 8.4-2. Rip Rap at Station 256+00 looking upstream

8.4.3. Riverbank Erosion

While there is some riverbank erosion occurring along the Wabash River of both the Vincennes and Brevoort Segments, no erosion is currently threatening the integrity of the levee or the levee right-of- way. A large portion of the Vincennes and Brevoort Segments have an ample set-back distance from the riverbank, with several feet of real estate between the levee toe and the riverbank.

8.4.4. Settlement

Both the Brevoort and Vincennes Segment have levee embankments have been in their current state for over 50 years. Therefore, the overburden pressures from the embankment on the foundation soils and within the embankment itself have long since finished consolidating and hence finished settling. Any additional settlement would be the result of other potential effects, such as loss of foundation material or mining/oil operations below the surface. There are no mining operations within the limits of the Brevoort-Vincennes Levee system and few oil rigs in the area. Loss of foundation material would be the result of seepage/piping, foundation washout from riverbank erosion adjacent to the levee or slope instability. The inspection did not indicate any areas in danger of being affected by riverbank erosion or any slope failures. Along the Vincennes Sound Reach, there have not been any seepage/piping concerns from past events. The lone event resulting in foundation loss and material transport happened on the Brevoort Segment along River Road, as described in the paragraph Performance of the Brevoort-Vincennes Levee System, May 2011 Event from Section 7. The cause of this material loss was from infiltration into poor joints at manhole connections in a sanitary sewer line. These joints were repaired by the sponsor in December 2011, and the sanitary sewer line since properly abandoned by grouting in November 2013.

In order to evaluate the magnitude of past settlement, a comparison of the as-built constructed elevations to recent survey data was performed. The Vincennes 2010 Periodic Inspection Report compared as-built elevations to the National Levee Database (NLD) elevations surveyed in 2007. This data indicated that for nearly all data points, the surveyed NLD data was higher than indicated on the as-built drawings. No significantly low areas were noted from the data. The Brevoort 2010 Periodic Inspection Report also compared as-built elevations to the NLD survey data. No large discrepancies indicating a lower top of levee were noted for the section of Brevoort being evaluated in the study.

Several areas which appeared lower than the adjacent levee were noted in the inspection. The Brevoort levee crown has an undulating profile, which is mostly the result of the construction grade control and methods from when it was constructed during the 1930’s and 40’s. However, based on the 2007 NLD survey comparison, these low areas still meet or exceed the as-built elevations.

8.4.5. Seepage Analysis

Seepage analyses were performed in general accordance with EM 1110-2-1913 *Design and Construction of Levees*, dated 30 April 2000 and ETL 1110-2-569 *Design Guidance for Levee Underseepage*, dated 01 May 2005. SEEP/W 2012 finite element software, developed by GEO-SLOPE International LTD., was used to perform the seepage analyses for this LSE. One of the primary roles of SEEP/W is to assess the change in hydraulic gradients experienced across the levee at various flood elevations. At the same time, the predicted phreatic surface is plotted across the embankment, which is a vital component in assessing the potential for seepage activity. SEEP/W analyses were performed in order to evaluate the potential for piping failures through the embankment and also through the foundation during a high water event. ETL 1110-2-569 requires a maximum exit gradient of 0.5 be met for all seepage analyses. Assuming a critical exit gradient of 1.0, this would produce a factor of safety of 2.0. Seepage analyses results will refer to the exit gradient in discussion of results.

In order to perform SEEP/W analyses, a permeability coefficient was assigned to each material type. Soil properties used for these analyses are summarized in Table 8.4-5. In all analyses the I-Walls were modeled impermeable.

Seepage analyses were conducted for the same sections as the slope stability analyses, since the steady state seepage models are needed for the landside slope stability analyses. Cross sections were developed from as-built profiles as well as survey data made available by the sponsor.

8.4.5.1. Earthen Embankment

The Vincennes Segment was constructed with toe drains, relief wells, and relief trenches to alleviate underseepage pressures during a flood event. When performing seepage analysis, the cross sections were first performed neglecting the toe drains and relief wells. The relief trenches were able to be easily modeled within the cross section, and as previously indicated these trenches have been observed to be functioning in past events. No indication of the relief wells functioning during past events was observed, and the toe drains are generally unobservable.

For each critical section, the loading scenario was evaluated using steady-state conditions. For analysis, the upstream boundary condition was a constant total head equal to the 1% chance (100-year) flood elevation with 95% chance assurance. Due to the limited duration of these loading conditions, the SEEP/W results for all of the steady-state analyses are conservative.

Seepage analysis was performed considering the 1% chance (100-year) flood level plus 95% chance assurance to determine if the toe drain system and relief wells are needed to achieve an adequate factor of safety. For the relief well locations, seepage analysis indicated that for the sections modeled from Station 311+20 to 333+10 where 28 relief wells are located, an adequate factor of safety was achieved without the wells. Therefore, inspection/evaluation of these wells is not required for the LSE.

From Station 255+94 to 241+00, there are 14 relief wells located along this portion of the embankment. Modeling of the levee in this section as shown in Figure 8.4-7 indicated the potential for high exit gradients. Based on this seepage analysis, an evaluation of the relief wells in this area was required. The relief wells for the Vincennes Segment have been analyzed utilizing a spreadsheet based on EM 1914 criteria (Appendix M Attachment 2). Relief wells from Sta. 242+00 to 255+91 are spaced randomly from 75 ft up to 146 ft. The actual spacing was analyzed in the spreadsheet using EM 1914 criteria. Results of the relief well analysis were favorable. However, the capacity of the relief wells should be verified to ensure the assumptions in the spreadsheet are correct. Therefore, inspection/evaluation of these relief wells is required for the LSE.

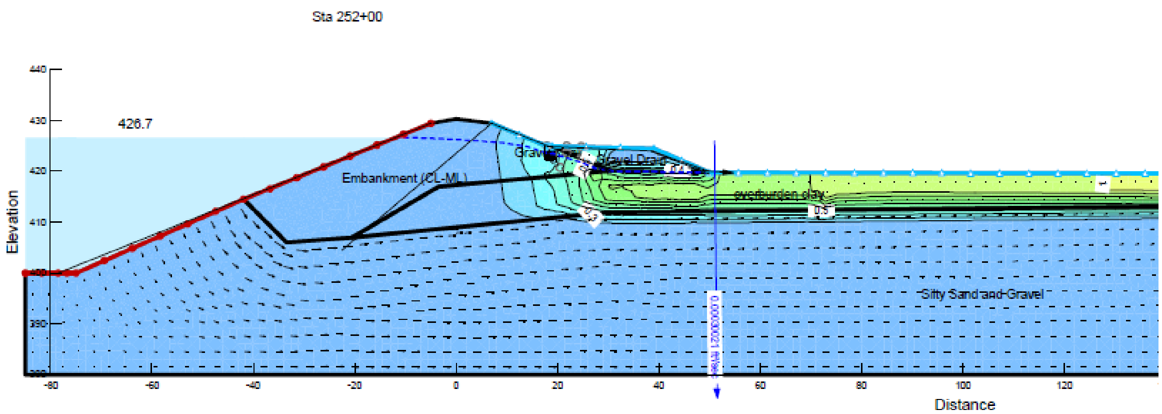


Figure 8.4-7. Seepage Modeling Output for Sta. 252+00

Initially, two cross sections were modeled along the Brevoort Segment, Sta. 1025+00 and 1125+69. Along the Brevoort Levee, the height of the embankment is lower than other areas upstream along the Vincennes Segment. This means the water levels on the levee embankment are higher, near the top in many areas for the 1% chance (100-year) flood level plus 95% chance assurance. A review of as-built borings as well as other recent borings toward the upstream end of the Brevoort Levee were used to develop soil profiles that were modeled. This modeling indicated the potential for high exit gradients in two of the four soil profiles.

Results of the seepage modeling for the embankment sections are presented below in Table 8.4-1. Current guidance requires an exit gradient of 0.5 of lower. Detailed seepage modeling parameters and results are presented in Appendix M.

Table 8.4-1. Embankment Seepage Modeling – Max Computed Exit Gradients

Sta.	321+00	312+60	252+00	1025+00	1125+69
Profile 1	0.4	0.1	0.9	0.7	0.8
Profile 2				0.1	0.1
Profile 3				0.1	0.1
Profile 4				1.0	1.2

Brevoort-Vincennes Levee Sponsors elected to proceed with a geotechnical investigation to gather more soils information, as little data was available for use in the seepage and slope stability modeling. Piezometers were also installed, which could allow for a better quantification of soil parameters if piezometer data is able to be collected during a flood event. Below is Figure 8.4-8 showing the locations of each of the borings/piezometers.

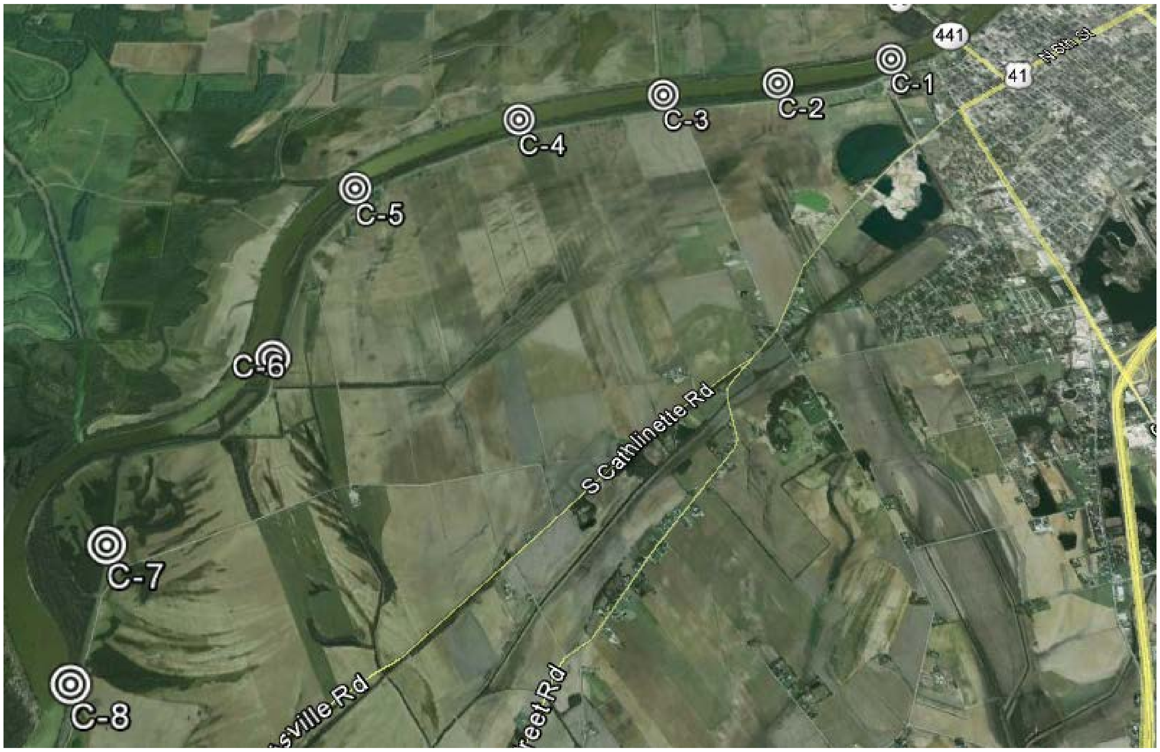


Figure 8.4-8. Location of Brevoort Borings/Piezometers

The results of lab testing for the Brevoort Segment embankment were provided in early July 2013. A report of the information gathered is included in Appendix M as Attachment M-3. In late April 2013, a record flood occurred, and data was able to be gathered on all 8 embankment piezometers as the flood progressed. Piezometer data was recorded every 12 hours when the levee was loaded during the 2013 event.

For each of the 8 piezometer locations, a transient seepage analysis utilizing the soils encountered at each location was performed. Material permeabilities for each analysis were adjusted in order to more closely match water levels encountered in the piezometers during the flood event. This led to 8 seepage models all accurately calibrated to water levels encountered during the April 2013 flood. The following table shows the calibrated permeability values for each material for each seepage model.

Once the materials were calibrated, each of the 8 models was subjected to a second transient hydrograph matching the 100 yr hydrograph plus 2.4 ft of risk and uncertainty (R&U). The 100 year hydrograph, utilizing the lowered discharge, was obtained from Andy Lowe, P.E. of the LRL Hydraulics Section, and was adjusted for each model so that the peak matched the 100 yr profile elevation of the specific location of the piezometer. The results of these transient analyses are shown in Table 8.4-2 below.

Table 8.4-2. Brevoort Seepage Exit Gradients

piezometer	exit gradient
C-2	0.3
C-3	0.9
C-4	0.3
C-5	0.4
C-6	0.3
C-7	0.4
C-8	0.7

In general, the exit gradients did improve throughout the 7 modeled sections. This is mostly due to the reduction in the permeability of the deeper sand and gravel aquifer, as well as the use of a transient analysis which is more realistic of how the embankment would be loaded and unloaded during a flood event. However, the exit gradient remains high for the C-3 and C-8 models as shown in Table 8.4-2. This is due to the confining clay layer modeled at the surface of the landside of the levee of these two analyses. During the April 2013 Flood event, 4 small sand boils were observed approximately 100 ft beyond the landside toe of the levee near the location of C-8. No other boils were noted on this upstream section of the project, though general clear seepage was present along much of the stretch of levee from C-3 to C-6. This is anticipated due to the amount of sandy soils present in the area. While the gradient at C-3 exceeds the required exit gradient of 0.5, in the plan view it is unlikely that a restrictive clay layer exists for a large area of the landside toe of the levee and beyond. The 2D modeling performed does not accurately portray this scenario. Combined with the past performance of this section of the embankment, the risk from a seepage perspective is low.

During the inspection, several animal burrows were noted along the Vincennes Sound Reach, particularly on the Brevoort Segment from Station 1050+00 to 1133+00, and on the Vincennes Segment from Station 214+00 to 274+00. These burrows are numerous enough that seepage issues could develop from burrow activity during a significant flood event. This item was considered an LSE issue, and the sponsors were provided with the USACE-LRL Standard Operating Procedure (SOP) to fill the burrows.

8.4.5.2. I-Wall

An analysis was conducted on the critical I-Wall cross-sections located at Stations 228+30, 256+75, and 258+50. These locations were chosen based on their soil profiles or landside geometry. The analysis was performed in the same manner as the levee embankment. Approximately 16 of the relief wells are located behind the I-wall section from station 256+00 to 265+50, continuing from the embankment section. Again, no relief wells were modeled in the seepage analysis. For Station 256+25, modeling produced an exit gradient of approximately 0.9. Based on this seepage analysis, a check of the relief well design utilizing the spreadsheet based on EM 1110-2-1913 criteria was performed. The spreadsheet yielded favorable results, however pump testing and verification of the condition of the wells is needed to verify assumptions in the spreadsheet. Therefore, inspection/evaluation of the relief wells in this area is required for the LSE. Details of the seepage analysis are located in Appendix M. Figure 8.4-9 is a typical output plot of a SEEP/W analysis for Station 228+30. Table 8.4-3 shows a summary of the results from the I-wall seepage analyses.

For Station 228+30, a toe drain exists both adjacent to and under Culbertson Blvd for the entire stretch. Seepage analyses of each cross section with the toe drain was performed and yielded favorable results. The results of these analyses are shown in Table 8.4-4. Based on the dependency of the toe drain for this section of I-wall, videotaping of the toe drains to verify their condition is required for the LSE.

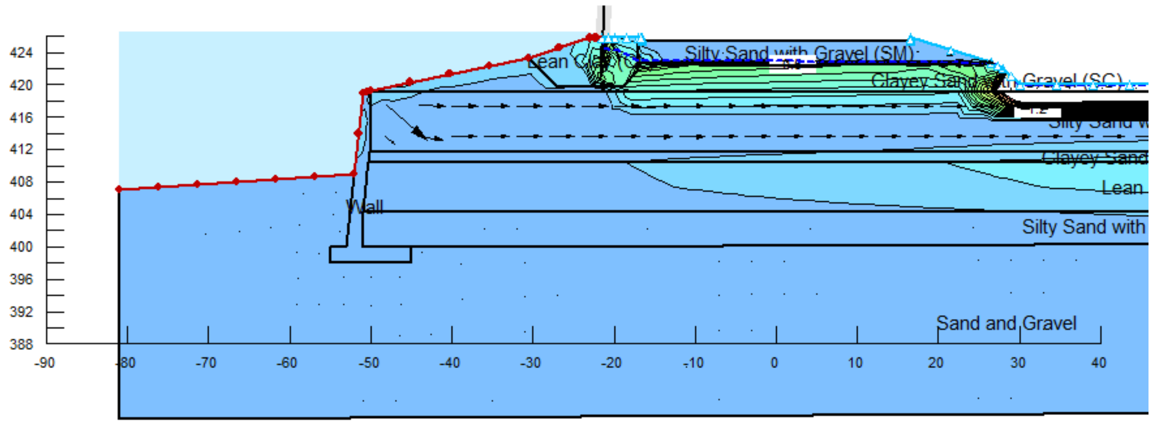


Figure 8.4-9. Typical SeepW Output for I-wall Section

Table 8.4-3. I-wall Seepage Modeling – Max Computed Exit Gradients

Station	228+30	258+50	256+75
Exit Gradient	2+	0.5	0.9

Table 8.4-4. I-Wall Seepage Modeling with Toe Drain

Station	Max Exit Gradient
223+50 with Toe Drain	<0.1
228+30 with Toe Drain	0.3

8.4.6. Embankment and Foundation Stability

8.4.6.1. Slope Stability

Slope stability analyses were performed in general accordance with EM 1110-2-1913 *Design and Construction of Levees*, dated 30 April 2000 and EM 1110-2-1902 *Slope Stability*, dated 31 October 2003. Per EM-1110-2-1913 various loading conditions to which a levee and its foundation may be subjected to and which should be considered in analyses are designated as: Case I - End of construction, Case II - Sudden rapid draw down from full flood stage, Case III - Steady seepage from full flood stage (fully developed phreatic surface), and Case IV – Earthquake. Case IV was not required to be analyzed for the Vincennes Sound Reach. See Section 8.4.7 regarding seismic evaluations.

Case I is not required for this levee because the project is an existing structure and pore water pressures have had ample time to stabilize since construction.

Case II and III load conditions were analyzed using GEO-SLOPE International, Ltd. SLOPE/W 2012. The load conditions considered included: 1) "existing levee" at the elevation of 95% certainty for the 1% chance (100-year) flood elevation; 2) drained "long-term (steady seepage)", and 3) undrained "rapid drawdown" conditions. Steady state analysis means the modeled system has been at its current state long enough for water pressures and seepage rates to achieve constant (non-fluctuating) values. A rapid drawdown analysis simulates the quick recession of flood waters after a high water event and is modeled by instantly returning the flood stage pool in a steady state model to the normal pool elevation while retaining the high pore water pressures in the embankment being analyzed. This replicates the loss of the stabilizing force of the high water level on the riverside face while introducing the destabilizing force of high pore pressures within the embankment. This condition has the net effect of decreasing the stability of the riverside face.

A total of seven cross sections representing different portions of the embankment were modeled for slope stability. These included three embankment sections and three I-Wall sections of the Vincennes Segment, and one embankment section of the Brevoort Segment with four different soil profiles. These sections were selected based on being representative of a large length of embankment or floodwall or if the section appeared to be critical based on the geometry.

For Case II, Rapid Drawdown Analysis, piezometric lines were defined within the embankment based on results of steady state seepage analyses. The flood loading were then removed from the riverside embankment to negate the stabilizing effect of the water against the riverside of the levee. This represents the theory of a rapid drawdown analysis, whereas the embankment remains saturated with pore pressures from the higher water level, yet the water weight acting against the levee in favor of riverside slope stability is removed.

For Case III, long term drained slope stability was analyzed using steady state piezometric conditions for the cross section. Phreatic surfaces, geometries, and material data were defined using the SEEP/W results, described in the previous section "Seepage Analysis", for the same cross section. For analysis, the upstream boundary condition was a constant total head (Steady State) equal to the 1% chance (100-year) flood elevation with 95% chance assurance for the corresponding levee station. On the landside face and toe of the levee, a flux equal to zero with a potential seepage face boundary condition was assumed. Case III slope stability was analyzed for failures occurring on the landside of the embankment.

For both Case II and III load conditions, Mohr-Coulomb was used to model each material's shear strength characteristics. Using Spencer's Method, SLOPE/W was allowed to auto-locate the critical slip surface. Soil properties used in the analyses are summarized in Table 8.4-5, and were obtained from the Phase II I-Wall Evaluation Report, a review of boring logs from as-builts, Design Memorandums, and the I-Wall Geotechnical Investigation results located in Appendix J. A summary of the soil properties and strengths used in the slope stability analyses are shown below in Table 8.4-5 and Table 8.4-6.

Table 8.4-5: Summary of Material Properties (Effective Stresses)

Soil	permeability, k (ft/s)	phi (deg)	cohesion c (psf)	unit weight (pcf)	anisotropy (Ky/Kx)
clayey silt and sand	2.00E-05	30		120	1
Embankment	1.00E-07	27	100	125	1.3
silty sand and gravel	4.00E-03	30		120	1
sandy silty clay	1.00E-05	28		120	1.3
Overburden clay	1.00e-7	27	100	125	1.3
Gravel drain	0.1	33		115	1

Table 8.4-6. Summary of Material Properties (Undrained Strength)

Soil	permeability, k (ft/s)	phi (deg)	cohesion c (psf)	unit weight (pcf)	anisotropy (Ky/Kx)
clayey silt and sand	2.00E-05	30		120	1
Embankment	1.00E-07	0	1200	125	1.3
silty sand and gravel	4.00E-03	30		120	1
sandy silty clay	1.00E-05	28		120	1.3
Overburden clay	1.00e-7	0	1200	125	1.3
Gravel drain	0.1	33		115	1

Computations indicate the factors of safety against failure of the riverside slope of the levee under "rapid drawdown" conditions and against failure of the landside slope under "steady seepage" conditions are greater than 1.0 and 1.4, respectively for the Vincennes Segment as shown in the below table. The levee sections analyzed were compared to the minimum factors of safety required for existing levees as dictated by EM 1110-2-1913 *Design and Construction of Levees*, Table 6-1b. Table 8.4-7 shows the results for all slope stability analyses. All analysis files are located in Appendix O.

Table 8.4-7: Factors-of-Safety for Slope Stability Analysis - Vincennes

Analysis Condition		**Sta. 228+30 (I-Wall)**	**Sta. 252+00 (levee)**	**Sta. 256+75 (I-wall)**	**Sta. 258+50 (I-wall)**	**Sta. 312+60 (levee)**	**Sta. 321+00 (levee)**
Long Term Steady Seepage, Required FS=1.4	Landside	N/A	1.5	N/A	N/A	1.9	2.0
Rapid Drawdown, Required FS=1.0	Riverside	1.5	1.3	1.3	1.2	1.2	2.4

For the Brevoort Segment, one cross section with four different soil profiles was analyzed. Pore water pressures were utilized from the seepage analysis. Soil strengths were gathered largely from the Vincennes investigations as well as some geotechnical investigation performed on the upstream end of the Brevoort Levee. Strengths are shown in the below Table 8.4-8.

Table 8.4-8. Brevoort Segment Soil Strengths (Effective Stresses)

Soil	permeability, k (ft/s)	phi (deg)	cohesion c (psf)	unit weight (pcf)
clayey silt and sand	2.00E-05	30	0	120
silty sand and gravel	4.00E-03	30	0	120

The four profiles modeled, as well as the resulting Factors of Safety for the Rapid Drawdown and Steady State analyses is shown in the below Table 8.4-9.

Table 8.4-9. Brevoort Segment Slope Stability Factors of Safety

Sta. 1125+69	Soil Profiles	Rapid Drawdown	Steady Seepage
Profile 1	Clayey silty sand over silty sand and gravel Aquifer	1.2	0.73
Profile 2	silty sand and gravel over silty sand and gravel Aquifer	1.2	1.34
Profile 3	silty sand and gravel over silty sand and gravel Aquifer	1.2	1.62
Profile 4	Clayey silty sand over silty sand and gravel over silty sand and gravel aquifer	1.0	0.52

As you can see, profile 1, profile 2, and profile 4 did not meet the required factors of safety. The lower factors of safety for profile 1 and 4 are largely due to the high pore water pressures at the levee landside toe. These high pore pressures reduce the friction between the soil particles causing lower strengths at these areas. The results of Profile 4 are shown in Figure 8.4-10 below.

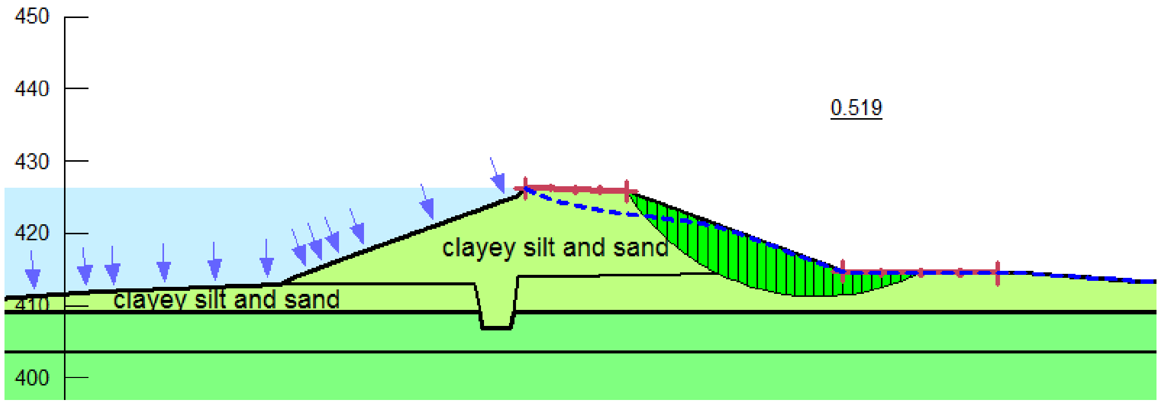


Figure 8.4-10. Brevoort Soil Profile 4 - Steady State Seepage Result

The rapid drawdown analyses results all met the required factor of safety of 1.0. The levee material in this area is sandier than portions of the Vincennes Segment, and the material likely would be able to drain at a sufficient rate to reduce the destabilizing effects of a rapid drawdown.

During February of 2013, the local sponsors (the City of Vincennes and the Brevoort Levee Conservancy) elected to perform 8 borings through the upstream Wabash section of the BrevoortSegment in order to hopefully obtain better soil information and strength data with optimism of improving the Long Term Drained slope stability results. Piezometers were installed within the borings as well, in order to obtain valuable information during any future flood event.

As previously noted, a record flood event occurred during April 2013, the third highest flood of record. Competent piezometer data was obtained during this event, further refining the seepage models as well as the pore water pressures present in the embankment during a flood which aided the slope stability analyses. It was determined that with such good piezometer data, a transient analysis would be appropriate for the Seepage modeling and the subsequent Slope modeling which utilizes the pore pressures of the Seepage models. Seep and Slope models were constructed for each of the 8 boring locations. Seepage models were calibrated to the April 2013 event piezometer data, and then subjected to a transient 100 year event for the LSE. Slope Stability models were analyzed for the LSE based on pore water pressure conditions from the 100 yr transient Seep model Parent analysis.

The geotechnical data from the Brevoort Segment investigation can be found in Appendix N. Results from the geotechnical investigation regarding the shear strength of the soil were improved over the initial values used. Based upon lab testing, the material properties of the Brevoort embankment were adjusted to the values as shown in the below Table 8.4-10.

Table 8.4-10. Adjusted Material Properties of the Brevoort Levee (Effective Stresses)

Soil	phi (deg)	cohesion c (psf)	unit weight (pcf)
clayey silt and sand	33	0	120
Sandy silty clay (values from Shear/Normal curve)	Approx. 33 to 35	usually 0	125
silty sand and gravel	34	0	120

Results of the Slope Stability Modeling were improved over previous analyses. This was due mostly to the higher shear strengths used, but also to slightly lower pore pressures from the transient seepage analyses. However, the water table remained high within the embankment for many analyses, as much of the levee is composed of silty sand. Results are shown in the following Table 8.4-11. Omitted from the analyses was any cohesion strength that would greatly aid the stability of the embankment. Since the triaxial testing samples failed to produce data that clearly defined the cohesive strength, it was conservatively input as zero.

Table 8.4-11. Results of Brevoort Slope Stability Analyses

	Slope FoS
C-2	1.4
C-3	1.3
C-4	1.3
C-5	1.4
C-6	1.3
C-7	1.3
C-8	1.2

As you can see from the results, all analyses hover within a FS range from 1.2 to 1.5. Based on well defined soil shear strength data and pore water pressures from the piezometer data, there is confidence that the modeling is well representative or somewhat conservative due to no cohesive strength being utilized. Past performance of this stretch of embankment which has been significantly loaded in 2005, 2008, 2011, and 2013 of which USACE has good records of was a major contribution to the slope stability consideration. The LSE team feels the evaluated section of the Brevoort Segment levee embankment can be issued a positive evaluation regarding slope stability.

8.4.7. Seismic Evaluation

Based on the 2008 USGS Hazard Map *PGA with 10% chance of exceedance in 50 year*s shown in Figure 8.4-11 below, the peak ground acceleration (PGA) for the Vincennes area is less than 0.06g. Per EC 1110-2-6067 paragraph 9h(6), if the PGA for the 100 year earthquake is less than 0.10g, no evaluation is required. 10% in 50 years is equivalent to 0.2% annual chance exceedance (500 yr event). Therefore, the 1% annual chance exceedance PGA is also less than the 0.06g and no seismic evaluation is required.

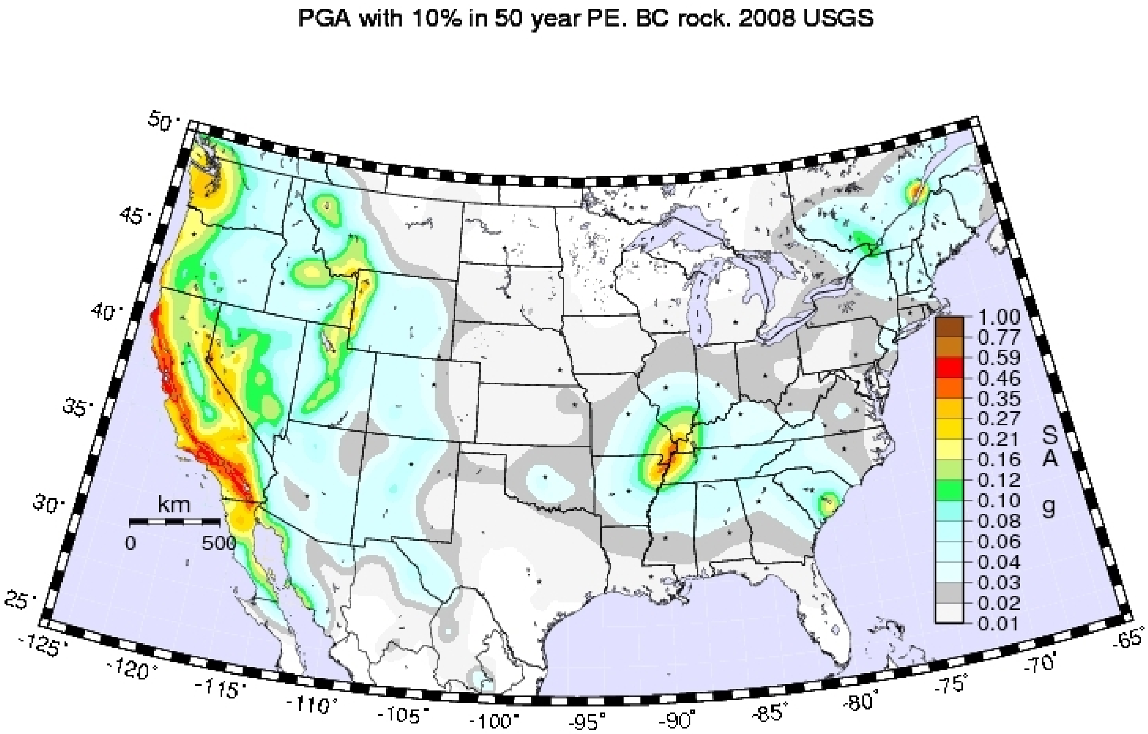


Figure 8.4-11. Seismic Hazard Map

8.4.8. Geotechnical Conclusions

Using the available data, and to the extents of the accuracy of the given data, for the 1% chance (100-year) flood elevation with 95% chance assurance, along with the geotechnical analyses described in this report, the Vincennes, Indiana Levee System does not yet meet all geotechnical requirements for a positive levee system evaluation letter. The findings of this section are summarized in Table 8.4-12.

Table 8.4-12: Geotechnical Analysis Summary

Analysis	Results
Stability	No Stability issues
Settlement	No settlement issues
Seepage	Animal burrows to be addressed, inspection and testing of relief wells and inspection of toe drains required
Erosion	No notable erosion
Seismic	No analysis required
Conclusion	**Seepage control measures to be verified**

8.5. Mechanical Evaluation

8.5.1. Mechanical Systems Summary

The Vincennes Sound Reach consists of 7 pumping plants: 2nd Street, College Avenue, Highland Street, Perry Street, St. Clair Avenue, 6th Street, and City Ditch. All pumping plants have electric motors for operation. The pumping plants are maintained and operated by the City of Vincennes Water and Wastewater storm departments.

The inspection team performed a visual inspection of the pump stations. The sumps were not entered due to confined space entry. Typically during operation of the pumps, when water levels are below the suction bells, coast-down times for dry conditions are taken. Due to water levels being high, these values could not be taken. These times aid in determining if there are possible pump equipment problems. For example, if the coast-down times changed drastically from a previous reading, this indicates a possible problem with the pumping equipment.

Velocity measurements were taken during the operation of the pumps for a vibration study. The measurements were taken using a Vibration Sound Level Meter at two locations X and Y. X is located near the thrust bearing at the top of the motor housing on the water discharge side and Y is located 90 degrees counterclockwise at the same elevation. Figure 8.5-1 shows the vibration sensor locations. The velocity measurement data was interpreted using the General Machinery Vibration Severity Chart, Figure 8.5-2. The chart was obtained from IRD Mechanalysis. Results from the vibration study are listed in tables in each pump station's summary report. COE design specifications require that vibration severity shall be in the "good" range or better of the General Machinery Vibration Severity Chart. A "good" or better rating requires that the velocity be 0.0785 in/sec or lower, within the red shaded area on Figure 8.5-2.

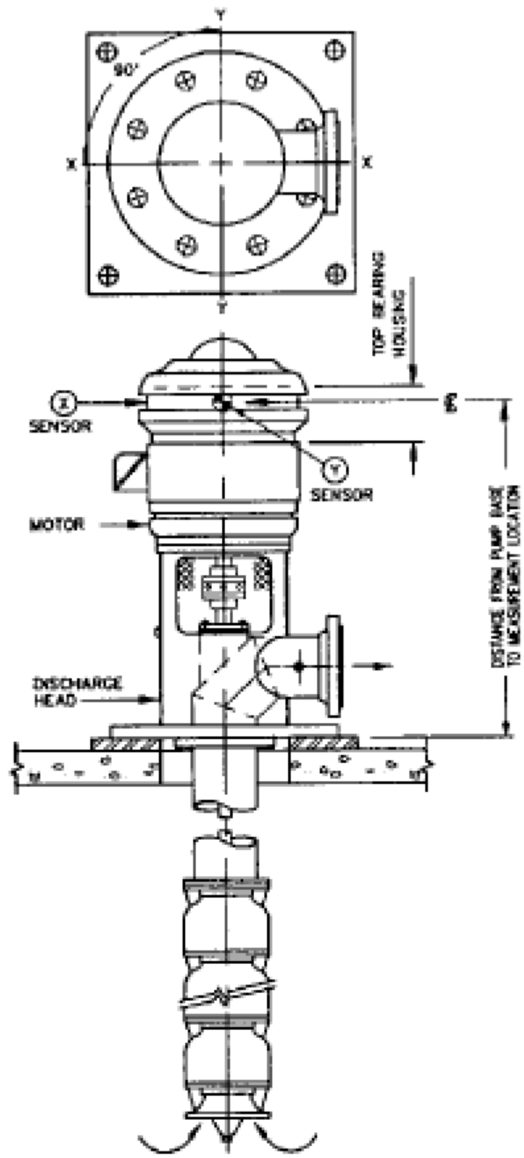


Figure 8.5-1 Vibration Sensor Locations

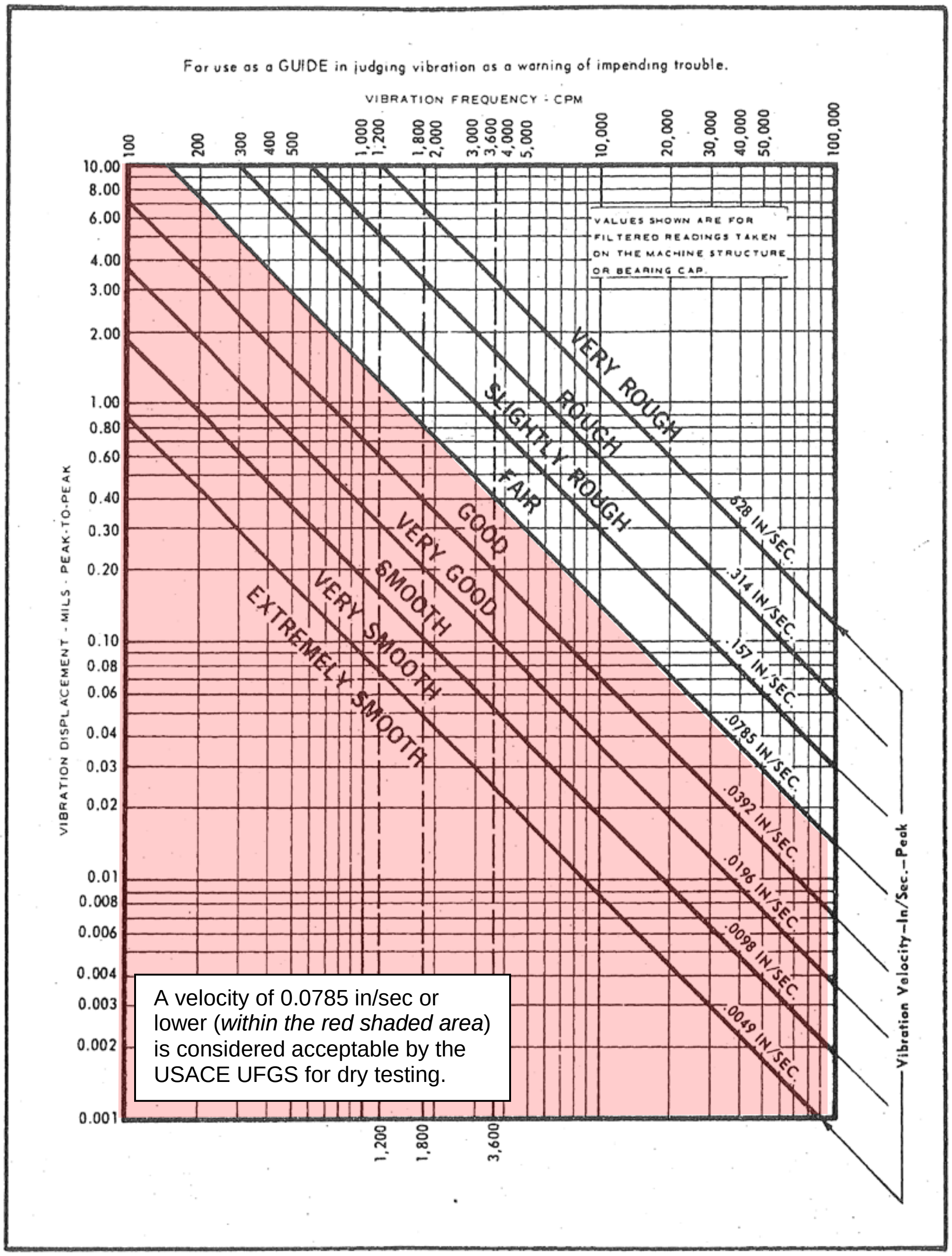


Fig. 1 General Machinery Vibration Severity Chart

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Figure 8.5-2 General Machinery Vibration Severity Chart

Some of the current operating procedures were spot checked and some water levels differ from the original COE Operation and Maintenance Manual dated as revised in 1983. It is recommended that City personnel follow the pumping schedule as shown in the O&M

Manual to prevent damage to the pumping equipment. The pumping level schedule for each pumping plant is shown in Table 8.5-1.

Table 8.5-1 Operating Levels for Pumping Equipment

Pumping Plant	Pump #	O&M Start Elevation	Tested Start Elevation	O&M Stop Elevation	Tested Stop Elevation
2nd Street	1	6.5	6.8	3.8	4.2
	2	7.0	8.2	4.3	3.1
College	1	6.65	---	4.15	---
	2	6.15	---	3.65	---
	3	5.65	---	3.15	---
Highland Street	1	7.4	7.4	4.5	4.5
	2	6.9	6.9	4.0	4.0
	3	6.4	6.4	3.5	3.5
Perry Street	1	11.0	---	6.3	---
	2	10.6	---	5.8	---
	3	10.0	---	5.3	---
	4	3.65	---	1.0	---
St Claire	1	13.1	13.1	8.3	8.3
	2	12.6	12.6	7.8	7.8
	3	12.1	12.1	7.3	7.3
	4	5.25	5.25	1.4	1.4
City Ditch	1	---	---	7.0	---
	2	---	---	7.0	---
6th Street	Lead	4.0	4.0	1.17	1.17
	Lag	5.0	5.0	1.17	1.17

Levee System Evaluation requires that the Inspection Guide for Flood Control Works (ICW) Checklist per EP 500-1-1 be followed for Pump Plants and Gate Wells (Interior Drainage Systems). The following items, required by the ICW checklists, were not located at each pump station:

a) Pumping Plant Operating, Maintenance, Training, & Inspection Records
b) Pumping Plant Operation and Maintenance Equipment Manuals.

It is recommended that an O&M Manual be provided by the City of Vincennes at each pumping plant. Operating logs and data provided by equipment should be entered into the log manuals. It is recommended that maintenance personnel review the manual and start logging necessary and required information in accordance with the manual.

8.5.1.1. Second Street Pumping Plant

Pump Plate Data:
See Table 8.5-2 for pump plate data.

Table 8.5-2 Pump Plate Data

Pump Number	Pump Manufacturer	Capacity (GPM)	Head (Feet of Water)	Size (Inches)	RPM
# 1	Cascade	6,180	17.4	18”	1175
# 2	Cascade	6,180	17.4	18”	1175

Pump Start/Stop Elevations:
Start and stop elevations were spot verified at this pumping plant and found to be out of the acceptable range. The start/stop elevations shall be changed back to USACE approved elevations. The start/stop elevations were not verified at every pump station because they were recently found to be acceptable during the periodic inspection conducted by Stantec.

Trash Racks:
Visual inspection found the inlet trash racks to be in acceptable condition.

Sluice Gates and Flap Gates:
The manually operated sluice gate (Photo 8.5-1) in the discharge well was stuck in place and not able to be operated. Additionally, the sluice gate in gate well #2 is inoperable. These are LSE items and shall be repaired. Both flap gates (Photos 8.5-1 & 8.5-2) were visually inspected from above and appeared to be in acceptable condition. The discharge flap gate near the train trussel has a previous repair (Photo 8.5-3) and damaged pipe (Photo 8.5-4). See Structural section of this report for pipe repair recommendation.

Photo 8.5-1 Second Street Pump Station Sluice Gate and Pump Discharge Flap Gate

Photo 8.5-2 Second Street Pump Station Pump Discharge Flap Gate

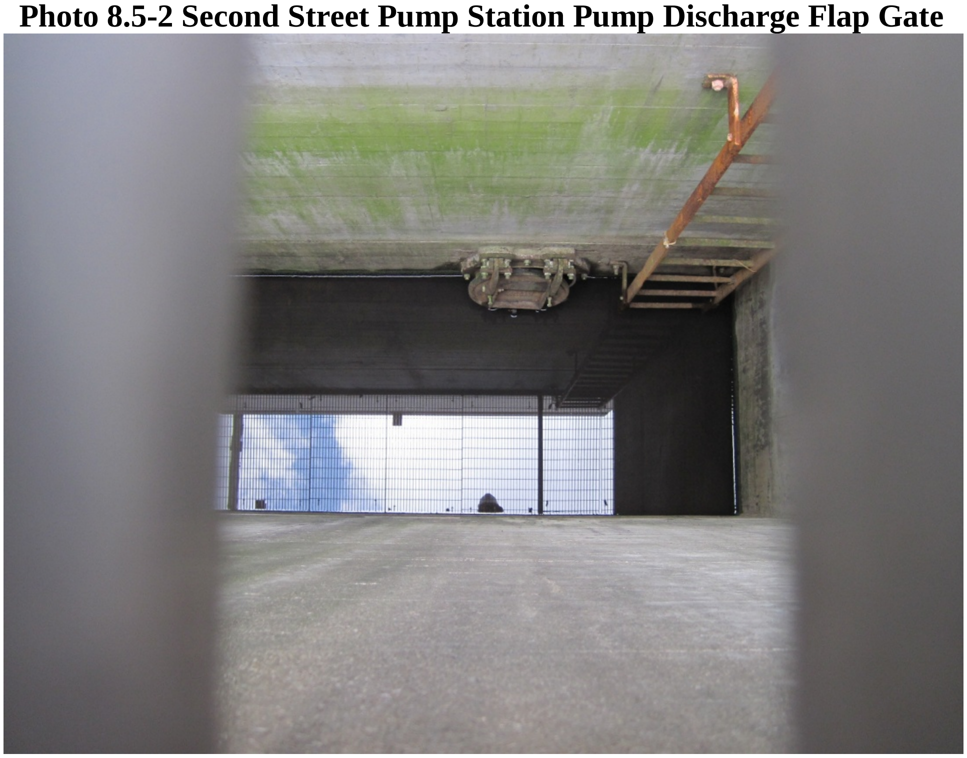


Photo 8.5-3 Second Street Pump Station Previous Flap Gate Repair

Photo 8.5-4 Second Street Pump Station Damaged Discharge Pipe

Air Vents and Siphon Breakers:
No air vents or siphon breakers are present at this pumping plant.

Pump Operation Inspection and Coast-Down Times:
Audio and visual inspections were performed during the operation of all pumps. Velocity readings, collected using a digital velocity meter, were used in conjunction with the General Machinery Vibration Severity Chart from IRD Mechanalysis to determine vibration level. Pump velocity and vibration data are recorded in Table 8.5-3. It was determined that both pumps were within the "good" operating category. Pump coast down times could not be recorded due to the impellers being submerged. Coast down times are shown in Table 8.5-4 below.

Table 8.5-3 Vibration Study Results

Second Street		Readings		Results	
		X	Y	X	Y
Pump #1	Vel. (in/sec)	0.04	0.03	Good	Very Good
Pump #2	Vel. (in/sec)	0.04	0.04	Good	Good

Table 8.5-4 Pump Coast-Down Times

Equipment	Coast Down Time
Pump #1	TBD
Pump #2	TBD

8.5.1.2. College Avenue Street Pumping Plant

Pump Plate Data:
See Table 8.5-5 for pump plate data.

Table 8.5-5 Pump Plate Data

Pump Number	Pump Manufacturer	Capacity (GPM)	Head (Feet of Water)	Size (Inches)	RPM
# 1	Peerless	3,800	22.7	16"	1180
# 2	Peerless	3,800	22.7	16"	1180
# 3	Peerless	3,800	22.7	16"	1180

Pump Start/Stop Elevations:
Start and stop elevations were not spot verified at this pumping plant. The start/stop elevations were not verified at every pump station because they were recently found to be acceptable during the periodic inspection conducted by Stantec.

Trash Racks:
Visual inspection found the inlet trash racks to be in acceptable condition.

Sluice Gates and Flap Gates:
All three inlet sluice gates were operated a full open and close cycle. The gates operated acceptably, but leakage was noted when the gates were closed (Photo 8.5-5). This may be corrected with wedge adjustment. The sluice gate in discharge gate well #7 (Photo 8.5-6) was also operated a full open and close cycle acceptably. The gate stem is bent (Photo 8.5-7) and is recommended to be straightened or replaced. The discharge flap gate is misaligned (Photo 8.5-8).

Photo 8.5-5 College Avenue Sluice Gate Leakage When Closed

Photo 8.5-6 College Avenue Pump Station Discharge Gatewell

Photo 8.5-7 College Avenue Discharge Gatewell #7 Has Bent Stem

Photo 8.5-8 College Avenue Pump Station Misaligned Flap Gate

Air Vents and Siphon Breakers:
Air vents and siphon breakers operated acceptably. There was minor air leakage from the siphon breakers during operation, but this is only noted for record. Ground settlement near the siphon breakers (Photo 8.5-9) was noted for record to see if the condition worsens. Levee personnel indicated that the settlement has been present for many years and has not changed.

Photo 8.5-9 College Avenue Ground Settlement Near Siphon Breakers

Pump Operation Inspection and Coast-Down Times:
Audio and visual inspections were performed during the operation of all pumps. Velocity readings, collected using a digital velocity meter, were used in conjunction with the General Machinery Vibration Severity Chart from IRD Mechanalysis to determine vibration level. Pump velocity and vibration data are recorded in Table 8.5-6. It was determined that all pumps were within the "good" operating category except for Pump #2 in the Y direction. It is recommended to monitor this pump to see if the condition worsens. Pump coast down times could not be recorded due to the impellers being submerged. Coast down times are shown below in Table 8.5-7.

Table 8.5-6 Vibration Study Results

College Avenue		Readings		Results	
		X	Y	X	Y
Pump #1	Vel. (in/sec)	0.07	0.04	Good	Good
Pump #2	Vel. (in/sec)	0.05	0.09	Good	Fair
Pump #3	Vel. (in/sec)	0.04	0.05	Good	Good

Table 8.5-7 Pump Coast-Down Times

Equipment	Coast Down Time
Pump #1	TBD
Pump #2	TBD
Pump #3	TBD

8.5.1.3. Highland Street Pumping Plant

Pump Plate Data:
See Table 8.5-8 for pump plate data.

Table 8.5-8 Pump Plate Data

Pump Number	Pump Manufacturer	Capacity (GPM)	Head (Feet of Water)	Size (Inches)	RPM
# 1	Peerless	9,250	17.6	24”	705
# 2	Peerless	9,250	17.6	24”	705
# 3	Peerless	9,250	17.6	24”	705

Pump Start/Stop Elevations:
Start and stop elevations were spot verified at this pumping plant and found to be within the acceptable range. The start/stop elevations were not verified at every pump station because they were recently found to be acceptable during the periodic inspection conducted by Stantec.

Trash Racks:
Visual inspection found the inlet trash racks to be in acceptable condition.

Sluice Gates and Flap Gates:
All three sluice gates were operated a full open and close cycle (Photo 8.5-10 & 8.5-11). The gates operated acceptably and showed no leakage when the gates were closed. The sluice gate in the discharge gatewell (Photos 8.5-12) was also operated a full open and close cycle acceptably. The smaller flap gate functioned acceptably, but cleaning and painting is recommended (Photo 8.5-13). During the initial visit the larger flap gate was submerged and unable to be completely inspected (Photo 8.5-14). While inspecting the flap gate during the follow-up inspection it was noted that a piece of the top of the flap gate has broken off (Photo 8.5-15 & 8.5-16) and the brace weld is cracked. This is an LSE item and shall be repaired..

Photo 8.5-10 Highland Pump Station Sluice Gates Open

Photo 8.5-11 Highland Street Pump Station Sluice Gates Closed

Photo 8.5-12 Highland Street Discharge Gatewell

Photo 8.5-13 Highland Street Pump Station Smaller Flap Gate

Photo 8.5-14 Highland Street Larger Flap Gate Initial Condition

Photo 8.5-15 Highland Street Larger Flap Gate Follow-Up Condition

Photo 8.5-16 Missing Section in Highland St Flap Gate

Air Vents and Siphon Breakers:
The siphon breakers could not be accessed due to a locked bar (Photo 8.5-17). It is recommended that the siphon breakers be inspected by levee personnel to assess their condition and repair as necessary. Typical air vent condition noted for record (Photo 8.5-18).

Photo 8.5-17 Highland Street Pump Station Air Vents and Siphon Breakers

Photo 8.5-18 Highland Street Pump Station Typical Air Vent Condition

Pump Operation Inspection and Coast-Down Times:

Audio and visual inspections were performed during the operation of all pumps. Velocity readings, collected using a digital velocity meter, were used in conjunction with the

General Machinery Vibration Severity Chart from IRD Mechanalysis to determine vibration level. Pump velocity and vibration data are recorded in Table 8.5-9. It was determined that pump #1 and #2 were fair and need to be monitored to see if condition worsens. Pump #3 was within the “good” operating. Pump coast down times could not be recorded due to the impellers being submerged. Coast down times are shown below in Table 8.5-10.

Table 8.5-9 Vibration Study Results

Highland Street		Readings		Results	
		X	Y	X	Y
Pump #1	Vel. (in/sec)	0.11	0.09	Fair	Fair
Pump #2	Vel. (in/sec)	0.08	0.08	Fair	Fair
Pump #3	Vel. (in/sec)	0.05	0.07	Good	Good

Table 8.5-10 Pump Coast-Down Times

Equipment	Coast Down Time
Pump #1	TBD
Pump #2	TBD
Pump #3	TBD

8.5.1.4. Perry Street Pumping Plant

Pump Plate Data:

Pump Plate data is shown in Table 8.5-11 below.

Table 8.5-11 Pump Plate Data

Pump Number	Pump Manufacturer	Capacity (GPM)	Head (Feet of Water)	Size (Inches)	RPM
# 1	Peerless	20,000	20.4	36”	510
# 2	Peerless	20,000	20.4	36”	510
# 3	Peerless	20,000	20.4	36”	510
# 4	Peerless	3,000	29.2	14”	1180

Pump Start/Stop Elevations:

Start and stop elevations were not spot verified at this pumping plant. The start/stop elevations were not verified at every pump station because they were recently found to be acceptable during the periodic inspection conducted by Stantec.

Trash Racks:

Visual inspection found the inlet trash racks to be in acceptable condition.

Sluice Gates and Flap Gates:
All three sluice gates were operated a full open and close cycle (Photo 8.5-19). The gates operated acceptably, but minor leakage was noted when the gates were closed (Photo 8.5-20). This may be corrected with wedge adjustment. The pump discharge flap gates are shown in (Photo 8.5-8.5-21). The flap gate for pump #2 is missing a nut (Photo 8.5-22). This is an LSE issue. The sluice gate in the gravity discharge gatewell (Photo 8.5-23) was operated a full open and close cycle acceptably. The flap gate for the gravity discharge had some debris around the seal face (Photo 8.5-24).

Photo 8.5-19 Perry Street Pump Station Sluice Gates

Photo 8.5-20 Perry Street Pump Station Minor Leakage

Photo 8.5-21 Perry Street Pump Station Flap Gates

Photo 8.5-22 Perry Street Pump Station Pump #2 Flap Gate Missing Nut

Photo 8.5-23 Perry Street Pump Station Gatewell Sluice Gate

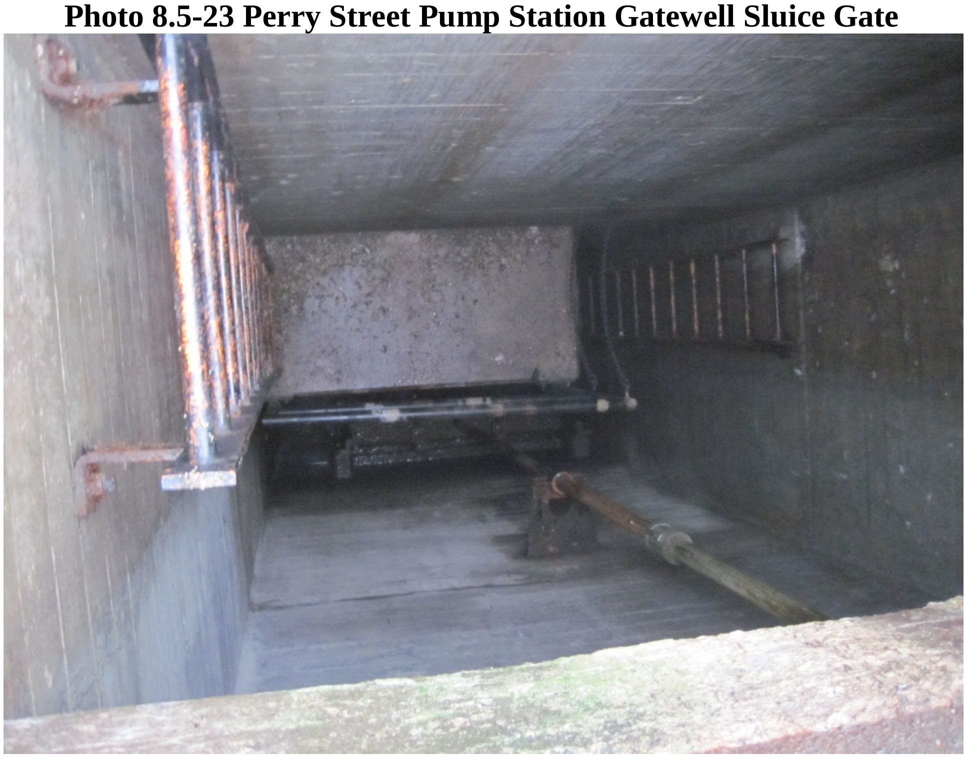


Photo 8.5-24 Perry Street Pump Station Gravity Discharge Flap Gate

Air Vents and Siphon Breakers:
Air vents and siphon breakers are not present at this station.

Pump Operation Inspection and Coast-Down Times:
Audio and visual inspections were performed during the operation of all pumps. Velocity readings, collected using a digital velocity meter, were used in conjunction with the General Machinery Vibration Severity Chart from IRD Mechanalysis to determine vibration level. Pump velocity and vibration data are recorded in Table 8.5-12. It was determined that all pumps were within the "good" operating category. Pump coast down times could not be recorded due to the impellers being submerged. Coast down times are shown below in Table 8.5-13.

Table 8.5-12 Vibration Study Results

Perry Street		Readings		Results	
		X	Y	X	Y
Pump #1	Vel. (in/sec)	0.03	0.05	Very Good	Good
Pump #2	Vel. (in/sec)	0.03	0.04	Very Good	Good
Pump #3	Vel. (in/sec)	0.03	0.02	Very Good	Very Good
Pump #4	Vel. (in/sec)	0.02	0.02	Very Good	Very Good

Table 8.5-13 Pump Coast-Down Times

Equipment	Coast Down Time
Pump #1	TBD
Pump #2	TBD
Pump #3	TBD

8.5.1.5. St. Clair Pumping Plant

Pump Plate Data:
See Table 8.5-14 for pump plate data.

Table 8.5-14 Pump Plate Data

Pump Number	Pump Manufacturer	Capacity (GPM)	Head (Feet of Water)	Size (Inches)	RPM
# 1	Peerless	23,000	14.7	36”	595
# 2	Peerless	23,000	14.7	36”	595
# 3	Peerless	23,000	14.7	36”	595
# 4	Peerless	8,000	23.2	20”	885

Pump Start/Stop Elevations:
Start and stop elevations were spot verified at this pumping plant and found to be within the acceptable range. The start/stop elevations were not verified at every pump station because they were recently found to be acceptable during the periodic inspection conducted by Stantec.

Trash Racks:
Visual inspection found the inlet trash racks to be in acceptable condition.

Sluice Gates and Flap Gates:
The sluice gate was operated a full open close cycle acceptably (Photo 8.5-25). The four pump discharge flap gates: pump #1 (Photo 8.5-26), pump #4 & #2 (Photo 8.5-27), and pump #3 & #4 (Photo 8.5-28) were visually inspected during operation and determined to be acceptable. The sluice gate in the discharge gatewell (Photo 8.5-29) was operated a full open and close cycle acceptably. The flap gate at the river needs realigned and painting is recommended (Photo 8.5-30).

Photo 8.5-25 St. Clair Pump Station Sluice Gate

Photo 8.5-26 St. Clair Pump Station Pump #1 Discharge

Photo 8.5-27 St. Clair Pump Station Pump #4 & #2 Discharge Flap Gate

Photo 8.5-28 St. Clair Pump Station #3 & #4 Discharge Flap Gate

Photo 8.5-29 St. Clair Pump Station Gatewell Sluice Gates

Photo 8.5-30 St. Clair Pump Station Discharge Flap Gate

Air Vents and Siphon Breakers:
Air vents and siphon breakers are not present at this pumping plant.

Pump Operation Inspection and Coast-Down Times:
Audio and visual inspections were performed during the operation of all pumps. Velocity readings, collected using a digital velocity meter, were used in conjunction with the General Machinery Vibration Severity Chart from IRD Mechanalysis to determine vibration level. Pump velocity and vibration data are recorded in Table 8.5-15. It was determined that all pumps were within the “good” operating category except Pump #2 in the Y direction. It is recommended that this pump be monitored to see if the condition worsens. Pump coast down times could not be recorded due to the impellers being submerged. Coast down times are shown in Table 8.5-16.

Table 8.5-15 Vibration Study Results

St. Clair		Readings		Results	
		X	Y	X	Y
Pump #1	Vel. (in/sec)	0.04	0.07	Good	Good
Pump #2	Vel. (in/sec)	0.04	0.08	Good	Fair
Pump #3	Vel. (in/sec)	0.04	0.06	Good	Good
Pump #4	Vel. (in/sec)	0.03	0.04	Very Good	Good

Table 8.5-16 Pump Coast-Down Times

Equipment	Coast Down Time
Pump #1	TBD
Pump #2	TBD
Pump #3	TBD
Pump #4	TBD

8.5.1.6. Sixth Street Pumping Plant

Pump Plate Data:
See Table 8.5-17 for pump plate data.

Table 8.5-17 Pump Plate Data

Pump Number	Pump Manufacturer	Capacity (GPM)	Head (Feet of Water)	Size (Inches)	RPM
# 1	Flygt P7050	9000	8.0	28	700
# 2	Flygt P7050	9000	8.5	28	700
# 3	Flygt P7050	9000	9.3	28	700

Pump Start/Stop Elevations:
Start and stop elevations were not spot verified at this pumping plant. The start/stop elevations were not verified at every pump station because they were recently found to be acceptable during the periodic inspection conducted by Stantec.

Trash Racks:
Visual inspection found the inlet trash racks to be in acceptable condition.

Sluice Gates and Flap Gates:
The electrically actuated sluice gate (Photo 8.5-31) initially would not operate due to faulty underground wiring. This wiring was replaced and the gate was operated a full open full close cycle. The three pump discharge gates (Photo 8.5-32) and the single gravity flap gate (Photo 8.5-33) were inspected and found to be acceptable other than delaminating paint and corrosion (Photo 8.5-34).

Photo 8.5-31 Sixth Street Pump Station Electric Gate Actuator

Photo 8.5-32 Sixth Street Pump Station Pump Discharge Flap Gates

Photo 8.5-33 Sixth Street Pump Station Gravity Discharge Flap Gate

Photo 8.5-34 Sixth Street Pump Station Delaminating Paint and Corrosion

Pump Operation Inspection and Coast-Down Times:
Due to these being submersible pumps, no vibration or coast time data could be taken.

8.5.1.7. City Ditch Pumping Plant

Pump Plate Data:
See Table 8.5-18 for pump plate data.

Table 8.5-18 Pump Plate Data

Pump Number	Pump Manufacturer	Capacity (GPM)	Head (Feet of Water)	Size (Inches)	RPM
# 1	Patterson	50,000	20.5	42”	400
# 2	Patterson	50,000	20.5	42”	400

Pump Start/Stop Elevations:
Start and stop elevations were not spot verified at this pumping plant. The start/stop elevations were not verified at every pump station because they were recently found to be acceptable during the periodic inspection conducted by Stantec.

Trash Racks:
Visual inspection found the inlet trash racks to be in acceptable condition.

Sluice Gates and Flap Gates:
Both sluice gates was operated a full open close cycle acceptably. Both flap gates were visually inspected. The flap gate for pump #1 was missing the rubber seal (Photo 8.5-35). It is recommended that a new seal be installed.. The flap gate for Pump #2 had slight movement at the ear attaching the hinge arm to the headwall (Photo 8.5-36). It is recommended that these bolts be investigated and the gate aligned if necessary. All three gravity sluice were operated a full open and close cycle acceptably (Photo 8.5-37).

Photo 8.5-35 City Ditch Pump Station Pump #1 Flap Gate Missing Rubber Seal

Photo 8.5-36 City Ditch Pump Station Pump #2 Flap Gate

Photo 8.5-37 City Ditch Gravity Sluice Gates

Air Vents and Siphon Breakers:
Air vents and siphon breakers are not present at this pumping plant.

Pump Operation Inspection and Coast-Down Times:
Audio and visual inspections were performed during the operation of all pumps. Velocity readings, collected using a digital velocity meter, were used in conjunction with the General Machinery Vibration Severity Chart from IRD Mechanalysis to determine vibration level. Pump velocity and vibration data are recorded in Table 8.5-19. It was determined that all pumps were within the "good" operating category. Pump coast down times could not be recorded due to the impellers being submerged. Coast down times are shown in Table 8.5-20 below.

Table 8.5-19 Vibration Study Results

City Ditch		Readings		Results	
		X	Y	X	Y
Pump #1	Vel. (in/sec)	0.04	0.07	Good	Good
Pump #2	Vel. (in/sec)	0.03	0.06	Very Good	Good

Table 8.5-20 Pump Coast-Down Times

Equipment	Coast Down Time
Pump #1	TBD
Pump #2	TBD

8.5.1.8. Miscellaneous Sluice Gates

The sanitary treatment plant sluice gate (Brevoort Levee Station 659+26) is inoperable. This is an LSE item and shall be repaired/replaced (Photo 8.5-38).

Photo 8.5-38 Sanitary Treatment Plant Gatewell

The sluice gate located at Patrick Henry Drive (GW-16) operated acceptably (Photo 8.5-39).

Photo 8.5-39 Patrick Henry Drive Sluice Gate

The sluice gate located at gatewell #14 is planned to be abandoned (Photo 8.5-40).

Photo 8.5-40 Gatewell #14 Sluice Gate

The sluice gate located at gatewell #13 is planned to be abandoned (Photo 8.5-41).

Photo 8.5-41 Gatewell #13 Sluice Gate

The sluice gate located at gatewell #11 is planned to be abandoned (Photo 8.5-42).

Photo 8.5-42 Gatewell #11 Sluice Gate

The sluice gate located at gatewell #9 is planned to be abandoned (Photo 8.5-43).

Photo 8.5-43 Gatewell #9 Sluice Gate

The sluice gate located at gatewell #10 is planned to be abandoned (Photo 8.5-44).

Photo 8.5-44 Gatewell #10 Sluice Gate

The sluice gate located at gatewell #8 operated acceptably (Photo 8.5-45).

Photo 8.5-45 Gatewell #8 Sluice Gate

The sluice gate located at gatewell #12 operated acceptably (Photo 8.5-46).

Photo 8.5-46 Gatewell #12 Sluice Gate

The sluice gate located at gatewell #15 operated acceptably (Photo 8.5-47).

Photo 8.5-47 Gatewell #15 Sluice Gate

The gravity sluice gate located at Perry Street P.S. operated acceptably (Photo 8.5-48).

Photo 8.5-48 Gravity Gatewell at Perry Street P.S.

The sluice gate located at gatewell #6 is inoperable and shall be properly abandoned as permitted. This is an LSE item (Photos 8.5-49 and 8.5-50).

Photo 8.5-49 Gatewell #6 Sluice Gate

Photo 8.5-50 Gatewell #6 Sluice Gate

The sluice gate located at gatewell #5 is inoperable and shall be properly abandoned as permitted (Photos 8.5-51 and 8.5-52). This is an LSE item.

Photo 8.5-51 Gatewell #5 Sluice Gate

Photo 8.5-52 Gatewell #5 Sluice Gate

The sluice gate located in Manhole 1C is inoperable and shall be replaced. This is an LSE item.

8.5.1.9. Miscellaneous Flap Gates

The flap gate located at Patrick Henry Drive (GW #16) is corroded and needs cleaned and painted (Photo 8.5-53).

Photo 8.5-53 Flap Gate Located at Patrick Henry Drive

The flap gate for the City condensation drainage at GW #15 is slightly misaligned and needs adjusted (Photo 8.5-54).

Photo 8.5-54 Flap Gate for City Condensation Drainage

The flap gate for gatewell #12 contains debris and is unable to close. Remove debris so gate can operate freely (Photo 8.5-55).

Photo 8.5-55 Flap Gate for Gatewell #12

The flap gate for gatewell #11 is silted in and is unable to close. Remove debris so gate can operate freely (Photo 8.5-56).

Photo 8.5-56 Flap Gate for Gatewell #11

The flap gate for gatewell #8 is misaligned and needs adjusted (Photo 8.5-57).

Photo 8.5-57 Flap Gate for Gatewell #8

The flap gate for gatewell #6 is corroded and needs painted. This line is to be abandoned.

Photo 8.5-58 Flap Gate for Gatewell #6

The flap gate located at Pearl City (Station 200+75) has corroded bolts and needs painted. This gate has been replaced under Permit No. 2011035.VIN (Photo 8.5-59).

Photo 8.5-59 Flap Gate Located at Pearl City

The flap gate for the waste water treatment plant is recommended to be cleaned and painted (Photo 8.5-60).

Photo 8.5-60 Flap Gate for Waste Water Treatment Plant

8.5.2. Mechanical Conclusion

Aside from the LSE items listed in Table 8.1-1, the Vincennes Sound Reach meets all mechanical requirements for a positive NFIP Levee System Evaluation.

8.6. Electrical Evaluation

8.6.1. Electrical Systems Summary

The Vincennes Sound Reach consists of seven pump stations; Sixth Street, Second Street, Highland Street, St. Claire Street, College Avenue, Perry Street and City Ditch. All pump stations are 480 VAC secondary. Duke Energy, the local utility, owns and maintains all service transformers except for St Claire and Perry Street Stations There is no contract for annual service of the transformers; issues are handled on a case by case basis. Emergency power is not available at six of the seven stations, but maintenance personnel indicate that during a power outage, the utility prioritizes the stations for repair. The City of Vincennes is presently in the process of upgrading all pump station power distribution equipment. All but two stations (Second St and Highland St) have been updated, and there are plans to upgrade Second Street and Highland Street pump stations in the near future.

Vincennes is currently implementing plans to integrate all of the flood pump stations into the existing city wide Supervisory Control and Data Acquisition (SCADA) system. At present, only College Avenue and Perry Street are connected to the SCADA system. The SCADA system will be utilized for remote status indication. The stations are currently controlled via float switches (original equipment) and hydrostatic level transducers (upgraded equipment). Stations with original controls are planned to be upgraded to hydrostatic level transducers.

An arc flash hazard analysis has not been performed therefore arc flash ratings are not on the power distribution equipment. If live electrical work must be performed, electrical maintenance personnel possess arc flash equipment and are familiar with National Fire Protection Association (NFPA) 70E, Electrical Safety in the Workplace, but have not been formally trained in arc flash safety.

Maintenance personnel are very knowledgeable about the project and are actively maintaining the levee system. The electrical systems within the pumping plants are in good condition and will perform effectively during a 1% chance (100 year) flood with the 95% chance assurance.

Sixth Street Pump Station

Power is provided to the Sixth Street Pump Station via pole-mounted transformers. The three pole-mounted, single phase transformers, each rated 50 kVA, with 480 volt grounded delta secondary, provides power to the pumps. The local utility, Duke Energy, owns and maintains the station service transformers. Control power is via a control power transformer mounted within the control panel.

Photo 8.6-1 Sixth St Control Panel

The Sixth Street Pump Station differs from all the other pump stations in that it is a submersible station. The pumps are submersible type and located within a sump adjacent to Niblack Blvd. Power distribution equipment and control hardware is located in a control panel (photo 8.6-1) next to the sump area. The control panel equipment is in good physical and operating condition. Pump Station system voltage readings (Table 8.6-1) were taken via the MCC mounted voltmeter:

Table 8.6-1 6th St Pump Station System Voltage Readings

A-B	A-C	B-C
492.7 Volts	491.1 Volts	493.6 Volts

The control panel feed the 3 station motors. Motors 1 through 3 are rated 40 HP. They were run dry while current readings (Table 8.6-2) were taken via handheld ammeter:

Table 8.6-2 6th St Motor Amperage

Motor Running	Phase	Amperage	Average	% Difference From Average
Motor #1	A	46.90	46.90	0.00%
	B	47.40		1.07%
	C	46.40		1.07%
Motor #2	A	47.10	47.27	0.36%
	B	47.90		1.33%
	C	46.80		0.99%
Motor #3	A	46.70	46.86	0.34%
	B	47.40		1.15%
	C	46.50		0.77%

An electrical actuator is present at the station and allows water to drain into a creek during low water rain events. (Photo 8.6-2)

Photo 8.6-2 Sixth St Electrical Actuator

The actuator is fed from the pump station and was not tested. The actuator ran partially then stopped working. Insulation testing was performed on the three phase conductors of the actuator controller (photo 18) and results showed 0Ω on the A phase of the circuit. This indicated a short on the branch circuit which caused the actuator to malfunction. This short was also causing the fuses (photo 3018) on the controller to blow. All three phase conductors were replaced and the actuator functioned properly. Maintenance personnel also noted lightning damage to motor contacts (photo 3008), which have since been replaced.

Backup power to the pump station is provided through a portable generator connected via pin and sleeve connectors. A 400 amp, double-throw, non fused manual safety switch transfers power from utility (normal) to portable generator (emergency) (Photo 8.6-3).

Photo 8.6-3 Sixth Street Generator Receptacles and Safety Switch

Second Street Pump Station

Power is provided to the Second Street Pump Station via pole-mounted transformers located adjacent to the pumping plant. Three pole-mounted single phase transformers rated 25kVA, with 480 volt delta secondary each provides power to the pumps. A 120/240 volt service provides power for lights, receptacles, sump pump, and heater. The local utility, Duke Energy, owns and maintains the station service transformers.

The existing motor starting equipment consists of two wall mounted Westinghouse control panels. The equipment is outdated but it is in good operating condition (photo 8.6-4).

Photo 8.6-4 Second Street Pump Station Motor Control Equipment

Pump Station system voltage readings were not taken due to the fact that the incoming power was fed through a tapped 200A non-fused disconnect (Photo 8.6-5), which presents an arc flash hazard.

Photo 8.6-5 Second Street Pump Station non-fused disconnect

Each control panel feeds an individual motor. Both motors are rated 25 HP. They were run dry while current readings (Table 8.6-3) were taken through the MCC mounted ammeter due to the arc flash concerns:

Table 8.6-3 Second St Motor Amperage

Equipment	Amperage
Motor 1 (Phase A)	26
Motor 2 (Phase A)	28 to 30

During a flood event the motors are controlled via a float level control system. In case of a control system failure, the motors can be manually controlled at the control panels within the pump station. (Photo 8.6-6).

Photo 8.6-6 Second Street Pump Station Wet Well Indicator and Float Control

Low hanging communication cables are currently resting on the station roof parapet wall (Photo 8.6-7).

Photo 8.6-7 AT&T Communications Lines resting on Second St. PS Parapet Wall

The cables in question belong to AT&T. The local sponsor has been given USACE's standard operating procedure for the routing of electrical lines over, under, and around floodwalls, levees, and pump stations. They are coordinating with AT&T to obtain the required clearances for the lines above the pump station.

Highland Street Pump Station

Power is provided to the Highland Street Pump Station via pole-mounted transformers located adjacent to the pumping plant. Three single phase pole-mounted transformers rated 50kVA, with 480 volt delta secondary provides power to the pumps. A 120/240 volt service provides power for lights, receptacles, sump pump, and heater. The local utility, Duke Energy, owns and maintains the station service transformers.

The existing motor control center (Photo 8.6-8) is Westinghouse switchgear. The controls for Motor 1 work intermittently, while Motor 3 is out of rotation due to its lack of reliability and breaker malfunctions.

Photo 8.6-8 Highland Street Pump Station Motor Control Center

Pump Station system voltage readings were not taken due to the fact that the incoming power was fed through a tapped 400A non-fused disconnect, which presents an arc flash hazard. The MCC is in need of replacement and the City of Vincennes is in the process of upgrading to a Square D Model 6 MCC in the future.

The MCC feeds 3 motors, rated 50 HP each. Pumps were run with water in the sump and current readings (Table 8.6-4) were taken through the MCC mounted ammeter due to the arc flash concerns:

Table 8.6-4 Highland St Motor Amperage

Motor Running	Phase	Amperage	Average	% Difference From Average
Motor #1	A	68.00	69.00	1.45%
	B	70.00		1.45%
	C	69.00		0.00%
Motor #2	A	68.00	68.00	0.00%
	B	68.50		0.74%
	C	67.50		0.74%
Motor #3	A	70.00	70.13	0.19%
	B	70.50		0.52%
	C	69.90		0.33%

The COE Operational Plate indicates pump motors 1 through 3 should have amperage of less than 28 A when dry run, and amperage of less than 66 A for wet run. All pumps were slightly above their wet run amperage rating.

During a flood event the station is automatically controlled by a float system. The city plans to utilize a hydrostatic pressure transducer in the future. Also, Highland Street pump station is planned to be added to the Vincennes SCADA system for remote status.

St. Claire Street Pump Station

Power is provided to the St. Claire Street Pump Station via a substation located adjacent to the pumping plant. Three single phase pad mounted transformers (photo 3053) rated 167kVA, with 480 volt delta secondary provides power to the pumps. A 120/240 volt service provides power for lights, receptacle, heater and sump pump. The city owns the station service transformers, and maintenance personnel indicate that they currently need to set up a contract for servicing the equipment.

The existing motor control center is a Square D Model 6, 4 section switchgear. Maintenance had indicated that MCC was installed within the past 12 years and is in good condition. Pump Station system voltage readings (Table 8.6-5) were taken using a handheld voltmeter. The readings showed a +10% variation from the 440VAC motor nameplate values.

Table 8.6-5 St. Claire P.S. System Voltage Readings

A-B	A-C	B-C
492.7 Volts	495.4 Volts	497.1 Volts

The MCC feeds 4 motors. Motors 1 through 3 are rated 125 HP. Motor 4 is rated 50 HP. Motors 1 through 3 were run dry while motor 4 was run under load. Current readings (Table 8.6-6) were taken through a handheld ammeter.

The COE Operational Plate indicates pump motors 1 through 3 should have amperage of less than 80 A when dry run, and amperage of less than 174 A for wet run. Pump motor 4 should have amperage of less than 27 A when dry run, and amperage of less than 64 A for wet run.

During a flood event the station is automatically controlled by a float system on a sensor.

Table 8.6-6 St. Claire Motor Amperage

Motor Running	Phase	Amperage	Average	% Difference From Average
Motor #1	A	95.10	97.77	2.73%
	B	98.20		0.44%
	C	100.00		2.28%
Motor #2	A	88.1	90.67	2.83%
	B	90.70		0.04%
	C	93.20		2.79%
Motor #3	A	179.10	172.37	3.91%
	B	178.00		3.27%
	C	160.00		7.17%
Motor #4	A	40.30	41.27	2.34%
	B	41.30		0.08%
	C	42.20		2.26%

College Avenue Pump Station

Power is provided to the College Avenue Pump Station via pole-mounted transformers located adjacent to the pumping plant. Three single phase pole-mounted transformers rated 50kVA, with 480 volt wye secondary provides power to the pumps. The local utility, Duke Energy, owns and maintains the station service transformers.

Photo 8.6-9 College Ave Pump Station Motor Control Center

The existing motor control center (Photo 8.6-9) is a Square D Model 6, 3 section switchgear. Maintenance had indicated that MCC was recently installed and in new condition. Panel mounted lighting transformer and lighting panel provides power for lighting, heat, and control power. Pump Station system voltage readings (Table 8.6-7) were taken using a handheld voltmeter. The readings showed a +10% variation from the 440VAC motor nameplate values.

Table 8.6-7 College St. P.S. System Voltage Readings

A-B	A-C	B-C
496.1 Volts	495.7 Volts	494.1 Volts

The MCC feeds 3 motors. Motors 1 through 3 are rated 30 HP. They were run dry while current readings (Table 8.6-8) were taken via handheld ammeter:

Table 8.6-8 College St. Motor Amperage

Motor Running	Phase	Amperage	Average	% Difference From Average
Motor #1	A	24.60	24.80	0.81%
	B	24.90		0.40%
	C	24.90		0.40%
Motor #2	A	22.90	23.43	2.28%
	B	23.90		1.99%
	C	23.50		0.28%
Motor #3	A	21.70	22.33	2.84%
	B	22.60		1.19%
	C	22.70		1.64%

During a flooding event the station is automatically controlled via the hydrostatic pressure transducer and it is monitored by the Vincennes SCADA system (Photo 8.6-10).

Photo 8.6-10 College Ave Pump Station SCADA System Enclosure

Perry Street Pump Station

Power is provided to the Perry Street Pump Station via a substation located adjacent to the pumping plant. Three single phase pad mounted transformers rated 167kVA, with 480 volt ungrounded delta secondary provides power to the pumps. Transformer cutouts have recently been replaced, indicated by maintenance personnel. A 120/240 volt service provides power for lights, receptacle, heater and sump pump. The city owns the pump service transformers, and maintenance personnel indicate that they currently need to set up a contract for servicing the equipment. Currently, plans are in place to update the decking on which the substation sits.

The existing motor control center is a Square D Model 6, 4 section switchgear. Maintenance had indicated that MCC was recently installed and in good working condition. Pump Station system voltage readings (Table 8.6-9) were taken using a handheld voltmeter.

Table 8.6-9 Perry St. P.S. System Voltage Readings

A-B	A-C	B-C
472.6 Volts	474.4 Volts	471.5 Volts

The MCC feeds 3 motors. Motors 1 through 3 are rated 125 HP and motor 4 is rated 30 HP. Maintenance noted that motor 4 had been installed within the past six months. The motors were run under load and current readings (Table 8.6-10) were taken via handheld ammeter:

Table 8.6-10 Perry St Motor Amperage

Motor Running	Phase	Amperage	Average	% Difference From Average
Motor #1	A	159.10	158.80	0.19%
	B	152.30		4.09%
	C	165.00		3.90%
Motor #2	A	161.60	163.97	1.44%
	B	161.20		1.69%
	C	169.10		3.13%
Motor #3	A	169.10	168.97	0.08%
	B	167.40		0.93%
	C	170.40		0.85%
Motor #4	A	33.90	33.53	1.09%
	B	32.90		1.89%
	C	33.80		0.80%

During a flooding event the station the station is automatically controlled via the hydrostatic pressure transducer and it is monitored by the Vincennes SCADA system.

City Ditch Pump Station

Power is provided to the City Ditch Pump Station via pole-mounted transformers located adjacent to the pumping plant. Three single phase pole-mounted transformers (Photo 8.6-11) rated 333kVA, with 480 volt delta secondary provides power to the pumps. The local utility, Duke Energy, owns the pump service transformers, and maintenance personnel indicate that they are serviced once a year.

Photo 8.6-11 City Ditch Pump Station Service Transformers

The existing motor control center is a Square D Model 6, 5 section switchgear. Panel mounted lighting transformer and lighting panel provides power for lighting, heat, and control power. Two ReactiVar power factor correction capacitors are used to correct the pumps' power factor due to the larger size pump being utilized.. Pump Station system voltage readings (Table 8.6-11) were taken using the MCC mounted PowerLogic Circuit Monitor.

Table 8.6-11 City Ditch P.S. System Voltage Readings

A-B	A-C	B-C
495 Volts	496 Volts	497 Volts

The MCC feeds 2 motors. Motors 1 and 2 (Photo 8.6-12) are rated 400 HP.

Photo 8.6-12 City Ditch Pump Station Pump Motors

The motors were run wet while current readings (Table 8.6-12) were taken from the MCC mounted PowerLogic Circuit Monitor:

Table 8.6-12 City Ditch Motor Amperage

Motor Running	Phase	Amperage	Average	% Difference From Average
Motor #1	A	213.00	222.00	4.05%
	B	228.00		2.70%
	C	225.00*		1.35%
Motor #2	A	246.00	253.33	2.89%
	B	263.00		3.82%
	C	251.00		0.92%

*Phase C on Motor #1 varied from 213A to 256A. This is an effect of the power factor correction system trying to stabilize the pump station's power factor.

During a flooding event the station is automatically controlled via a bubbler level controller system. Plans are in place to incorporate the pump station onto the Vincennes SCADA system.

The pump station also has two electrically driven sluice gates. They were both run under load conditions and operated without incident. Current measurements were taken (Table 8.6-13) using a handheld multimeter:

Table 8.6-13 City Ditch Sluice Gate Motor Amperage

Motor Running	Direction	Phase	Amperage	Average	% Difference From Average
Sluice Gate Motor #1	Up	A	4.20	4.00	5.00%
		B	3.80		5.00%
		C	4.00		0.00%
	Down	A	3.80	3.73	1.79%
		B	3.40		8.93%
		C	4.00		7.14%
Sluice Gate Motor #2	Up	A	4.80	4.63	3.60%
		B	4.40		5.04%
		C	4.70		1.44%
	Down	A	4.30	4.13	4.03%
		B	3.70		10.48%
		C	4.40		6.45%

8.6.2. Motor Insulation Testing

Below are the results of the 2012 motor winding insulation testing:

Table 8.6-14 2012 Motor Winding Insulation Testing

Station	**Motor Number**	**10 Minute Resistance**	**1 Minute Resistance**	**Polarization Index Value**	**Status**
Sixth Street PS					
	1	132.85 G Ohm	69.087 G Ohm	1.923	
	2	168.01 G Ohm	74.374 G Ohm	2.259	
	3	213.67 G Ohm	111.93 G Ohm	1.909	
Second Street PS					
	1	1.68 G Ohm	1.31 G Ohm	1.275	
	2	2.62 G Ohm	1.53 G Ohm	1.716	
Highland Street PS					
	1	882.61 M Ohm	618.94 M Ohm	1.426	
	2	2.16 G Ohm	990.14 M Ohm	2.183	
	3	433.42 M Ohm	202.72 M Ohm	2.138	
St. Clair Street PS					
	1	32.58 M Ohm	22.77 M Ohm	1.431	
	2	987.28 M Ohm	651.24 M Ohm	1.516	
	3	522.59 M Ohm	362.16 M Ohm	1.443	
	4	965.49 M Ohm	517.69 M Ohm	1.865	

College Avenue PS					
	1	353.76 G Ohm	262.24 G Ohm	1.349	
	2	444.01 G Ohm	329.14 G Ohm	1.349	
	3	581.54 G Ohm	413.91 G Ohm	1.405	
Perry Street PS					
	1	252.10 M Ohm	186.88 M Ohm	1.349	
	2	363.72 M Ohm	229.62 M Ohm	1.584	
	3	168.72 M Ohm	129.67 M Ohm	1.301	
	4	144.95 M Ohm	82.312 M Ohm	1.761	
City Ditch PS					
	1	2.97 G Ohm	1.21 G Ohm	2.467	
	2	4.01 G Ohm	1.57 G Ohm	2.541	

Ok -
Future Concern -

Motor winding insulation resistance testing tests the electrical resistance of the windings of a motor. The insulation of the windings degrades over time when exposed to heat, moisture and pollution. Resistance readings are taken in pre-set intervals to indicate the status of the insulation value. A polarization (PI) index is the ratio of the insulation value at 10 minutes over the insulation value at 60 seconds. For motors manufactured before 1970 (which includes most of the motors above), a PI of between 2 and 7 indicates that the motor insulation is in good condition. Normally, a PI of below 2 indicates that moisture damage to the winding insulation has most likely occurred. The reported data has the majority of the pump motors below 2 for their PI values. However, when the resistance values are above 1000 megohms (1 gigaohm) the PI value is not utilized since it is clear that the winding is clean and dry. The electrical inspectors have designated different status's looking at both resistance values and PI ratios. Further investigation of the questionable motors is recommended. Possible repair of the motors (including disassemble, dipping and baking of the motor windings) will have to be accomplished if damage is revealed in the investigation.

8.6.3. Levee System Evaluation Issues

1. Replace existing unreliable MCC equipment (motors #1 and #3 power distribution equipment) with new MCC equipment at Highland Street PS.

8.6.4. Operation and Maintenance Recommendations

1. Investigate conducting an Arc Flash study for each pump station.
2. Set up transformer servicing contract for Perry Street PS and St. Claire Street PS.
3. Replace non-fused disconnects with fused disconnects at Second Street PS and Highland Street PS.

8.6.5. Electrical Conclusions

Aside from the need for repair to the power distribution equipment at Highland Street Pump Station, the Vincennes Sound Reach meets all applicable electrical requirements for a positive Levee System Evaluation.

9. SYSTEM EVALUATION

9.1. Flood Warning and Emergency Evacuation Plan

The Flood Warning and Emergency Evacuation Plan (FWEEP) for the subject project is located in Appendix T.

9.2. Probability of Failure

There is only a 0.3% chance of levee overtopping for the 1% chance (100-year) flood and only a 0.5% chance of overtopping for the 0.2% chance (500-year) flood.

9.3. Capacity Exceedance

The Vincennes Segment is designed based on exceeding the height of the Illinois levee across the river (Russell Allison) by three feet. There is no designed overflow section of the levee/floodwall system, which would allow for the interior area to backflow without a failure of the levee embankment. If an event occurred that exceeded the design capacity, the Brevoort Section would theoretically overtop first, and portions of the City would be flooded from the south. For the majority of the city of Vincennes to be flooded, a breach prior to overtopping along the Vincennes Segment would have to occur. If an event occurred that did exceed the design capacity of the levee/floodwall for this reach, there would be the potential for the development of high velocity flows in the interior, which could impair or limit the ability to evacuate the area. However, the frequency of an overtopping event for the Vincennes Segment is very low.

10. RESIDUAL RISK AND PUBLIC SAFETY

It is understood that there will always be a chance that a levee system composed of embankment and floodwalls can be overtopped by an extreme event. As such, any levee system can have residual risks and public safety concerns that are significant during the occurrence of flood events exceeding the capacity of the levee/floodwall system. The following paragraphs describe the issues associated with potential overtopping and discuss specifically how those risks are being addressed for the Vincennes segment of the Brevoort-Vincennes Levee System.

As discussed earlier, there is only a 0.3% chance of levee overtopping for the 1% chance (100-year) flood and only a 0.5% chance of overtopping for the 0.2% chance (500-year) flood.

For any overtopping event, there will always be an impact on floodplain residents, businesses, transportation systems, and other critical infrastructure systems. For example, Figure 1.2-1 shows the 1% chance floodplain area that would be impacted by levee failure. An overtopping flood event may show similar results. For the Vincennes area within the levee system, it's recognized that there would be two primary routes for evacuation, U.S. Highway 41 and U.S. Highway 150. With the flood warning forecasts that could predict levee overtopping many days in advance, there would be sufficient time for a complete evacuation from the area. Based on current early warning systems, no loss of life is anticipated for an extreme event due to sufficient time to evacuate.

11. RESULT OF PROJECT SYSTEM EVALUATION STUDY

Based on each specific disciplines' conclusions and all other criteria evaluated as part of EC 1110-2-6067 *USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation*, dated 31 August 2010, it has been determined that the subject project can be provided a positive LSE letter with the proper correction and positive findings to the listed LSE issues shown in Table 8.1-1 and Table 8.1-2.

Vincennes Levee Issue Summary 7/14/14

The original local flood protection project for the City of Vincennes was authorized by the Federal Flood Control Act of 1946 and was funded by Congress through the US Army Corps of Engineers (USACE). It consisted of five sections: Section A, Parts 1 & 2, and Section B, Parts 1, 2a and 2b. Section A, Parts 1 & 2 and Section B, Part 2 were constructed by the USACE from 1952 to 1962 and were assigned to the City of Vincennes for operation and maintenance in November 1960. The two remaining sections, which would complete the protection of the city, were not constructed due to what is recorded in the 1983 economic study as "problems encountered during right of way acquisition". The USACE designed and built the levee on easements and right of way the City of Vincennes acquired per the USACE requirements and when the levee was turned over to the city, the Mayor and City Council agreed to "… maintain and operate without expense to the United States the completed flood control structures and works in accordance with regulations prescribed by the Secretary of the Army".

In 1980, Mayor Rose requested the USACE complete "the final stage of the Vincennes City Flood Protection". The USACE then began a study that culminated in the "USACE Design Memorandum No. 3, Report on Economics", completed in 1983. This report investigated the completion of the Vincennes levee from an economic standpoint and finally recommended reclassifying "the uncompleted portion of the local flood protection project for Vincennes, Indiana…from the "deferred" to the "inactive" category of civil works projects", which was approved on April 21st, 1983. The project funding was then deauthorized by Congress through Public Law 99-662 on November 17, 1986.

What the study declared was that the Brevoort agricultural Levee south of Vincennes provided enough protection to Vincennes that it was not economically feasible to complete the remaining unconstructed portions of the Vincennes Levee. The report states that the Brevoort Levee only officially provides a 50-year level of protection when including the FEMA required 3' of freeboard but was considered adequate because the USACE stated it does provide 100-year protection with minimal freeboard (1.5'). In simple terms the report said that even though Brevoort didn't meet the exact FEMA requirements to provide a 100 year level of flood protection for the 100 year base flood event (BFE), it provided enough protection to terminate the completion of the Vincennes Levee.

Consequently, when FEMA created the most current Flood Insurance Rate Map (FIRM) for Vincennes and Knox County in 1984, both the Vincennes and Brevoort Levees were shown as providing protection "from the one-percent annual chance (100-year) flood by levee, dike, or other structures". All development within these levees was built under the minimal requirements for levee protected Zone B. The only exceptions in the Brevoort area were the areas that were rated as Zone A due to internal drainage issues.

Fast forward to August 2006 when FEMA notified all communities with a levee system that as part of the Map Modernization Program that they were verifying "that all levees recognized as providing protection from the 1% annual chance (or "base") flood meet the requirements outlined in Title 44 of the Code of Federal Regulations, Section 65.10". FEMA is requesting that these communities, of which Vincennes is one, have an agency such as the USACE or a private engineering firm certify that the levee was adequately designed, constructed and has been operated and maintained to provide protection against the base flood for FEMA to continue to show the levee as providing that protection on the FIRM.

When the USACE looked at Vincennes to grant it Provisional Accredited Levee (PAL) status so the certification process could move forward, the USACE uncovered the issues described above and determined that even though the Brevoort Levee had been deemed minimally adequate to protect the south end of Vincennes in the past, they could no longer support that conclusion that it is adequate at the current time and could not grant PAL status. When Vincennes questioned this change due to the decisions made by the USACE in 1983, the USACE responded that what had happened in the past was not valid because the people who made those conclusions no longer worked for the USACE. Vincennes was dead in the water and worried about losing the flood protection status on the FIRMs, which would cause two major problems if 75% of Vincennes was suddenly declared to be in a Zone A floodplain (area of the 100 year flood) instead of the levee protected Zone B it is currently in. The first problem is that most properties would have to obtain costly flood insurance mandated by their mortgage holders and FEMA. The second problem is that any redevelopment or new development would have to build to stricter floodplain requirements. Most or all new development in Zone A would have to have a finish floor elevation built 2’ above the base flood elevation (BFE) and would be several feet higher than existing ground. These two requirements alone would basically shut down the City of Vincennes.

Vincennes decided to pick up a thread throughout past USACE studies in the region that due to the construction of several reservoirs upstream of Vincennes on the Wabash River, the BFE is actually lower now than it was when the levee was constructed. Another factor to be considered was that the Russell-Allison Levee across the river in Illinois is significantly shorter than Vincennes or Brevoort and had breached in the last two record flood events due to overtopping so additional storage could be considered on the Illinois side. Combine that with more precise modern engineering and surveying methods and there was a real possibility that the revised BFE could be low enough that the Brevoort Levee could provide 100 year protection after all. The USACE, Louisville District was very supportive of this idea and has always tried to help Vincennes as best as it could during the whole process.

Vincennes hired the USACE, Louisville District in February 2010 to perform a hydrology study for the fee of $50,000, which was funded entirely by Vincennes and its partners within the community. The scope of the study was to investigate the current BFE through hydraulic modeling and hydrologic analysis to see how much protection the Vincennes and Brevoort Levees actually provided to the city.

The study is complete and found that the BFE is 2.4’ lower than was used in the original design and mapping. The Levee Evaluation Report states that the Vincennes Levee, in combination with eight miles of the Brevoort Levee can be considered a “sound reach” under FEMA’s new policies regarding non-accredited levees. The eight miles of Brevoort runs from Willow Street to the Wabash Cannonball Bridge and stability issues below the bridge preclude certification of any more of the Brevoort Levee. The USACE has designated the Vincennes Levee and eight miles of Brevoort as the “Vincennes Sound Reach”.

NO. 8-1954

A RESOLUTION

WHEREAS, in the construction by the United States of flood protection works for the City of Vincennes, Indiana, which work is authorized by an Act of Congress known as the Flood Control Act of 1936, approved June 22, 1936, and subsequent Acts of Congress, approved June 28, 1938, and July 24, 1946, the said City executed Assurances on November 26,1951, in connection with said flood protection works; and

WHEREAS, in accordance with said Assurances the City of Vincennes has faithfully fulfilled its obligation with respect to the furnishing of required rights of way for Sections A, Parts I and II, and B, Part I, of the project; and

WHEREAS, there remains to be completed Section B, Part II, Pumping Plants, railroad track alterations of the Baltimore and Ohio, Chicago and Eastern Illinois, and Pennsylvania Railroads and other minor features of work; and

WHEREAS, at the time of execution of the aforementioned Assurances the alignment of a part of the Flood Protection Works, including Section B, Part II, and the location and extent of work of the aforementioned facilities, had not definitely been determined; and

WHEREAS, the alignment of Section B, Part II, has been established, subject only to minor modifications to be agreed upon between the City and the Corps of Engineers; and

WHEREAS, by the charter of the City of Vincennes, Indiana, and the statutes of Indiana, said City of Vincennes is authorized to condemn, purchase or otherwise acquire lands and rights of way and to construct and maintain structures for flood control, drainage and other purposes; and

WHEREAS, the City of Vincennes is financially able to comply with the requirements of said Section 3 of the Flood Control Act of June 22, 1936, as to local cooperation and therefore desires to reaffirm and supplement those Assurances heretofore furnished;

NOW, THEREFORE, be it resolved.

(a) That the City of Vincennes will furnish without cost to the United States all lands, easements and rights of way necessary for the completion of construction of flood protection works, as shown on drawings prepared by the Corps of Engineers and on file in the office of the District Engineer at Louisville, Kentucky, including Section B, Part II, as shown on Drawings V128-16.1/14, 15, 16, 17, 18, and 19. The lands, easements and rights of way contained therein shall include those needed as sites for pumping plants and structures, for borrow pits and spoil disposal areas, for access roads, for ponding areas, and all rights in, upon, through, or over private property needed by the United States in connection with the flood protection works. The City of Vincennes will take timely action to acquire the lands and interest therein necessary for the project in order that construction may be started in the

Spring of 1955. Detailed property surveys and title searches necessary to acquire the land or interests therein will be performed by and at the expense of the City of Vincennes and abstracts of title or other necessary supporting title papers furnished by the said City of Vincennes. The said City of Vincennes will assume the cost of relocating and reconstructing highways, bridges, buildings, railroad lines, and any other structures, facilities or properties, as may be required to prosecute the work to completion.

(b) That the said City of Vincennes will hold and save the United States, its officers and employees free from all claims, damages, actions or causes of action of whatever nature, due directly or indirectly to the construction, operation or maintenance of the flood protection works and appurtenances.

(c) That the said City of Vincennes will accept, maintain and operate without expense to the United States the completed flood control structures and works in accordance with regulations prescribed by the Secretary of the Army.

BE IT FURTHER RESOLVED, that the foregoing Assurances are furnished on the premise that (1) the United States will closely examine the advantages and disadvantages from the standpoint of the City as well as that of the United States with respect to the need of a pumping plant and attendant ponding areas in the general area where the line of protection crosses City ditch and will endeavor to keep the cost to the City of such construction to a minimum and that (2) the United States will consider requests of the City for minor changes in the alignment of the Flood Protection Works where such changes appear to be in the public interest and will not result in an appreciable increase in the cost to the United States.

BE IT FURTHER RESOLVED, that Eugene Stocker, Mayor, and Floyd G. Combs, City Clerk-Treasurer, be and hereby are authorized to execute, acknowledge and deliver, for and on behalf of the said City of Vincennes to the United States, any and all instruments of assurance which may be required by the United States in order to prosecute the work of improvement, and that the Board of Public Works and Safety of the City of Vincennes, be, and hereby is, authorized to execute any permits necessary for the United States to act for, and on behalf of the City of Vincennes under any easements, grants, or rights-of-way, that have been obtained by, or may be hereafter obtained by said City of Vincennes in connection with said improvement.

BE IT FURTHER RESOLVED, that nothing in this Resolution or other action by the said City of Vincennes or its said agents shall operate or be construed to prohibit the said City of Vincennes from receiving the advantage of any Congressional or Presidential action, or other action, which might operate to reduce the obligation or expense of said City of Vincennes in connection with said work.

Passed this 1st day of September, 1954, by the unanimous vote of all councilmen present.

/s/ Eugene Stocker
Mayor, City of Vincennes

ATTEST:

/s/ Floyd G. Combs
City Clerk-Treasurer

CERTIFICATE OF RESOLUTION

STATE OF INDIANA)
) SS
COUNTY OF KNOX)

Floyd G. Combs, being duly sworn upon his oath, says that he is the duly elected, qualified and acting Clerk-Treasurer of the City of Vincennes, Knox County, State of Indiana.

That by virtue of his office, he is custodian of the public records of the City of Vincennes, Knox County, Indiana, including the minutes of all Ordinances and Resolutions passed and adopted by the Common Council of the City of Vincennes, and that as such, he knows of his own knowledge, that Resolution No. 8-1954 of the Common Council of the City of Vincennes was duly passed and adopted at a Special session held at 6:00 P.M. on the 1st day of September, 1954, of the Common Council, by the Councilmen, as set out in the minutes attached hereto and made a part of this record, and that said Resolution as adopted and attached hereto and made a part of this record appears on Councilmatic Record Book 5 Page _____ of said record and that said copy of said Resolution and said minutes of said meeting which are attached hereto, are a true copy of said minutes and Resolution as same appear in the Councilmatic Record of the City of Vincennes.

SEAL

/s/ Floyd G. Combs
Clerk-Treasurer of the
City of Vincennes

Subscribed and sworn to before me this 7 day of September 1954.

/s/ Muriel Brooks
Notary Public

My Commission Expires:

January 2, 1956

SEAL

ASSURANCES

WHEREAS, pursuant to Resolution No. 28A, adopted by the Common Council of the City of Vincennes, Indiana, on November 26, 1951, the City of Vincennes, acting by and through its Mayor and Clerk-Treasurer, duly authorized in the premises, executed Assurances on November 26, 1951, in connection with the construction, maintenance and operation of the Vincennes Flood Protection Project; and

WHEREAS, in accordance with said Assurances, the City of Vincennes has faithfully fulfilled its obligation with respect to the furnishing of required rights of way for Sections A, Parts I and II, and B, Part I, of the project; and

WHEREAS, there remains to be completed Section B, Part II, Pumping Plants, railroad track alterations of the Baltimore and Ohio, Chicago and Eastern Illinois, and Pennsylvania Railroads and other minor features of work; and

WHEREAS, at the time of execution of the aforementioned Assurances the alignment of a part of the Flood Protection Works, including Section B, Part II, and the location and extent of work of the aforementioned facilities, had not definitely been determined; and

WHEREAS, the alignment of Section B, Part II, has been established, subject only to minor modifications to be agreed upon between the City and the United States of America; and

WHEREAS, it is desired to confirm and supplement those Assurances heretofore furnished and to provide these Assurances to cover the uncompleted work of the project.

NOW THEREFORE, pursuant to Resolution No. 8-1954, adopted by the Common Council of the City of Vincennes, Indiana, on the 1st day September, 1954, the City of Vincennes, acting by and through its Mayor and Clerk-Treasurer, duly authorized by vote of the Common Council in said Resolution, does hereby agree:

(a) To furnish without cost to the United States, all lands, easements, and rights of way necessary for the completion of construction of flood protection works, as shown on drawings prepared by the Corps of Engineers and on file in the office of the District Engineer at Louisville, Kentucky, including Section B, Part II, as on Drawings W128-16.1/14, 15, 16, 17, 18, and 19. The lands, easements and rights of way contained therein shall include those needed as sites for pumping plants and structures, for borrow pits and spoil disposal areas, for access roads, for ponding areas, and all rights in, upon, through, or over private property needed by the United States in connection with the flood protection works. The City of Vincennes will take timely action to acquire the lands and interest therein necessary for the project in order that construction may be started in the Spring of 1955. Detailed property surveys and title searches necessary to acquire the land or interests therein will be performed by and at the expense of the City of Vincennes and abstracts of title or other necessary supporting title papers furnished by the said City of Vincennes. The said City of Vincennes will assume the cost of relocating and reconstructing highways, bridges, buildings, railroad lines, and any other structures, facilities or properties, as may be required to prosecute the work to completion.

(b) That the said City of Vincennes will hold and save the United States, its officers and employees free from all claims, damages, actions or causes of action of whatever nature, due directly or indirectly to the construction, operation or maintenance of the flood protection works and appurtenances.

(c) That the said City of Vincennes will accept, maintain and operate without expense to the United States the completed flood control structures and works in accordance with regulations prescribed by the Secretary of the Army.

The foregoing Assurances are furnished on the premise that (1) the United States will closely examine the advantages and disadvantages from the standpoint of the City as well as that of the United States with respect to the need of a pumping plant and attendant ponding areas in the general area where the line of protection crosses City ditch and will endeavor to keep the cost to the City of such construction to a minimum and that (2) the United States will consider requests of the City for minor changes in the alignment of the Flood Protection Works where such changes appear to be in the public interest and will not result in an appreciable increase in the cost to the United States.

These Assurances are in confirmation of and supplementary to the Assurances executed by the City of Vincennes on November 26, 1951.

IN WITNESS WHEREOF, the said City of Vincennes has caused this instrument to be executed in its name and on its behalf by its duly authorized Mayor and Clerk-Treasurer and its corporate seal to be affixed hereto this 2nd day of September, 1954.

CITY OF VINCENNES

SEAL

By /s/ Eugene Stocker
Mayor

ATTEST:

/s/ Floyd G. Combs
City Clerk-Treasurer

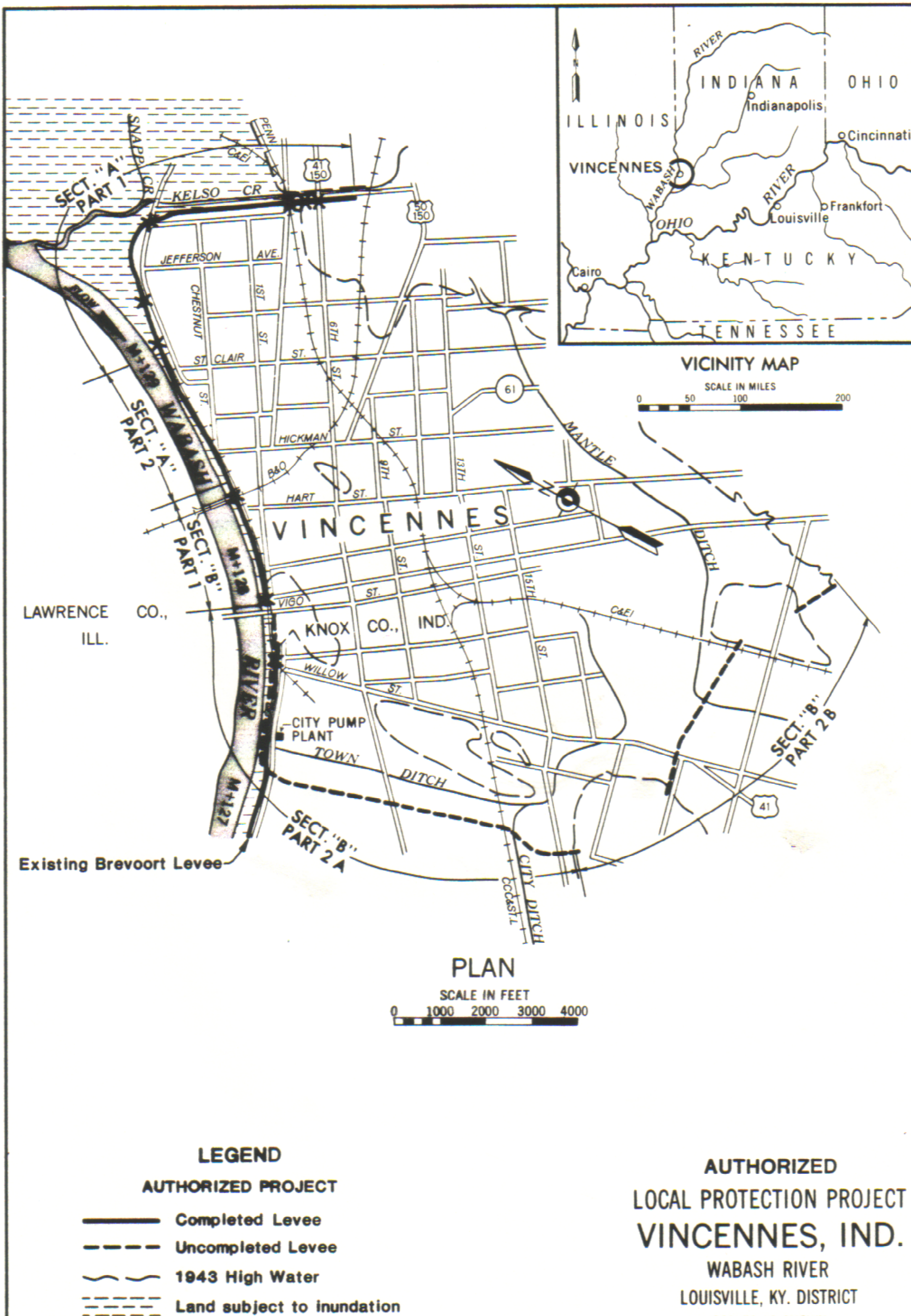
I, Wayne Combs, Attorney for the City of Vincennes, in the County of Knox, State of Indiana, hereby certify that the Assurances contained in the foregoing agreement, executed by the City of Vincennes, pursuant to Resolution No. 8-1954, duly adopted by its Common Council, are made within the scope of the corporate powers of the said City of Vincennes, Indiana; and that it is within the scope of the authority of the Mayor and Clerk-Treasurer of the said City to execute said agreement on behalf of said City.

Given under my hand at the City of Vincennes, Indiana, this 2nd day of September, 1954.

/s/ Wayne Combs
City Attorney

ACCEPTED: 21 October 1954

/s/ W. D. Milne
W. D. MILNE
Colonel, CE
District Engineer



AUTHORIZED
LOCAL PROTECTION PROJECT
VINCENNES, IND.
WABASH RIVER
LOUISVILLE, KY. DISTRICT
SCALES AS SHOWN

KEY TO MAP

500-Year Flood Boundary — ZONE B
100-Year Flood Boundary
Zone Designations* — ZONE A1 / ZONE A5
100-Year Flood Boundary
500-Year Flood Boundary — ZONE B

Base Flood Elevation Line With Elevation In Feet** — 513

Base Flood Elevation in Feet Where Uniform Within Zone** — (EL 987)

Elevation Reference Mark — RM7×

Zone D Boundary

River Mile — •M1.5

**Referenced to the National Geodetic Vertical Datum of 1929

*EXPLANATION OF ZONE DESIGNATIONS

ZONE	EXPLANATION
A	Areas of 100-year flood; base flood elevations and flood hazard factors not determined.
A0	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; average depths of inundation are shown, but no flood hazard factors are determined.
AH	Areas of 100-year shallow flooding where depths are between one (1) and three (3) feet; base flood elevations are shown, but no flood hazard factors are determined.
A1-A30	Areas of 100-year flood; base flood elevations and flood hazard factors determined.
A99	Areas of 100-year flood to be protected by flood protection system under construction; base flood elevations and flood hazard factors not determined.
B	Areas between limits of the 100-year flood and 500-year flood; or certain areas subject to 100-year flooding with average depths less than one (1) foot or where the contributing drainage area is less than one square mile; or areas protected by levees from the base flood. (Medium shading)
C	Areas of minimal flooding. (No shading)
D	Areas of undetermined, but possible, flood hazards.
V	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors not determined.
V1-V30	Areas of 100-year coastal flood with velocity (wave action); base flood elevations and flood hazard factors determined.

NOTES TO USER

Certain areas not in the special flood hazard areas (zones A and V) may be protected by flood control structures.

This map is for flood insurance purposes only; it does not necessarily show all areas subject to flooding in the community or all planimetric features outside special flood hazard areas.

INITIAL IDENTIFICATION:
JUNE 21, 1974

FLOOD HAZARD BOUNDARY MAP REVISIONS:
SEPTEMBER 24, 1976
MAY 27, 1977

FLOOD INSURANCE RATE MAP EFFECTIVE:
DECEMBER 18, 1984

FLOOD INSURANCE RATE MAP REVISIONS:

To determine if flood insurance is available in this community, contact your insurance agent, or call the National Flood Insurance Program, at (800) 638-6620.

APPROXIMATE SCALE
1000 0 1000 FEET

ELEVATION REFERENCE MARKS

REFERENCE MARKS	ELEVATION FEET (NGVD)	DESCRIPTION OF LOCATION
RM 1	419.784	U.S. Coast and Geodetic Survey disk stamped "K 285 1954" about 3.25 feet above ground located at southwest face of the concrete foundation of Vincennes sewage disposal plant building, about 55 feet southeast of center of a gravel road.
RM 2	432.32	U.S. Geological Survey benchmark located at southwest corner of Chessie System bridge over Kelso Creek on east side of Niblack Drive.
RM 3	425.386	U.S. Geological Survey benchmark located at the northeast corner of Union Station, about 26.5 feet south of Chessie System south track, about 34 feet west of Louisville and Nashville Railroad main track, about 2.7 feet above the platform.

NATIONAL FLOOD INSURANCE PROGRAM

FIRM D-16
FLOOD INSURANCE RATE MAP

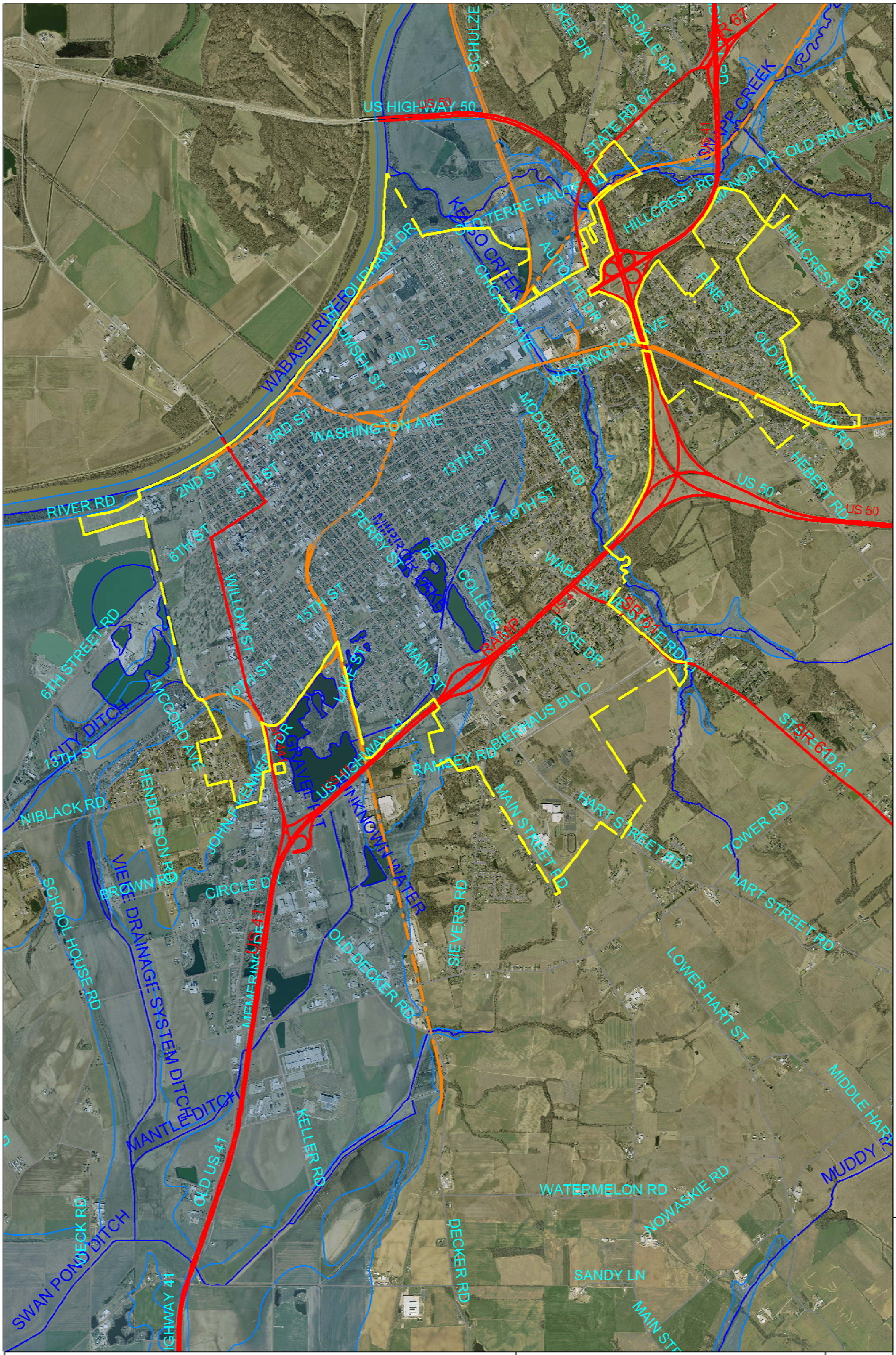
CITY OF
VINCENNES,
INDIANA
KNOX COUNTY

(ONLY PANEL PRINTED)

COMMUNITY-PANEL NUMBER
180120 0005 C

EFFECTIVE DATE:
DECEMBER 18, 1984

Federal Emergency Management Agency



Knox Floodplains
Hydrology
Railroads
Local Roads
Highways
Corporation Boundary

0 4000 8000

1" = 4000ft

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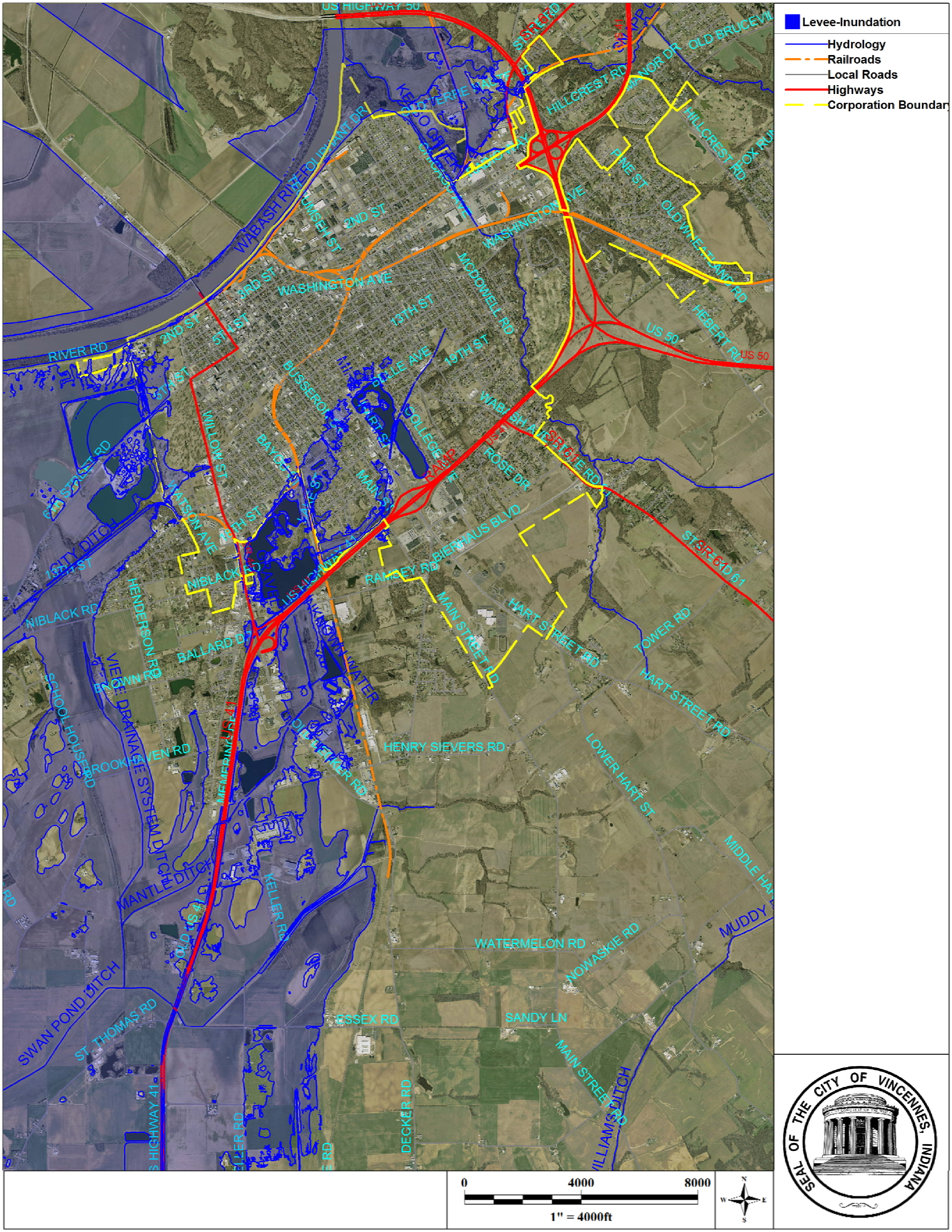
SEAL OF THE CITY OF VINCENNES, INDIANA


Levee-Inundation
Hydrology
Railroads
Local Roads
Highways
Corporation Boundary
WABASH RIVER
WASHINGTON AVE
US 50
US 41
RIVER RD
NIBLACK RD
HENRY SIEVERS RD
WATERMELON RD
ESSEX RD
SANDY LN
SWAN POND DITCH
MANTLE DITCH
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1" = 4000ft
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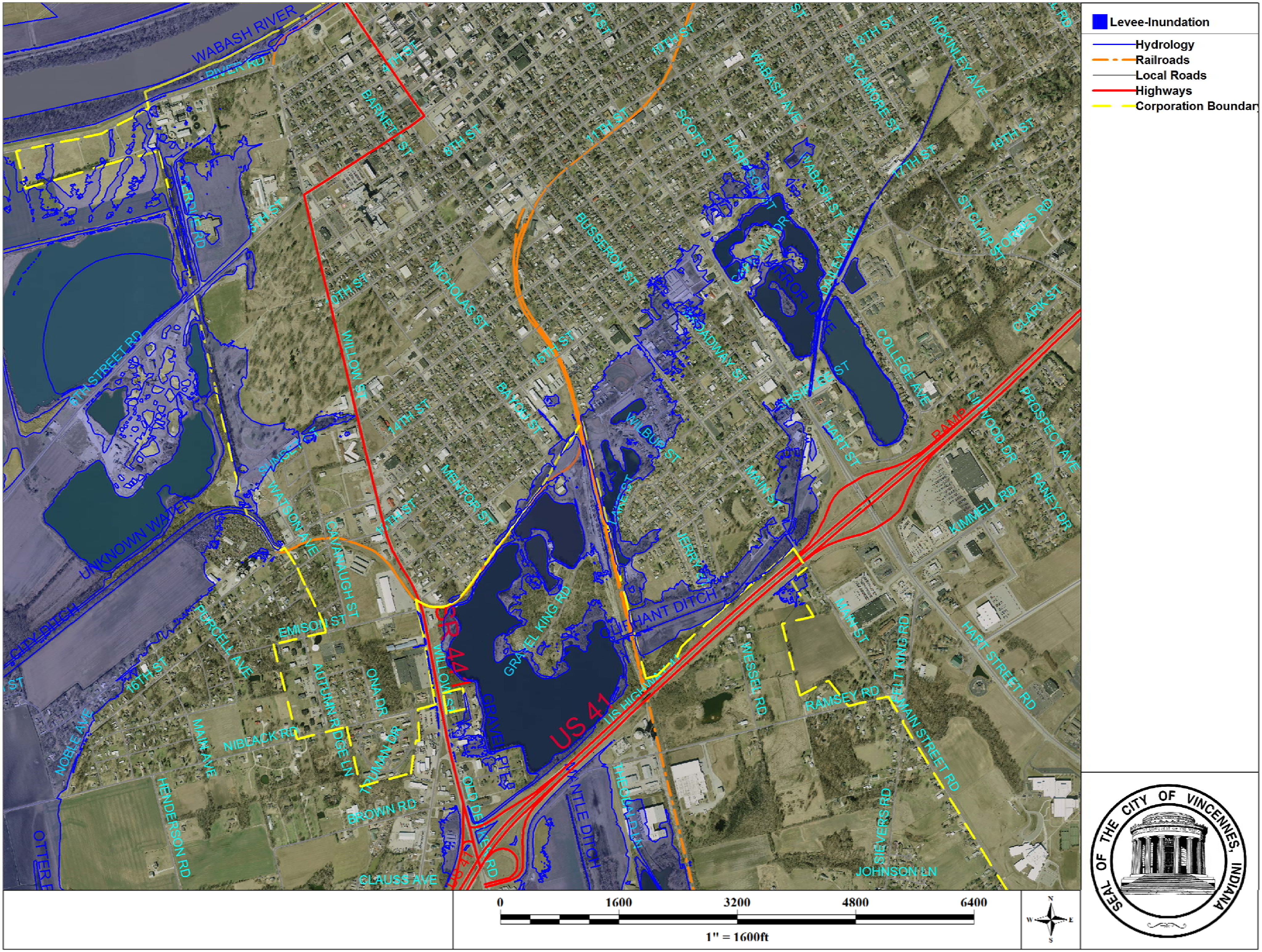
SEAL OF THE CITY OF VINCENNES, INDIANA


Levee-Inundation
Hydrology
Railroads
Local Roads
Highways
Corporation Boundary
WABASH RIVER
RIVER RD
BARNETT ST
6TH ST
8TH ST
10TH ST
11TH ST
SCOTT ST
WABASH AVE
SYCAMORE ST
13TH ST
MCKINLEY AVE
19TH ST
17TH ST
HART ST
WABASH ST
BUSSERON ST
NICHOLAS ST
WILLOW ST
15TH ST
BAYOU ST
14TH ST
MENTOR ST
WILBUR ST
MAIN ST
BROADWAY ST
COLLEGE AVE
ST CLAIR ST
CLARK ST
PROSPECT AVE
RANEY DR
KIMMELL RD
RAMP
HART STREET RD
UNKNOWN WATER
WATSON AVE
CAVANAUGH ST
EMISON ST
PURCELL AVE
16TH ST
CITY DITCH
NOBLE AVE
MAIN AVE
NIBLACK RD
AUTUMN RIDGE LN
ONA DR
HENDERSON RD
OTTER
BROWN RD
CLAUSS AVE
SR 441
GRAVEL KING RD
OLIPHANT DITCH
US 41
US HIGHWAY 41
WESSEL RD
RAMSEY RD
BELT KING RD
MAIN STREET RD
SIEVERS RD
JOHNSON LN
KIRCHOFF DITCH
0
1600
3200
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1" = 1600ft
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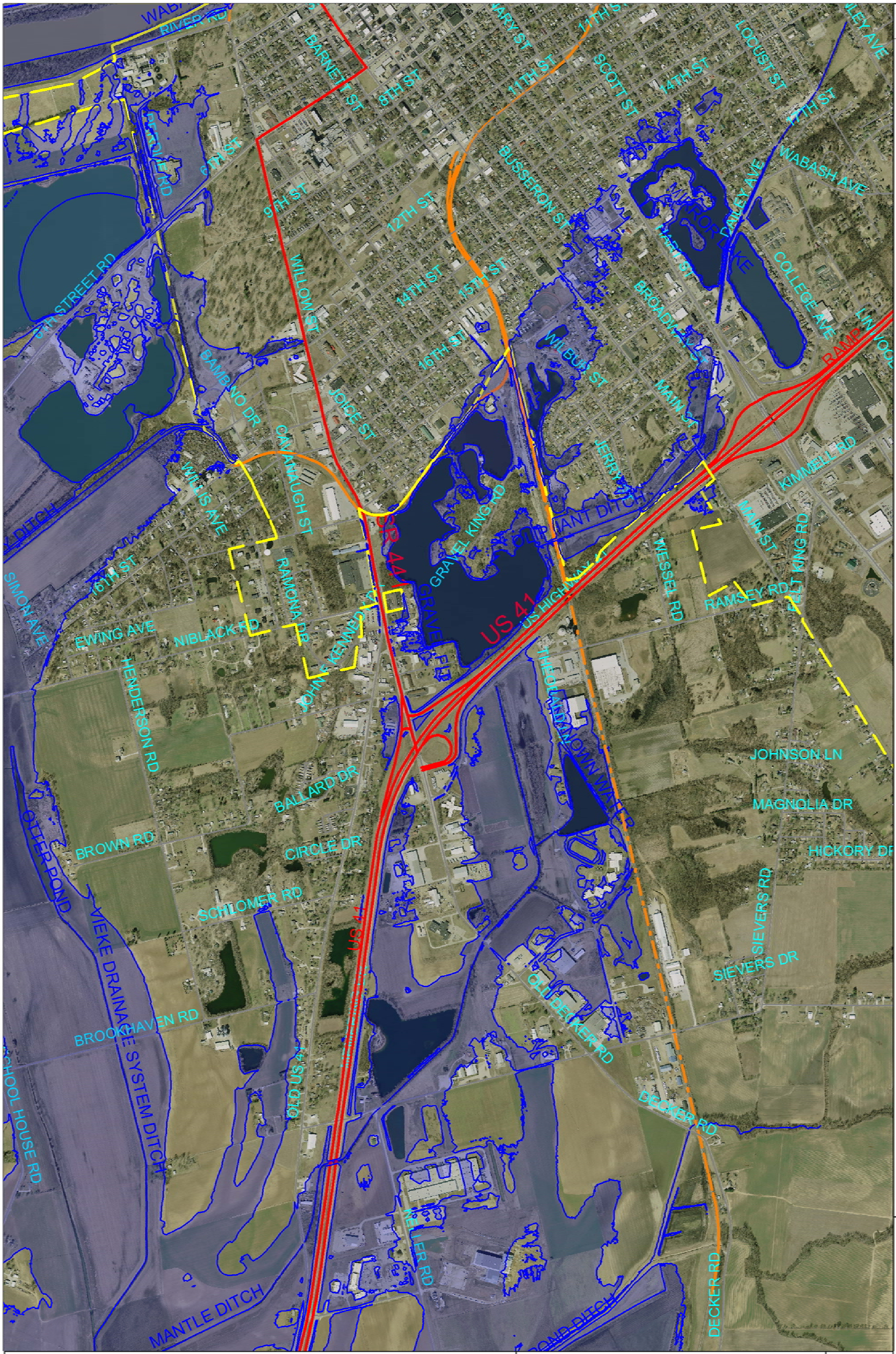
SEAL OF THE CITY OF VINCENNES, INDIANA



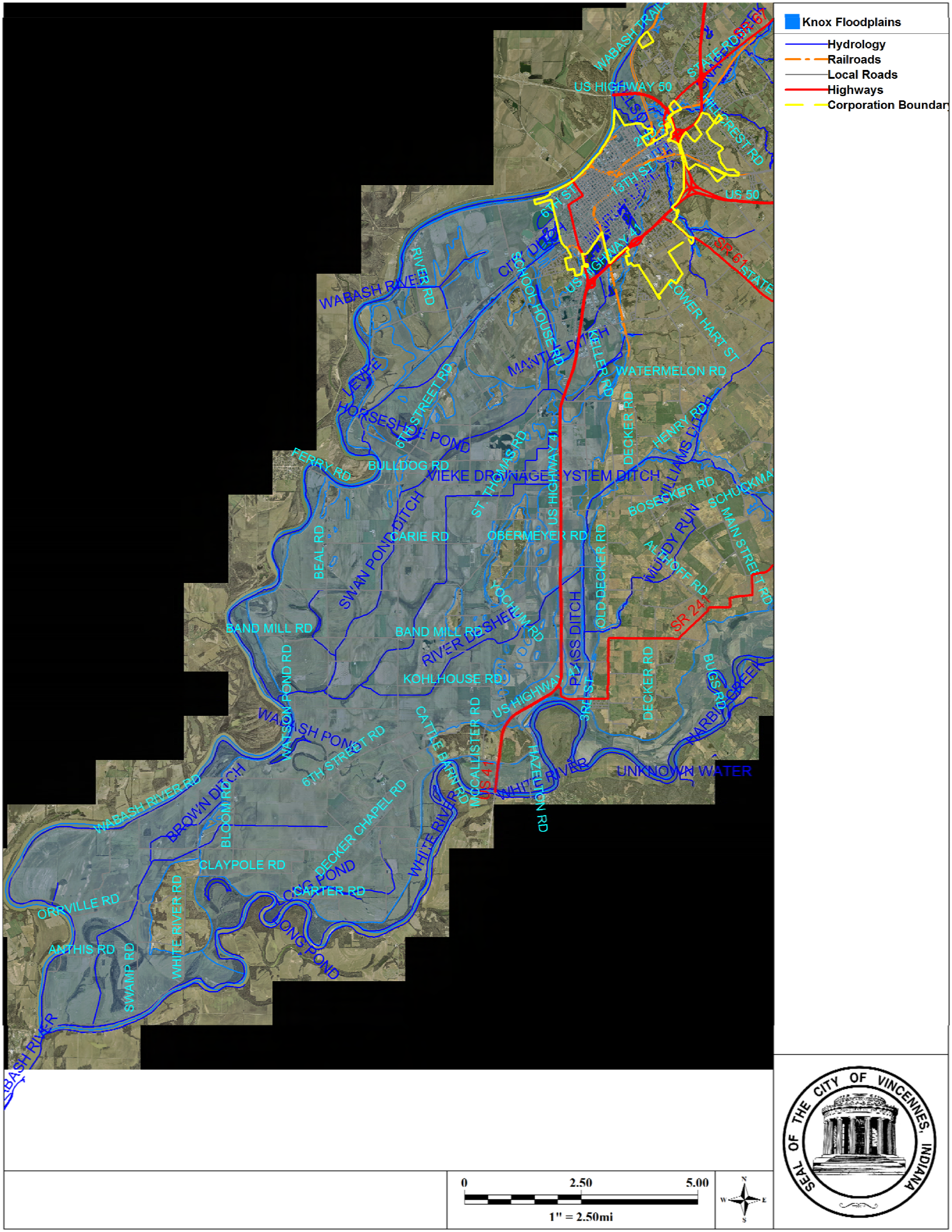
- Levee-Inundation
- Hydrology
- Railroads
- Local Roads
- Highways
- Corporation Boundary

0 2000 4000

1" = 2000ft

N W E S

SEAL OF THE CITY OF VINCENNES, INDIANA



Knox Floodplains
Hydrology
Railroads
Local Roads
Highways
Corporation Boundary
US HIGHWAY 50
WABASH TRAIL
US 50
SR 61
WABASH RIVER
RIVER RD
CITY DITCH
MANTLE DITCH
WATERMELON RD
HORSESHOE POND
BULLDOG RD
FERRY RD
VIEKE DRAINAGE SYSTEM DITCH
CARIE RD
OBERMEYER RD
BEAL RD
SWAN POND DITCH
BAND MILL RD
KOHLHOUSE RD
WATSON POND RD
WABASH POND
6TH STREET RD
WABASH RIVER RD
BROWN DITCH
BLOOM RD
CLAYPOLE RD
DECKER CHAPEL RD
CARTER RD
ORRVILLE RD
ANTHIS RD
SWAMP RD
WHITE RIVER RD
LONG POND
WHITE RIVER
UNKNOWN WATER
HAZELTON RD
MCALLISTER RD
US 41
SR 241
DECKER RD
OLD DECKER RD
BOSECKER RD
HENRY RD
MUDDY RUN
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1" = 2.50mi
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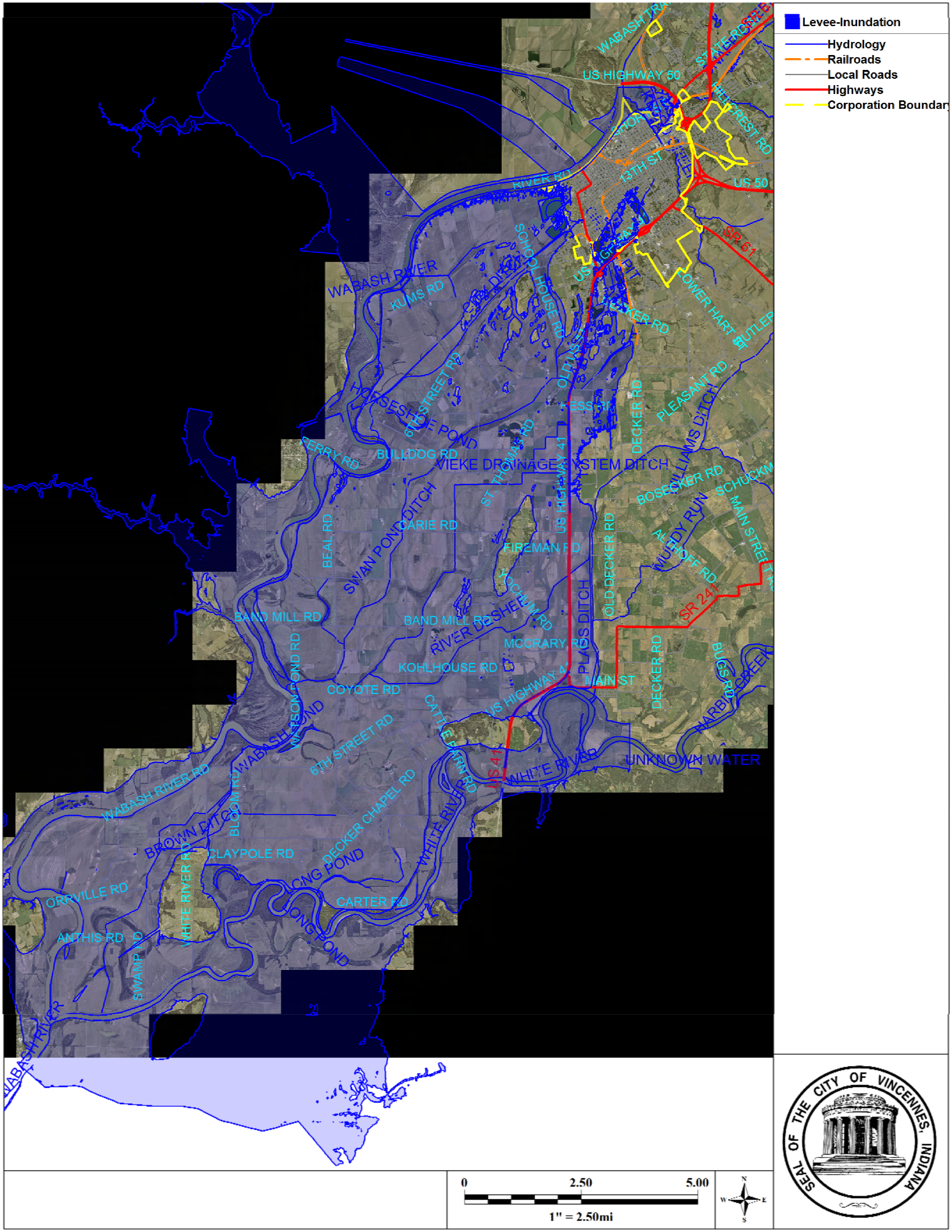
SEAL OF THE CITY OF VINCENNES, INDIANA



Levee-Inundation
Hydrology
Railroads
Local Roads
Highways
Corporation Boundary
WABASH RIVER
US HIGHWAY 50
US 50
13TH ST
SR 61
RIVER RD
KUMS RD
HORSESHOE POND
6TH STREET RD
BULLDOG RD
FERRY RD
VIEKE DRAINAGE SYSTEM DITCH
ST THOMAS RD
US HIGHWAY 41
DECKER RD
PLEASANT RD
BOSECKER RD
WILLIAMS DITCH
SCHUCKMAN
MAIN STREET
MUDDY RUN
ALTHOFF RD
SR 241
OLD DECKER RD
PLASS DITCH
CARIE RD
SWAN POND DITCH
BEAL RD
FIREMAN RD
YOCHUM RD
BAND MILL RD
RIVER DESHEE
MCCRARY RD
KOHLHOUSE RD
COYOTE RD
MAIN ST
BUGS RD
HARBIN CREEK
WATSON POND RD
CATTLE FARM RD
US 41
WHITE RIVER
UNKNOWN WATER
WABASH RIVER RD
BLOOM RD
BROWN DITCH
CLAYPOLE RD
DECKER CHAPEL RD
LONG POND
CARTER RD
ORRVILLE RD
WHITE RIVER RD
ANTHIS RD
SWAMP RD
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1" = 2.50mi
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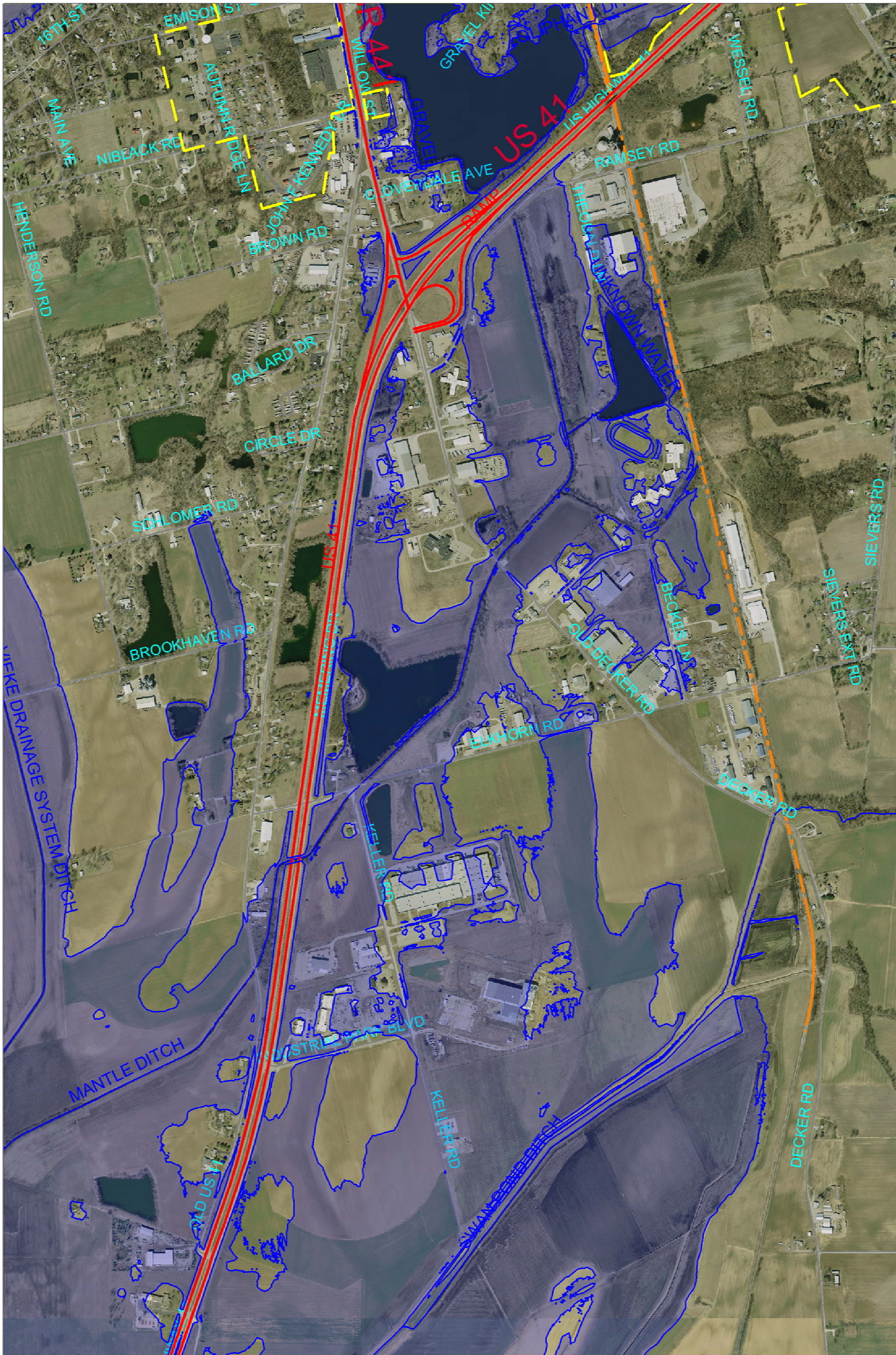
SEAL OF THE CITY OF VINCENNES, INDIANA



Levee-Inundation

Hydrology

Railroads

Local Roads

Highways

Corporation Boundary

0 1500 3000

1" = 1500ft

N W E S

SEAL OF THE CITY OF VINCENNES, INDIANA

8. ENGINEERING STUDIES, INVESTIGATIONS AND ANALYSES

8.1. Site Visit Summary

The initial and most comprehensive site visit for the report was conducted by thirteen team members on 6-10 February 2012; reference Chapter 4 of this report for a list of the primary study team members and their discipline. Items noted as requiring attention or repair were placed into one of two categories, LSE issues (unacceptable deficiencies) that would prevent the project from receiving a positive evaluation report, and O&M issues that require attention but would not prevent the project from being considered eligible to be in the FEMA program. Initially, a total of 16 items were documented as LSE issues as shown in Table 8.1-1.

Table 8.1-1: Initial LSE Issues Documented During the Field Inspection

	Discipline	Item of Deficiency	Report Reference
1	Geotechnical	Animal Burrows throughout both Vincennes and Brevoort embankments	8.4.5.1
2	Geotechnical	No relief well performance testing or maintenance records	8.4.5
3	Geotechnical	Willow St Closure does not pass stability evaluation	2.2.2
4	Electrical	Highland St Pump Station; repair to motor #3 circuit breaker is required	8.6.1, 8.6.3
5	Mechanical	2^{nd} St. Pump Station; Sluice gate located in discharge well was inoperable at time of inspection, repair as required.	8.5.1.1
6	Mechanical	Gatewells #5 and #6; gatewells are inoperable and were indicated in inspection to be abandoned: should be properly abandoned	8.5.1.8
7	Mechanical	The sluice gate in Manhole 1C is inoperable and needs to be replaced.	8.5.1.8
8	Mechanical	Highland St P.S. discharge flap gate is cracked and requires repair	8.5.1.3
9	Mechanical	Gatewell #2 in 2^{nd} St. is inoperable and should be repaired. Access to the gatewell should be restored.	8.5.1.1
10	Mechanical	Gatewell #7 sluice gate stem should be repaired, misaligned flap gate should be repaired.	8.5.1.2
11	Mechanical	Treatment Plant Effluent gatewell (Brevoort Sta.	8.5.1.8

		1118+54) is inoperable and needs to be replaced.	
12	Mechanical	Perry St. P.S.; repair replace new bolts/nuts missing from pump discharge flapgates.	8.5.1.4
13	Mechanical	Pump start/stop elevations should be verified as current with O&M procedures.	8.5
14	Structural	Kimmel Park closure is required to be trial erected with USACE team member present. –Accomplished 17 December 2012 with no issues	8.3.2.3
15	Structural	Pipes receiving a PACP structural grade of 4 or 5 have not yet been remediated.	8.3.6
16	Structural	Manway closure at Sta. 263+15 is improperly installed (upside down) – corrected by Sponsor in September 2013	8.3.2.2

8.1.1. Additions to Initial List of Levee System Evaluation Issues

Based on modeling and analysis of project features and conditions, some items were added to the list of LSE issues, given in Table 8.1-2 below.

Table 8.1-2. Additions to LSE Issues List

17	Geotechnical	Toe Drain Inspection, Sta 214+34 to 241+00; Seepage models indicate this toe drain is required to achieve adequate factor of safety, video inspection of this line is required.	8.4.4
18	Geotechnical	Brevoort Levee Embankment; Levee does not meet seepage criteria during the flood event at a specific location downstream (Sta. 710+00). The levee downstream of this location cannot be included as a Sound Reach.	8.4.4
19	Geotechnical	Relief wells along the Wabash River are required to be inspected, and selective wells pump tested to determine their flow capacity. This capacity will then be used to verify their adequacy.	8.4.4
20	Hydraulics	In conjunction with the Vincennes Levee Segment, a portion of the Brevoort Levee Segment is relied upon for providing flood reduction for the City. Select areas of Vincennes are shown to be vulnerable to a backwater condition from a breach downstream of the Sound Reach. Measures to address this backwater flooding may be required in order to receive a positive Levee System Evaluation for these impacted areas, or these areas could be delineated as within the floodplain on inundation mapping.	8.2

3-May-1988		1110+00-1137+00	Placement of fiber optic cables along NW right-of-way of River Road
6/2013	2012010.BRE	1122+56, 1126+59	Repair of pipe joints for two existing sanitary manholes along toe of levee
completed	2011044.BRE	1135+00-1120+00	Abandonment of sanitary line in levee toe
completed	200613.BRE	891+80	Pipe sliplined
completed	201047.BRE	1116+98	Close drain at STA 1116+98 that used to provide drainage to the water treatment plant that no longer exists.
Not yet performed	2012021.BRE	1116+80, 1118+54	Sluice gate replacement and sliplining of WWTP outfall
completed	2012071.bre	814+57	Sliplining of 36" CMP
completed	2013045.bre	731+81	Abandonment of 30" CMP

7.1.2. Issues, Repairs and Alterations associated with the Vincennes Sound Reach

Since completion of the project in July 1962, there have been minimal repairs or alterations to the project beyond normal maintenance.

- 197? – B&O Railroad sandbag closure abandoned, sta. 238+40
- 1996 - GW-1 abandoned, 6th St PS installed, 6th St Closure abandoned
- 2006 - Slipline of pipe at station 891+80 (Brevoort)
- 2007 - Surficial repairs were made to the I-wall concrete and joint sealant of random sections of I-wall from Sta. 212+00 to 230+70.
- 2012 - replacement of 25 lf of pipe with RCP and new headwall, Station 198+40 (Brevoort)
- 2013- Two monoliths of floodwall replaced to grade and other monoliths repaired with epoxy and membrane treatment, Sta. 213+59 – 230+62
- 2013-Sliplining of 36" CMP at Sta. 814+57 (Brevoort)
- 2013-Abandonment of 30 inch CMP at Sta. 731+81 (Brevoort)

7.2. Review of Levee Routine Inspections

Routine inspections have been conducted on the Vincennes Segment and on the Brevoort Segment since 1988. A more standardized format for recording observations was adopted in 2003 with changes made in the Inspection of Completed Works (ICW) program, and only those results have been included in Table 7.2-1. Individual levee items are evaluated and the overall project segments are rated as either 'Acceptable', 'Minimally Acceptable', or 'Unacceptable'. A project rating of 'Unacceptable' means there are one or more deficient conditions that may prevent the project from functioning as designed and require corrective action for the project to remain eligible for rehabilitation assistance under Public Law 84-99. The most recent routine inspection report for the Vincennes Segment was conducted in February 2012 in conjunction with the LSE inspection. The most recent Brevoort Segment routine inspection was conducted November 2012. Both reports cited an overall project rating of Minimally Acceptable.

Table 7.2-1: Findings of Routine Inspections Since 2003

Date of Inspection	Comments and Deficiencies
03 Oct 2003	**Items noted as minimally acceptable:** • The concrete wall is cracking and spalling throughout its length and should be repaired as necessary. • There has been some settling in some areas of the concrete wall in the past which appears to have stabilized. • Animal control, burrows • Trees and brush at the floodwall, riverside toe, and rip rap areas. • Monolith joints in need of repair • Pump station sumps • Corrugated metal pipes • Roadway cover plates damaged **Items noted as unacceptable: none**
24Sept 2004	**Items noted as minimally acceptable:** • Tree and brush on the riverside toe and slope, rip rap areas, and floodwall • Settling of concrete wall that appears to have stabilized • Monolith joints in need of repair • Animal control, burrows • Concrete wall is cracking and spalling throughout its length • Corrugated metal pipes • Gatewell concrete surfaces **Items noted as unacceptable: none**
11 Aug 2005	**Items noted as minimally acceptable:** • Tree and brush on the riverside toe and slope, rip rap areas, and floodwall • Animal control, burrows • Settling of concrete wall that appears to have stabilized • Monolith joints in need of repair • Concrete wall is cracking and spalling throughout its length • Corrugated metal pipes • Gatewell concrete surfaces • Gate operators • Pump station sumps **Items noted as unacceptable:** • Pumps- one or more pumps is not operational-City Ditch P.S.

6 Feb 2012 (The inspection format significantly changed from the prior inspection)	**Items noted as minimally acceptable:** • Sod cover, railroad bridge • Encroachments, utility poles, vehicular traffic • Settlement- sta. 299+27 • Rip rap displaced • Relief wells, inadequate inspection records • Fencing and gates are corroded • Gatewell concrete surfaces • Gatewell cover plates corroded • Riprap/revetments of discharge areas • No P.S. safety inspection reports • Pumps: Sump pumps inoperable • P.S. Power source • Electrical panels- minor corrosion • Intake and discharge pipelines: minor corrosion • P.S. access hatches corroded **Items noted as unacceptable:** • Vegetation growth • Closure Structures: Oliphant storage vault, Kimmel Park Closure sill, B and O closure ponds water, 2nd and Niblack Closure railroad issue, Oliphant closure sill deteriorated, trial erections not performed. • Animal control; burrows • Culverts/discharge pipes; several pipes need to be repaired • Relief Wells; several well standpipes damaged, some missing • I-wall Concrete surfaces • Monolith joints • Sluice gates; 2nd St P.S. discharge, GW#2 gate, MH1 gate inoperable • Flap Gate; GW#6-flapgate removed at time of inspection • P.S. inspection records • O&M Manuals not present in P.S. • Plant Buildings • Motors-Highland St P.S. circuit breaker • Electrical Systems

7.3. Overall Performance of Brevoort-Vincennes Levee System

The Brevoort-Vincennes Levee System has been subjected to four significant events during the past 7 years, as shown in the below Table 7.3-1. Data from the 2005, 2008, 2011, and 2013 events is well documented. However, these events did not significantly load the system. The top of levee elevation at the Memorial Bridge where the gauge is located is approximately 429 ft NAVD, leaving roughly 7.5 feet of freeboard for the 2008 and 2011 events, and 7.3 feet of freeboard for the 2013 event. Photo 7.3-1 below shows the water height just reaching the base of the I-wall during the 2013 event.

FEMA

Modeling and Mapping Non-Accredited Levees:

Sound Reach Procedure

The Federal Emergency Management Agency (FEMA) has developed a new set of procedures for analyzing and mapping flood hazard on the landward side of non-accredited levee systems on Flood Insurance Rate Maps (FIRMs). Non-accredited levee systems are those that do not meet all the requirements outlined in Title 44 of the Code of Federal Regulations (CFR), Section 65.10.

This fact sheet summarizes the **Sound Reach** procedure. A “sound reach” is a levee reach designed, constructed, and maintained to withstand and reduce the flood hazard posed by a 1-percent-annual-chance flood event. The **Sound Reach** procedure can be used to analyze sound reaches in a levee system that is not accredited, thus, accounting for reaches of a non-accredited levee that may provide a measure of flood risk reduction. The **Sound Reach** procedure can be applied to one or more reaches in a levee system and mapped on a FIRM.

When to Use the Sound Reach Procedure

Figure 1 illustrates a sound levee reach. To use the **Sound Reach** procedure, the levee reach must both be structural sound and have adequate freeboard (see Fact Sheet 4 for additional information on freeboard). To qualify for the **Sound Reach** procedure, the reach must have proper desig operation, and maintenance. While only a full levee syst can be shown to meet 44 CFR 65.10, FEMA will use the standards outlined to determine when a reach has the proper design, operation, and maintenance to be shown as a sound reach. If any of the criteria are not met, one of the other procedures may apply (refer to side bar).

Updated Levee Analysis and Mapping Methodologies

FEMA has developed procedures for analyzing and mapping hazards associated with non-accredited levees shown on FIRMs. An overview is provided in Fact Sheets titled:

1. **Dividing Levee Systems into Multiple Reaches**
2. ***Natural Valley* Procedure**
3. ***Sound Reach* Procedure**
4. ***Freeboard Deficient* Procedure**
5. ***Overtopping* Procedure**
6. ***Structural-Based Inundation* Procedure**
7. **Understanding the Zone D Designation**

For more information, please visit: http://www.fema.gov/final-levee-analysis-and-mapping-approach

The CFR can be accessed at: http://ecfr.gpoaccess.gov

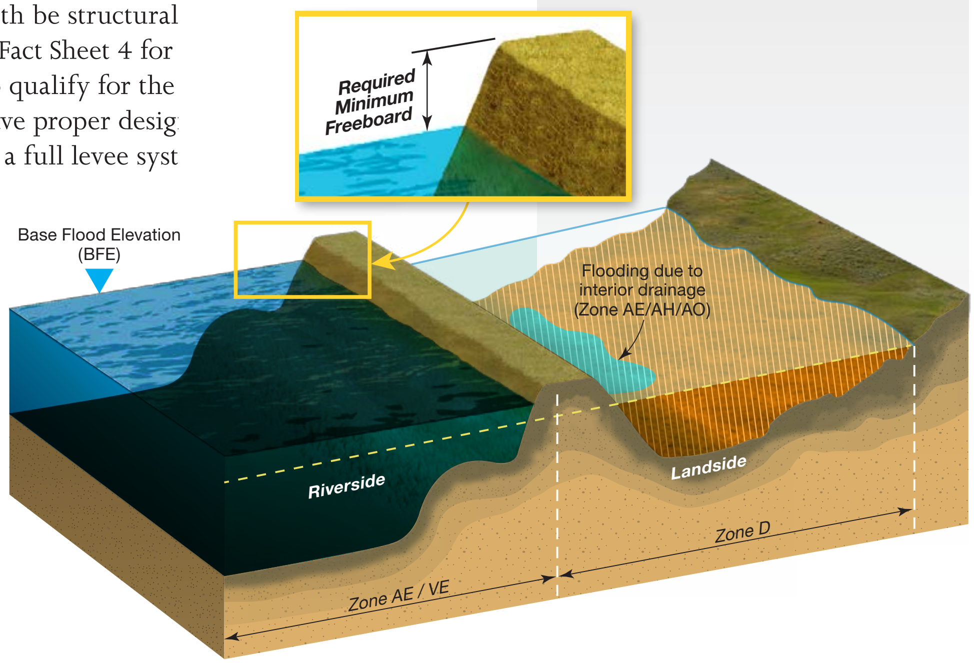


Figure 1: Cross-section of a Sound Levee Reach

RiskMAP
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Minimum Levee Documentation Requirements

The ***Sound Reach*** procedure requires documentation by levee owners and/or the associated communities for their levee systems. FEMA will perform a completeness check for levee submittal documentation currently on file and will notify owners of any missing information.

When using the ***Sound Reach*** procedure, the levee documentation submitted to FEMA must denote the reaches along the levee system that meet the design, operation, and maintenance standards as outlined in 44 CFR 65.10. The upstream and downstream limits of each sound reach along the levee system must be clearly identified.

Sound Reach Analysis and Mapping Procedures

FEMA will map all non-accredited levee systems using the ***Natural Valley*** procedure (Fact Sheet 2) to establish areas of potential inundation. Figure 2 shows how flood zones may be mapped for non-accredited levee systems with ***Sound Reaches***.

Analysis using the ***Sound Reach*** procedure must examine the potential for flood waters resulting from upstream levee systems/reaches that do not meet all the requirements of 44 CFR 65.10, and are therefore not considered sound. It must also include an interior drainage analysis for backwater areas resulting from larger streams downstream and areas drained by pumping systems. Coastal levees must also be examined for potential flooding from adjacent reaches.

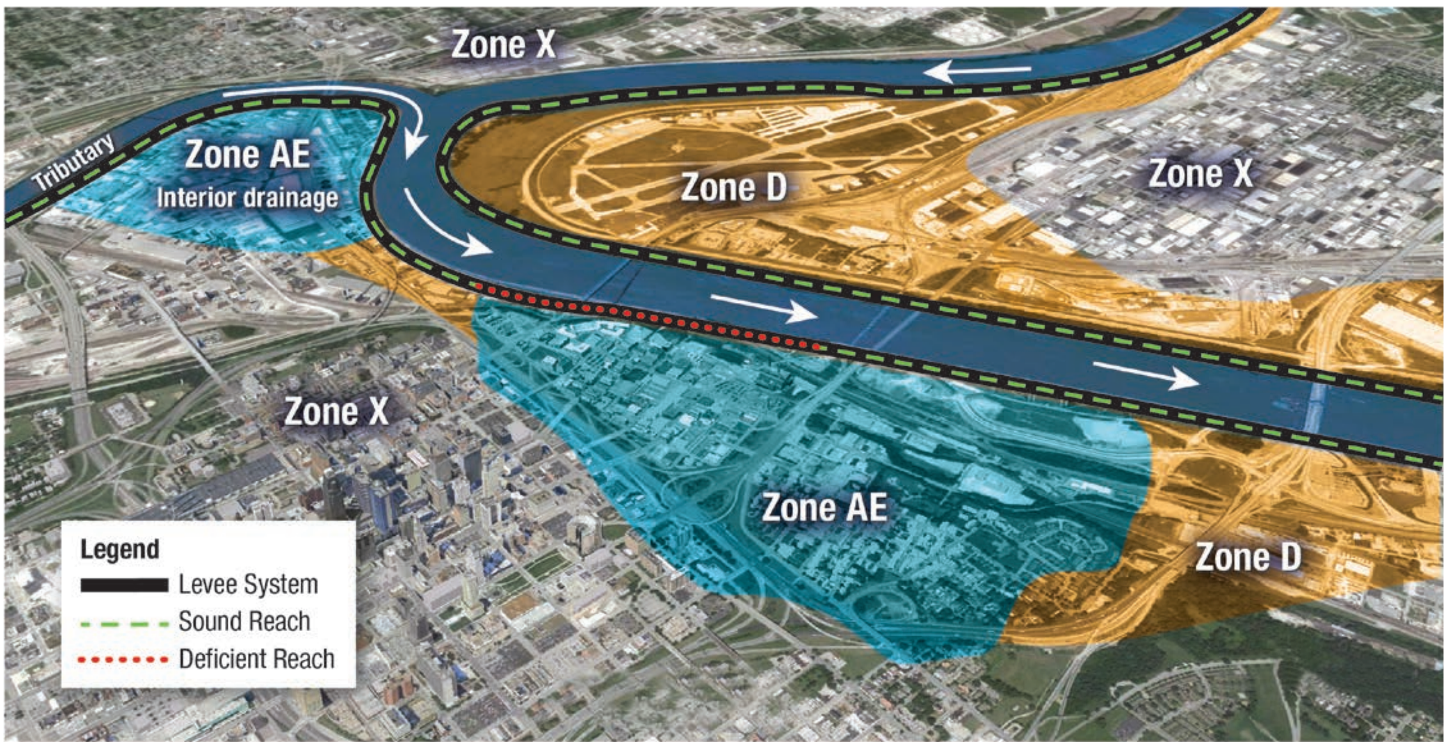

Figure 2: Mapped flood zones behind a Sound Reach

Definitions of FEMA Flood Zones

Flood zones are geographic areas that FEMA has defined according to varying levels of flood risk and type of flooding. These zones are depicted on the published Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map (FHBM).

Special Flood Hazard Areas – High Risk

Special Flood Hazard Areas represent the area subject to inundation by 1-percent-annual chance flood. Structures located within the SFHA have a 26-percent chance of flooding during the life of a standard 30-year mortgage. Federal floodplain management regulations and mandatory flood insurance purchase requirements apply in these zones.

ZONE	DESCRIPTION
A	Areas subject to inundation by the 1-percent-annual-chance flood event. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown.
AE, A1-A30	Areas subject to inundation by the 1-percent-annual-chance flood event determined by detailed methods. BFEs are shown within these zones. (Zone AE is used on new and revised maps in place of Zones A1–A30.)
AH	Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are 1–3 feet. BFEs derived from detailed hydraulic analyses are shown in this zone.
AO	Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are 1–3 feet. Average flood depths derived from detailed hydraulic analyses are shown within this zone.
AR	Areas that result from the decertification of a previously accredited flood protection system that is determined to be in the process of being restored to provide base flood protection.
A99	Areas subject to inundation by the 1-percent-annual-chance flood event, but which will ultimately be protected upon completion of an under-construction Federal flood protection system. These are areas of special flood hazard where enough progress has been made on the construction of a protection system, such as dikes, dams, and levees, to consider it complete for insurance rating purposes. Zone A99 may be used only when the flood protection system has reached specified statutory progress toward completion. No BFEs or flood depths are shown.

Moderate and Minimal Risk Areas

Areas of moderate or minimal hazard are studied based upon the principal source of flood in the area. However, buildings in these zones could be flooded by severe, concentrated rainfall coupled with inadequate local drainage systems. Local stormwater drainage systems are not normally considered in a community's flood insurance study. The failure of a local drainage system can create areas of high flood risk within these zones. Flood insurance is available in participating communities, but is not required by regulation in these zones. Nearly 25-percent of all flood claims filed are for structures located within these zones.

ZONE	DESCRIPTION
B, X (shaded)	Moderate risk areas within the 0.2-percent-annual-chance floodplain, areas of 1-percent-annual-chance flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent-annual-chance flood by a levee. No BFEs or base flood depths are shown within these zones. (Zone X (shaded) is used on new and revised maps in place of Zone B.)
C, X (unshaded)	Minimal risk areas outside the 1-percent and .2-percent-annual-chance floodplains. No BFEs or base flood depths are shown within these zones. (Zone X (unshaded) is used on new and revised maps in place of Zone C.)

Undetermined Risk Areas

ZONE	DESCRIPTION
D	Unstudied areas where flood hazards are undetermined, but flooding is possible. No mandatory flood insurance purchase requirements apply, but coverage is available in participating communities.