Inflow Design Flood Control System Plan

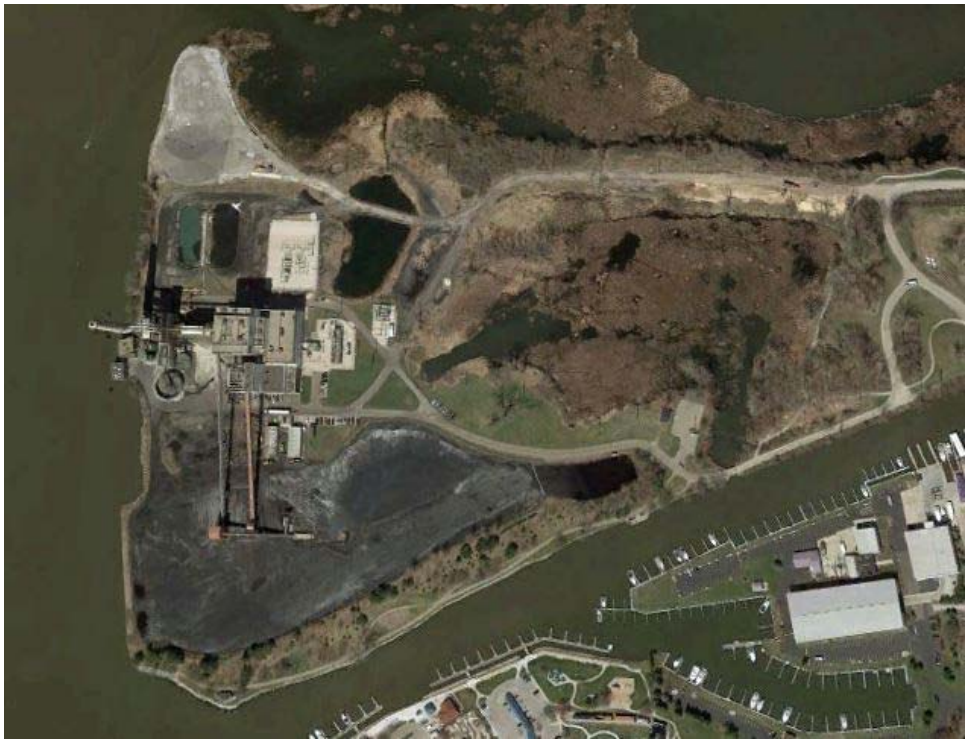
GRAND HAVEN BOARD OF LIGHT AND POWER

J.B. GENERATING STATION

CCR Surface Impoundments
Inflow Design Flood Control System Plan

Pursuant to 40 CFR 257.82

Unit 3 East and West Ash Pond Surface Impoundments



Submitted To: Grand Haven Board of Light and Power
17000 Easton Drive
Grand Haven, Michigan 49417

Submitted By: Golder Associates Inc.
15851 South US 27, Suite 50
Lansing, MI 48906 USA

April 2017

1775416

Golder Associates

CERTIFICATION

Professional Engineer Certification Statement [40 CFR 257.82(c)(5)]

I hereby certify that, having reviewed the attached documentation and being familiar with the provisions of Title 40 of the Code of Federal Regulations Section 257.82 (40 CFR Part 257.82), I attest that this Inflow Design Flood Control System Plan is accurate and has been prepared in accordance with good engineering practices, including the consideration of applicable industry standards, and with the requirements of 40 CFR Part 257.82.

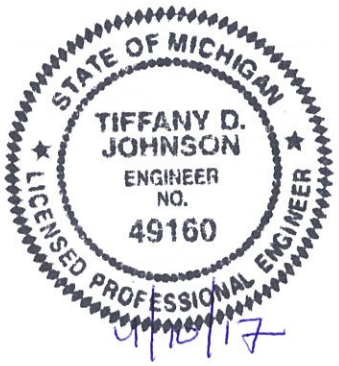
Golder Associates Inc.

Tiffany D Johnson

Signature

April 10, 2017

Date of Report Certification



Tiffany D. Johnson, PE

Name

6201049160

Michigan P.E. #

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1. INTRODUCTION

1.1 Background

The Grand Haven Board of Light and Power (GHBLP) J.B. Sims Generating Station (JBSGS) is a 65 megawatt (MW) coal-fired power plant located in Grand Haven, Michigan, on Harbor Island (see Figure 1). It is bounded by the Grand River on both the east and west sides. The station utilizes two bottom ash treatment ponds, Unit 3 East and West Bottom Ash Ponds, located at the northern end of the plant property between the power plant to the south and Grand Haven Island City Park to the north (see Figure 2). These ponds are used to treat bottom ash from the power plant. The ash is sluiced to the treatment ponds where it is allowed to settle. The ash ponds are operated in a cyclic manner with the active pond receiving ash and other waste streams while the inactive pond is being cleaned of accumulated ash.

The bottom ash treatment ponds are located adjacent to each other and are formed by earthen embankments or ring dikes with a common embankment between them. The impoundment areas range from 175 to 190 feet long by 71 to 80 feet wide with an approximate surface area of 0.2 and 0.3 acres for the east and west ponds, respectively. The ponds were designed by Black & Veatch in 1981 and are constructed with compacted clay embankments with 3H:1V exterior slopes and 2H:1V interior slopes with an approximately 10 feet wide crest. The embankments are not regulated as dams by the Michigan Dam Safety office.

Both ponds were constructed with 3 feet of $3x10^{-7}$ centimeters per second (cm/sec) clay over the floor and are approximately 9 feet deep. The design bottom elevation of the ponds is Elevation (El) 585 feet and the current crest elevation ranges from 591.2 to 592.7 feet. Based on discussions with GHBLP personnel, normal operating conditions maintain a pond elevation of approximately El 588 to 590 feet (1.2 to 4.7 feet of freeboard). The estimated storage capacity of each pond (with two feet of freeboard) is approximately 68,000 and 77,000 cubic feet for the east and west ponds, respectively.

A concrete overflow structure and sluice gate conduit between the east and west ponds allow for water level regulation between the two ponds and prevents overtopping of the embankment. These ponds do not have an outlet structure that discharges from the ponds. Water from the ponds is pumped back to the plant for reuse in plant operations after the bottom ash has settled out. A side stream from the recycled water is discharged to control solids in the recycled water and is regulated by the Michigan Department of Environmental Quality Permit number MI-0000278. Bottom ash is excavated from these ponds via crane or excavator and transported off-site. Periodically, GHBLP relines the ash ponds with clay to replace the clay liner that is removed during pond cleaning.

1.2 Purpose

The purpose of the Inflow Design Flood Control System Plan (Plan) is to provide a basis for the certification required by 40 CFR 257.82 Hydrologic and Hydraulic Capacity Requirements for CCR Surface Impoundments. GHBLP has determined that the Unit 3 East and West Ash Ponds at JBSGS are subject to the requirements of the CCR Final Rule. The east and west ponds have been rated a significant hazard as determined under 40 CFR 257.73(a)(2). 40 CFR 257.82(a) requires the owner or operator of a CCR surface impoundment to design, construct, operate, and maintain an inflow flood control system as follows:

- Adequately manage the flow into the CCR unit during and following the peak discharge of the inflow of the 1,000-year flood event.
- Adequately manage the flow from the CCR unit to collect and control the peak discharge resulting from the 1,000-year flood event.
- Handle discharge from the CCR unit in accordance with the surface water requirements under 40 CFR 257.3-3.

2. FLOOD CONTROL SYSTEM

To satisfy the requirements of 40 CFR 257.82(a), the flood control system must provide flood protection to the CCR unit during the inflow design flood (1,000 year event) for two cases: 1) floodwater from outside the unit, and 2) controlling internal water levels within the unit. The sections below describe the run-on control systems in place, describe the analysis performed to evaluate the adequacy of the existing structure, and list any operational limitations required to maintain adequate flood control measures as required by 40 CFR 257.82(a).

2.1 External Floodwater Protection

The Unit 3 East and West ash ponds are surrounded by a perimeter berm that provides external floodwater protection. The berms were constructed of compacted clay and have a top crest elevation of between El. 591.2 and 592.7 feet. The surrounding exterior grade ranges between El. 583.8 to 590.5 feet, which results in an average grade separation of approximately 5 feet. The Grand River was identified as a potential inflow source to the east and west pond.

A publicly available 1,000-year flood elevation for the Grand River has not been determined by Federal Emergency Management Agency (FEMA). As a result, Golder Associates Inc. (Golder) has estimated the 1,000-year flood elevation by extrapolation of the available FEMA data. The Unit 3 East and West Ash Ponds are located approximately 1.3 miles upstream from the mouth of the Grand River at Lake Michigan. The FEMA Flood Insurance Study (FEMA 2013) reported the Lake Michigan shoreline elevations for the 10-, 50-, 100-, and 500-year recurrence intervals. The 100- and 500-year levels are 584.3 and 585.2 feet, respectively. Based on FEMA Firm Map Numbers 26139C0078E cross section lines E and F (located just upstream and downstream of the station), both Lake Michigan and Grand River (in the area of the Unit 3 East and West Ash Ponds) have 100-year flood elevations of 584.3 feet indicating a close correlation between these two flood level locations. Based on a logarithmic best fit curve extrapolation, the 1,000-year Lake Michigan shoreline level is approximately 585.7 feet. Therefore, Golder has applied the extrapolated 1,000-year level of Lake Michigan shoreline to the upstream area of Grand River that borders Unit 3 East and West Ash Ponds. Refer to Appendix A for the FEMA Flood Elevations.

The lowest elevation along the east and west pond perimeter berm is 591.2 feet, which allows for 5.5 feet of freeboard during the 1,000-year flood event. Therefore, the Grand River should not be an inflow source to the Unit 3 East and West Ash Ponds.

2.2 Internal Flood Control

The Unit 3 East and West Ash Ponds are surrounded by a ring perimeter berm and have no upland drainage areas that discharge into them. The ash ponds are operated in a cyclic manner with the active pond receiving ash and other waste streams while bottom ash is removed from the inactive pond. The only inflow

to the active pond other than sluiced bottom ash and miscellaneous wastewater will be precipitation directly falling on the pond from a 1,000-year 24-hour storm event of 11.4 inches, as provided in Appendix B - Rainfall Data.

A concrete overflow structure and sluice gate conduit is located between the east and west ponds to allow for water level regulation between the two ponds and to prevent overtopping of the embankment. As discussed above, these ponds do not have a discharge outlet structure. Water from the active pond is pumped back to the plant for reuse in plant operations. Under normal operating conditions, GHBLP circulates approximately 0.5 million gallons per day of water from the active pond which maintains an operating pond elevation of approximately El 588 to 590 feet. Based on berm crest elevations of 591.2 to 592.7 feet, the normal operating available free board ranges between 1.2 and 4.7 feet.

This analysis assumes a worst case normal operating condition, pre-1,000 year storm event freeboard of 1.2 feet (pre-storm water level El. 590 feet). Since there are no direct outlets and no additional inflows due to the storm other than the precipitation that falls directly on the pond, by inspection the water level in the pond will rise by 11.4 inches (0.95 feet), the amount of the 1,000-year storm event. This results in post 1,000-year storm event freeboard of 0.25 feet, or a post 1,000-year pond elevation of 590.95. Therefore, the current configuration and operation of the Unit 3 East and West Ash Ponds is compliant with 40 CFR 257.82(a).

3. PLAN REVISION AND RECORDKEEPING

Per 40 CFR 257.82(c)(2): “The owner or operator of the CCR unit may amend the inflow design flood control system plan at any time provided the revised plan is placed in the facility's operating record as required by §257.105(g)(3). The owner or operator must amend the written inflow design flood control system plan whenever there is a change in conditions that would substantially affect the written plan in effect.”

Per 40 CFR 257.81(c)(4); “The owner or operator must prepare periodic inflow design flood control system plans required by paragraph (c)(1) of this section every five years. The date of completing the initial plan is the basis for establishing the deadline to complete the first subsequent plan. The owner or operator may complete any required plan prior to the required deadline provided the owner or operator places the completed plan into the facility's operating record within a reasonable amount of time. In all cases, the deadline for completing a subsequent plan is based on the date of completing the previous plan. For purposes of this paragraph (c)(4), the owner or operator has completed a periodic inflow design flood control system plan when the plan has been placed in the facility's operating record as required by §257.105(g)(3).”

Per 40 CFR 257.82(d); “The owner or operator of the CCR unit must comply with the recordkeeping requirements specified in §257.105(g), the notification requirements specified in §257.106(g), and the internet requirements specified in §257.107(g).”

4. REFERENCES

Dewberry & Davis 2012. USEPA Draft Coal Combustion Residue Impoundment Round 12 – Dam Assessment Report, JB Sims Power Plant (Site 04) East and West Bottom Ash Ponds Grand Haven Board of Power and Light Grand Haven, Michigan, October 2012.

Soils & Structures 2016. Grand Haven BLP – Ash Impoundment Evaluation, July 1, 2016.

Black & Veatch 1983. City of Grand Haven Michigan Board of Light and Power, J.B. Sims Station, Unit 3, Ash Pond Construction, August 19, 1983.

Golder Associates 2017, Grand haven Board of Light and Power J.B. Sims Generating Station, Hazard Potential Classification Assessment and Visual Inspection Report – RCRA CCR Units, Unit 3 East and West Ash Pond Surface Impoundments.

USEPA (US Environmental Protection Agency). 2015. Disposal of Coal Combustion Residuals from Electric Utilities; Final Rule. 40 CFR Part 257. Effective Date October 19, 2015.

FIGURES

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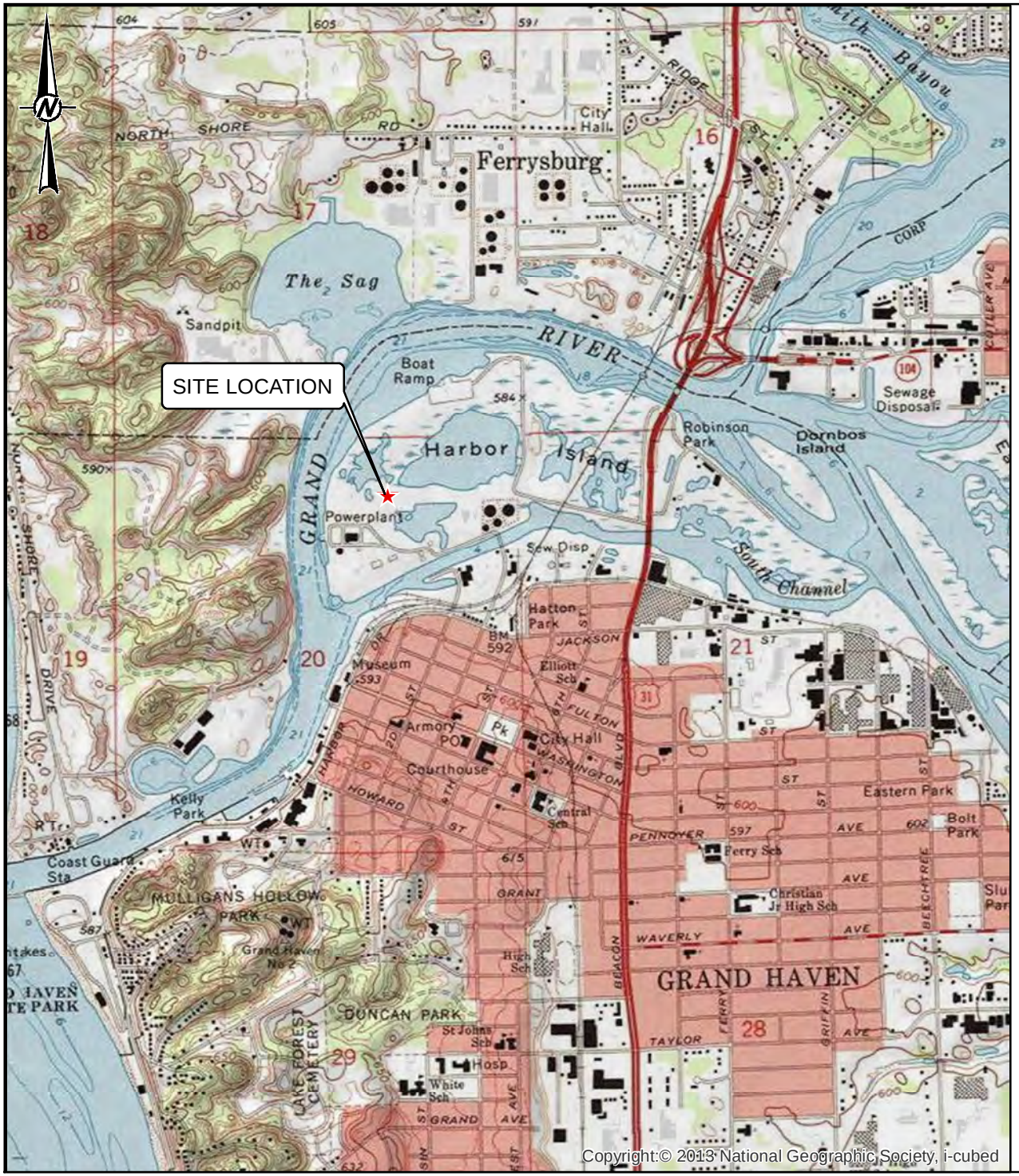
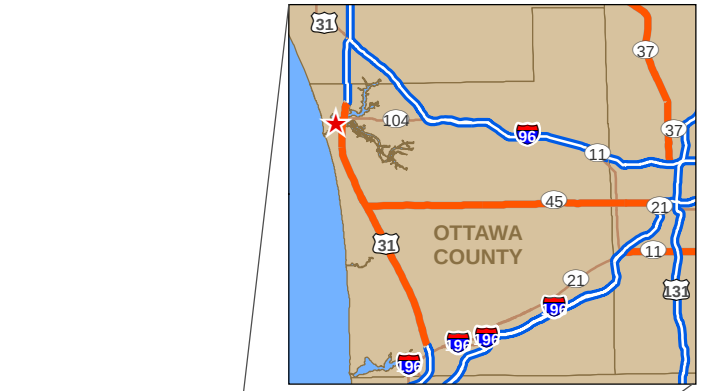




0 1,000 2,000 3,000 4,000

Feet

CLIENT
GRAND HAVEN BOARD OF LIGHT AND POWER
HARBOR ISLAND DRIVE
GRAND HAVEN, MI

PROJECT
CCR RULE COMPLIANCE

TITLE
SITE LOCATION MAP

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-20
PREPARED	JJS
DESIGN	JJS
REVIEW	DML
APPROVED	TDJ

PROJECT No.	CONTROL	Rev.	FIGURE
1775461	1775461A000-GIS.mxd	0	1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET HAS BEEN MODIFIED FROM: ANSI A

0 150 300
1" = 300' FEET

REFERENCE(S)

Service Layer Credits: Source: ESRI, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

CLIENT
GRAND HAVEN BOARD OF LIGHT AND POWER
HARBOR ISLAND DRIVE
GRAND HAVEN, MI

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-03-20
DESIGNED	JJS
PREPARED	JJS
REVIEWED	DML
APPROVED	TDJ

PROJECT
CCR RULE COMPLIANCE

TITLE
OVERALL SITE PLAN

PROJECT NO.	CONTROL	REV.	FIGURE
1775461			2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

Last Edited By: jschmuecker Date: 2017-03-20 Time:11:03:07 AM | Printed By: JSchmuecker Date: 2017-03-20 Time:11:03:18 AM
Path: \\ansing\CAD\Projects\17x-Projects\1775461_Grand Haven BWL\PRODUCTION\A-CCR RULE COMPLIANCE\ | File Name: 1775461A001.dwg

APPENDIX A
FEMA Flood Elevations

NOTES TO USERS

This map is for use in administering the National Flood Insurance Program. It does not necessarily identify all areas subject to flooding, particularly from local drainage sources of small size. The **community map repository** should be consulted for possible updated or additional flood hazard information.

To obtain more detailed information in areas where **Base Flood Elevations** (BFEs) and/or **floodways** have been determined, users are encouraged to consult the Flood Profiles and Floodway Data and/or Summary of Stillwater Elevations tables contained within the Flood Insurance Study (FIS) report that accompanies this FIRM. Users should be aware that BFEs shown on the FIRM represent rounded whole-foot elevations. These BFEs are intended for flood insurance rating purposes only and should not be used as the sole source of flood elevation information. Accordingly, flood elevation data presented in the FIS report should be utilized in conjunction with the FIRM for purposes of construction and/or floodplain management.

Coastal Base Flood Elevations shown on this map apply only landward of 0.0' North American Vertical Datum of 1988 (NAVD 88). Users of this FIRM should be aware that coastal flood elevations are also provided in the Summary of Stillwater Elevations table in the Flood Insurance Study report for this jurisdiction. Elevations shown in the Summary of Stillwater Elevations table should be used for construction and/or floodplain management purposes when they are higher than the elevations shown on this FIRM.

Boundaries of the **floodways** were computed at cross sections and interpolated between cross sections. The floodways were based on hydraulic considerations with regard to requirements of the National Flood Insurance Program. Floodway widths and other pertinent floodway data are provided in the Flood Insurance Study report for this jurisdiction.

Certain areas not in Special Flood Hazard Areas may be protected by **flood control structures**. Refer to Section 2.4 "Flood Protection Measures" of the Flood Insurance Study report for information on flood control structures for this jurisdiction.

The **projection** used in the preparation of this map was Michigan State Plane South zone 6401 (FIPSZONE 2113). The **horizontal datum** was NAD83. Differences in datum, spheroid, projection or state plane zones used in the production of FIRMs for adjacent jurisdictions may result in slight positional differences in map features across jurisdiction boundaries. These differences do not affect the accuracy of this FIRM.

Flood elevations on this map are referenced to the North American Vertical Datum of 1988. These flood elevations must be compared to structure and ground elevations referenced to the same **vertical datum**. For information regarding conversion between the National Geodetic Vertical Datum of 1929 and the North American Vertical Datum of 1988, visit the National Geodetic Survey website at http://www.ngs.noaa.gov/ or contact the National Geodetic Survey at the following address:

NGS Information Services
NOAA, N/NGS12
National Geodetic Survey
SSMC-3, #9202
1315 East-West Highway
Silver Spring, Maryland 20910-3282
(301) 713-3242

To obtain current elevation, description, and/or location information for **bench marks** shown on this map, please contact the Information Services Branch of the National Geodetic Survey at **(301) 713-3242**, or visit its website at http://www.ngs.noaa.gov/.

Base Map Information shown on this FIRM was derived from the Ottawa County, Michigan GIS Office from photography dated 2004.

This map reflects more detailed and up-to-date **stream channel configurations** than those shown on the previous FIRM for this jurisdiction. The floodplains and floodways that were transferred from the previous FIRM may have been adjusted to conform to these new stream channel configurations. As a result, the Flood Profiles and Floodway Data tables in the Flood Insurance Study report (which contains authoritative hydraulic data) may reflect stream channel distances that differ from what is shown on this map.

Corporate limits shown on this map are based on the best data available at the time of publication. Because changes due to annexations or de-annexations may have occurred after this map was published, map users should contact appropriate community officials to verify current corporate limit locations.

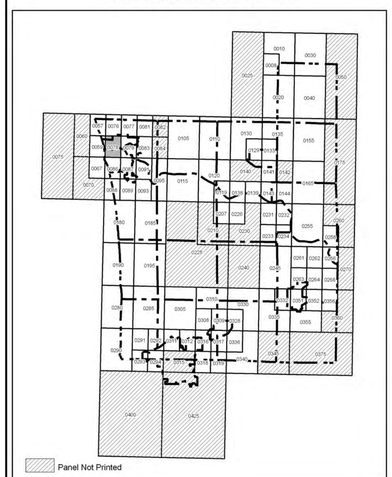
Please refer to the separately printed **Map Index** for an overview map of the county showing the layout of map panels; community map repository addresses; and a Listing of Communities table containing National Flood Insurance Program dates for each community as well as a listing of the panels on which each community is located.

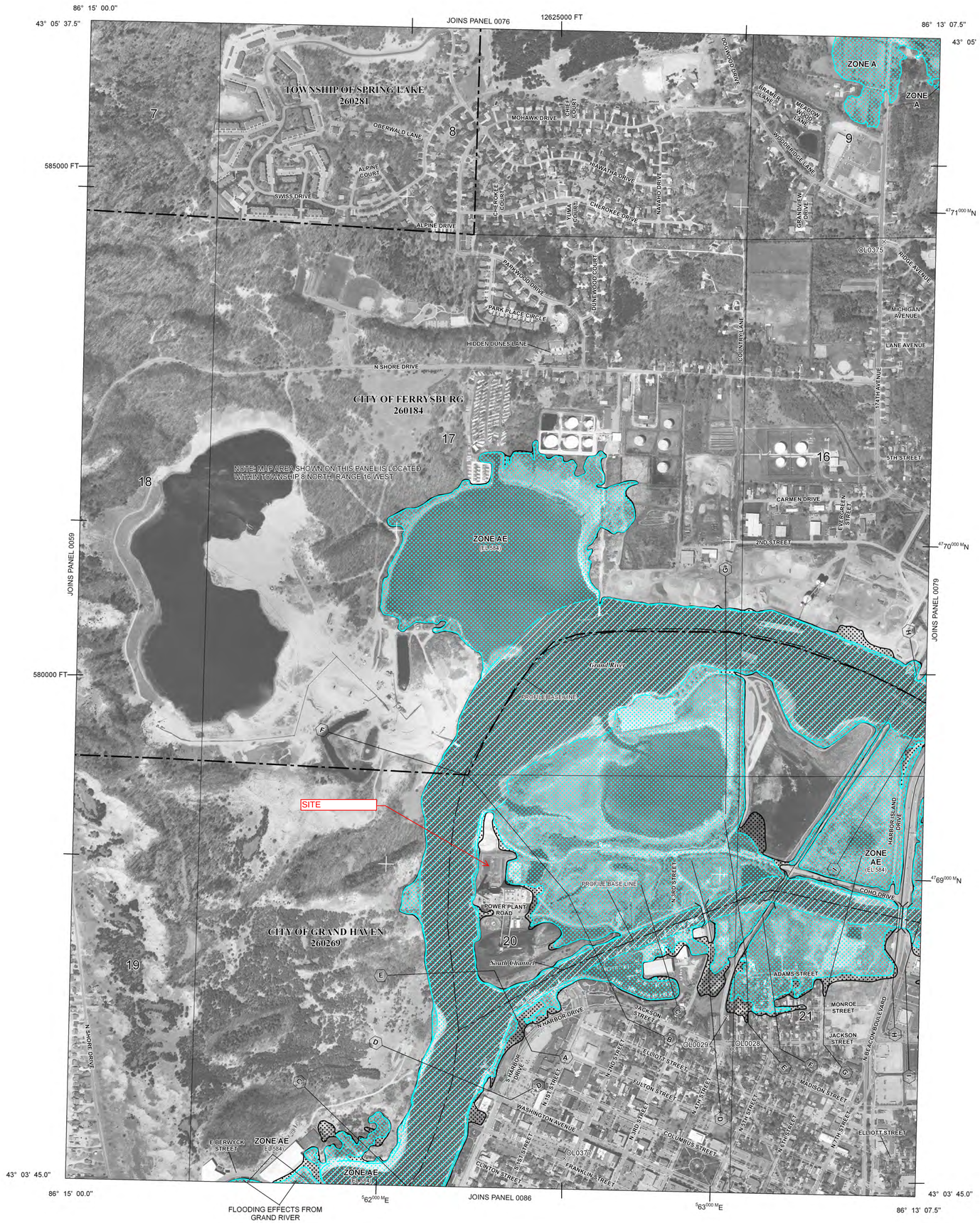
For information on available products associated with this FIRM visit the **Map Service Center (MSC)** website at http://msc.fema.gov/. Available products may include previously issued Letters of Map Change, a Flood Insurance Study Report, and/or digital versions of this map. Many of these products can be ordered or obtained directly from the MSC website.

If you have **questions about this map,** how to order products, or the National Flood Insurance Program in general, please call the **FEMA Map Information eXchange (FMIX)** at **1-877-FEMA-MAP** or visit the FEMA website at http://www.fema.gov/business/nfip.

The **profile base lines** depicted on this map represent the hydraulic modeling baselines that match the flood profiles in the FIS report. As a result of improved topographic data, the **profile base line**, in some cases, may deviate significantly from the channel centerline or appear outside the SFHA.

PANEL INDEX





LEGEND

SPECIAL FLOOD HAZARD AREAS SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD

The 1% annual chance flood (100 year flood), also known as the base flood, is the flood that has a 1% chance of being equaled or exceeded in any given year. The Special Flood Hazard Area is the area subject to flooding by the 1% annual chance flood. Areas of Special Flood Hazard may include Zones A, AE, AH, AO, AR, A99, V, and VE. The Base Flood Elevation is the water-surface elevation of the 1% annual chance flood.

ZONE A	No Base Flood Elevations determined.
ZONE AE	Base Flood Elevations determined.
ZONE AH	Flood depths of 1 to 3 feet (usually areas of ponding); Base Flood Elevations determined.
ZONE AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
ZONE AR	Area of special flood hazard formerly protected from the 1% annual chance flood event by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
ZONE A99	Area to be protected from 1% annual chance flood event by a Federal flood protection system under construction; no Base Flood Elevations determined.
ZONE V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
ZONE VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined.

FLOODWAY AREAS IN ZONE AE

The floodway is the channel of a stream plus any adjacent floodplain areas that must be kept free of encroachment so that the 1% annual chance flood can be carried without substantial increases in flood heights.

OTHER FLOOD AREAS

ZONE X	Areas of 0.2% annual chance flood; areas of 1% annual chance flood with average depths of less than 1 foot or with drainage areas less than 1 square mile; and areas protected by levees from 1% annual chance flood.

OTHER AREAS

ZONE X	Areas determined to be outside of the 0.2% annual chance floodplain.
ZONE D	Areas in which flood hazards are undetermined, but possible.

COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS

OTHERWISE PROTECTED AREAS (OPAs)

CBRS areas and OPAs are normally located within or adjacent to Special Flood Hazard Areas.

- 1% annual chance floodplain boundary
- 0.2% annual chance floodplain boundary
- Floodway boundary
- Zone D boundary
- CBRS and OPA boundary
- Boundary dividing Special Flood Hazard Areas of different Base Flood Elevations, flood depths or flood velocities.
- 513 — Base Flood Elevation line and value; elevation in feet*
- (EL 10) — Base Flood Elevation value where uniform within zone; elevation in feet*

*Referenced to the North American Vertical Datum of 1988

- A — A — Cross section line
- 23 — 23 — Transect line
- Bridge
- Culvert
- 85° 03' 45.0", 41° 24' 22.5" — Geographic coordinates referenced to the North American Datum of 1983 (NAD 83), Western Hemisphere
- 4587000 M — 1000-meter Universal Transverse Mercator grid values, zone 16
- 2250000 FT — 5000-foot grid ticks: Michigan State Plane South Coordinate System, 6401 zone (FIPSZONE 2113), Lambert Conformal Conic projection
- KA0015 × — Bench mark (see explanation in Notes to Users section of this FIRM panel)
- M1.5 ● — River Mile

MAP REPOSITORY
Refer to listing of Map Repositories on Map Index

EFFECTIVE DATE OF COUNTYWIDE FLOOD INSURANCE RATE MAP
December 16, 2011

EFFECTIVE DATE(S) OF REVISION(S) TO THIS PANEL

For community map revision history prior to countywide mapping, refer to the Community Map History table located in the Flood Insurance Study report for this jurisdiction.

To determine if flood insurance is available in this community, contact your insurance agent or call the National Flood Insurance Program at 1-800-638-6620.

MAP SCALE 1" = 500'
250 0 500 1000 FEET
150 0 150 300 METERS

NFIP
NATIONAL FLOOD INSURANCE PROGRAM

PANEL 0078E

FIRM
FLOOD INSURANCE RATE MAP
OTTAWA COUNTY, MICHIGAN
(ALL JURISDICTIONS)

PANEL 78 OF 425
(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
FERRYSBURG, CITY OF	260184	0078	E
GRAND HAVEN, CITY OF	260269	0078	E
SPRING LAKE, TOWNSHIP OF	260281	0078	E

Notice to User: The Map Number shown below should be used when placing map orders; the Community Number shown above should be used on insurance applications for the subject community.

MAP NUMBER
26139C0078E

EFFECTIVE DATE
DECEMBER 16, 2011

Federal Emergency Management Agency

FLOOD INSURANCE STUDY

VOLUME 1 OF 2

OTTAWA COUNTY, MICHIGAN

(ALL JURISDICTIONS)

Community Name	Community Number
Allendale, Charter Township of	260490
* Blendon, Township of	261005
Chester, Township of	260829
Coopersville, City of	260491
Crockery, Township of	260981
Ferrysburg, City of	260184
Georgetown, Charter Township of	260589
Grand Haven, City of	260269
Grand Haven, Charter Township of	260270
Holland, City of (Allegan and Ottawa Counties)	260006
Holland, Charter Township of	260492
Hudsonville, City of	260493
Jamestown, Charter Township of	261001
* Olive, Township of	261006
Park, Township of	260185
Polkton, Charter Township of	260923
Port Sheldon, Township of	260278
Robinson, Township of	260913
Spring Lake, Township of	260281
Spring Lake, Village of	260282
Tallmadge, Charter Township of	260494
Wright, Township of	260495
Zeeland, Charter Township of	260932
Zeeland, City of	260983

* No Special Flood Hazard Areas identified

REVISED:
May 16, 2013

Federal Emergency Management Agency

FLOOD INSURANCE STUDY NUMBER
26139CV001B

FLOODING SOURCE		FLOODWAY				1-PERCENT-ANNUAL-CHANCE FLOOD WATER SURFACE ELEVATION (FEET NAVD)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	WIDTH REDUCED FROM PRIOR STUDY (FEET)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
GRAND RIVER									
A	0.19	383	10,023	6.1		584.3	580.6[2]	580.6	0.0
B	0.38	417	11,698	5.2		584.3	580.9[2]	580.9	0.0
C	0.75	595	14,211	4.3		584.3	581.2[2]	581.2	0.0
D	0.98	668	14,500	4.2		584.3	581.3[2]	581.3	0.0
E	1.16	473	11,766	4.8		584.3	581.4[2]	581.4	0.0
F	1.57	732	13,209	4.2		584.3	581.9[2]	581.9	0.0
G	2.13	595	12,291	4.6		584.3	582.3[2]	582.3	0.0
H	2.47	505	9,193	6.1		584.3	582.5[2]	582.5	0.0
I	2.51	523	9,674	5.8		584.3	582.7[2]	582.7	0.0
J	2.55	463	10,151	5.5	59	584.3	582.9[2]	582.9	0.0
K	2.64	887	13,049	4.3		584.3	583.2[2]	583.2	0.0
L	2.91	1,791	16,757	3.3		584.3	583.7[2]	583.7	0.0
M	3.28	3,042	26,556	2.3		584.3	584.1[2]	584.1	0.0
N	4.00	3,900	33,780	1.8		584.6	584.6	584.6	0.0
O	4.38	3,925	30,426	2.0		584.9	584.9	584.9	0.0
P	4.75	2,467	22,422	2.7		585.2	585.2	585.2	0.0
Q	5.17	3,586	31,809	1.9		585.6	585.6	585.6	0.0
R	5.53	2,920	26,717	2.3		585.8	585.8	585.8	0.0
S	6.21	2,100	24,982	2.4		586.3	586.3	586.3	0.0
T	6.45	2,964	27,565	2.2		586.5	586.5	586.5	0.0
U	6.97	3,178	28,956	2.1		587.0	587.0	587.0	0.0
V	7.38	3,322	28,641	2.1		587.3	587.3	587.3	0.0
W	7.97	3,382	29,203	3.4		587.8	587.8	587.9	0.1
X	9.60	3,179	27,264	4.4		588.5	588.5	588.6	0.1
Y	11.30	4,039	38,831	3.7		589.8	589.8	589.9	0.1

[1] Miles above mouth at Lake Michigan

[2] Elevation computed without consideration of backwater effects from Lake Michigan

TABLE 13

FEDERAL EMERGENCY MANAGEMENT AGENCY

OTTAWA COUNTY, MI
(ALL JURISDICTIONS)

FLOODWAY DATA

GRAND RIVER

TABLE 8 – Summary of Stillwater Elevations *(continued)*

Flooding Source and Location	Peak Elevation (feet NAVD88) 10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Lake Macatawa				
Charter Township and City of Holland and Township of Park	582.8[1]	583.9[1]	584.3[1]	585.2[1]
Lake Michigan				
Entire shoreline	582.8	583.9	584.3	585.2
Lloyd's Bayou				
Township and Village of Spring Lake	582.8[1]	583.9[1]	584.7[2]	586.6[2]
Morning Dew Lake				
Charter Township of Holland	*	*	610.3	*
Mill House Bayou				
Chater Township of Grand Haven	584.9[2]	586.7[2]	587.5[2]	589.5[2]
Pigeon Lake				
Township of Port Sheldon	582.8[1]	583.9[1]	584.3[1]	585.2[1]
Pottawattomie Bayou				
Charter Township and City of Grand Haven	584.4[2]	586.3[2]	587.1[2]	589.1[2]
Rushmore Lake				
Charter Township of Georgetown	*	*	606.8	*
Spring Lake				
City of Ferrysburg and Township and Village of Spring Lake	582.8[1]	583.9[1]	584.3[1]	585.2[1]
Waterfront Lake				
Charter Township of Georgetown	*	*	606.7	*
West Georgetown Shores Lake				
Charter Township of Georgetown	*	*	608.9	*

* Data not available

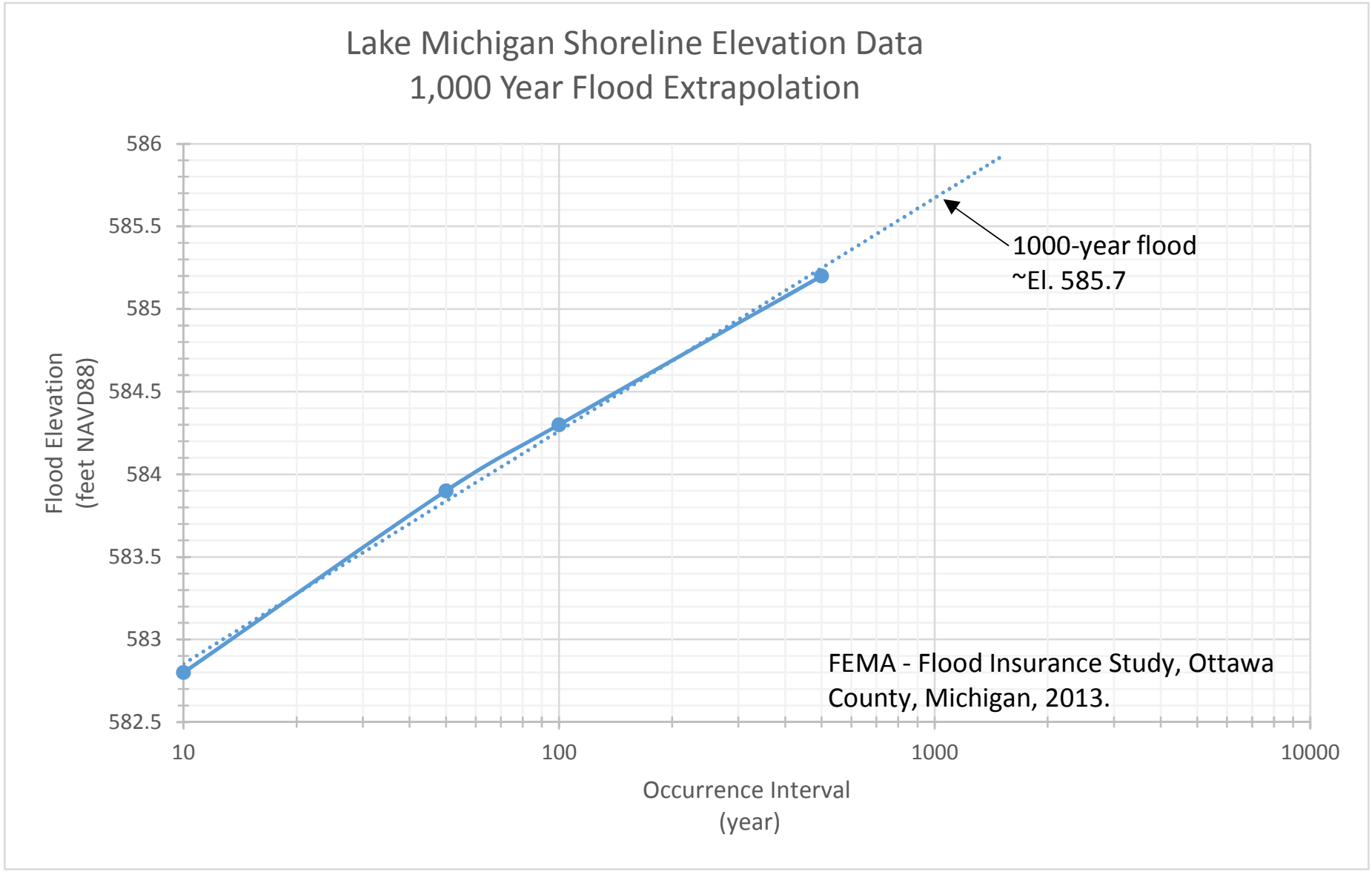
1 Elevation controlled by peak flood elevation of Lake Michigan

2 Elevation controlled by peak flood elevation of the Grand River

Hydrologic calculations were performed using approximate methods for each of the approximate-study streams listed in Section 1.2 to estimate the peak 1-percent-annual-chance flood discharges.

Discharges for the approximate-study streams studied as a part of Phase I were provided by MDEQ. No information regarding the hydrologic analyses performed to estimate the discharges for these streams was available for this study.

Discharges for the approximate-study stream studied as a part of Phase II were calculated by Stantec. Subbasins were delineated at various locations along each reach. The method of analysis used for each subbasin was selected based upon the contributing drainage area.


Lake Michigan Shoreline Elevation Data
1,000 Year Flood Extrapolation
Flood Elevation (feet NAVD88)
586
585.5
585
584.5
584
583.5
583
582.5
10
100
1000
10000
Occurrence Interval (year)
1000-year flood
~El. 585.7
FEMA - Flood Insurance Study, Ottawa County, Michigan, 2013.

APPENDIX B
Rainfall Data

NOAA Atlas 14, Volume 8, Version 2 GRAND HAVEN FIRE DEPT
Station ID: 20-3290
Location name: Grand Haven, Michigan, USA*
Latitude: 43.0622°, Longitude: -86.2244°
Elevation:
Elevation (station metadata): 620 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffery Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.305 (0.254-0.371)	0.360 (0.299-0.439)	0.457 (0.379-0.559)	0.544 (0.448-0.668)	0.672 (0.536-0.864)	0.777 (0.603-1.01)	0.889 (0.664-1.19)	1.01 (0.719-1.39)	1.18 (0.803-1.67)	1.31 (0.866-1.88)
10-min	0.446 (0.371-0.543)	0.527 (0.438-0.643)	0.669 (0.555-0.818)	0.796 (0.655-0.978)	0.984 (0.785-1.27)	1.14 (0.883-1.48)	1.30 (0.972-1.74)	1.48 (1.05-2.03)	1.72 (1.18-2.44)	1.92 (1.27-2.75)
15-min	0.544 (0.453-0.663)	0.643 (0.535-0.784)	0.816 (0.676-0.998)	0.971 (0.799-1.19)	1.20 (0.957-1.54)	1.39 (1.08-1.81)	1.59 (1.19-2.12)	1.80 (1.28-2.48)	2.10 (1.43-2.97)	2.34 (1.55-3.35)
30-min	0.751 (0.625-0.914)	0.888 (0.738-1.08)	1.13 (0.935-1.38)	1.35 (1.11-1.65)	1.67 (1.33-2.15)	1.93 (1.50-2.52)	2.22 (1.66-2.97)	2.52 (1.80-3.47)	2.95 (2.01-4.17)	3.29 (2.17-4.71)
60-min	0.970 (0.808-1.18)	1.14 (0.951-1.40)	1.46 (1.21-1.78)	1.74 (1.43-2.14)	2.18 (1.74-2.81)	2.54 (1.98-3.32)	2.93 (2.19-3.93)	3.36 (2.40-4.63)	3.96 (2.71-5.62)	4.46 (2.94-6.37)
2-hr	1.19 (0.995-1.44)	1.40 (1.17-1.70)	1.78 (1.49-2.17)	2.14 (1.77-2.61)	2.68 (2.16-3.46)	3.15 (2.46-4.10)	3.65 (2.75-4.87)	4.20 (3.02-5.76)	4.98 (3.43-7.03)	5.62 (3.74-7.99)
3-hr	1.34 (1.12-1.61)	1.57 (1.31-1.89)	2.00 (1.67-2.41)	2.40 (1.99-2.92)	3.03 (2.45-3.90)	3.57 (2.80-4.64)	4.16 (3.14-5.54)	4.81 (3.47-6.59)	5.75 (3.97-8.09)	6.52 (4.35-9.23)
6-hr	1.61 (1.36-1.93)	1.88 (1.58-2.25)	2.38 (2.00-2.86)	2.87 (2.39-3.46)	3.65 (2.98-4.69)	4.33 (3.43-5.61)	5.09 (3.87-6.75)	5.93 (4.31-8.08)	7.15 (4.98-10.0)	8.16 (5.48-11.5)
12-hr	1.92 (1.63-2.28)	2.21 (1.87-2.63)	2.79 (2.35-3.33)	3.36 (2.82-4.04)	4.29 (3.54-5.50)	5.12 (4.08-6.61)	6.04 (4.64-7.99)	7.08 (5.19-9.61)	8.60 (6.03-12.0)	9.86 (6.67-13.8)
24-hr	2.25 (1.91-2.65)	2.56 (2.18-3.03)	3.20 (2.71-3.80)	3.85 (3.24-4.59)	4.91 (4.08-6.26)	5.87 (4.71-7.53)	6.94 (5.36-9.12)	8.15 (6.01-11.0)	9.93 (7.01-13.8)	11.4 (7.77-15.8)
2-day	2.58 (2.20-3.03)	2.92 (2.49-3.43)	3.62 (3.08-4.26)	4.32 (3.65-5.11)	5.48 (4.57-6.93)	6.52 (5.26-8.31)	7.69 (5.98-10.0)	9.02 (6.69-12.1)	11.0 (7.80-15.1)	12.6 (8.64-17.4)
3-day	2.79 (2.39-3.26)	3.15 (2.70-3.69)	3.89 (3.32-4.56)	4.62 (3.92-5.45)	5.82 (4.86-7.32)	6.89 (5.57-8.73)	8.08 (6.30-10.5)	9.43 (7.02-12.6)	11.4 (8.14-15.6)	13.1 (8.98-17.9)
4-day	2.97 (2.56-3.47)	3.35 (2.88-3.91)	4.10 (3.51-4.80)	4.84 (4.12-5.69)	6.05 (5.06-7.57)	7.12 (5.77-8.99)	8.32 (6.50-10.8)	9.67 (7.22-12.9)	11.7 (8.33-15.9)	13.3 (9.18-18.2)
7-day	3.52 (3.04-4.08)	3.88 (3.35-4.50)	4.60 (3.95-5.36)	5.33 (4.55-6.23)	6.52 (5.48-8.10)	7.58 (6.18-9.51)	8.78 (6.88-11.3)	10.1 (7.59-13.4)	12.1 (8.71-16.4)	13.8 (9.55-18.7)
10-day	4.02 (3.48-4.65)	4.40 (3.80-5.08)	5.13 (4.42-5.95)	5.86 (5.02-6.83)	7.04 (5.92-8.68)	8.10 (6.61-10.1)	9.28 (7.29-11.9)	10.6 (7.97-13.9)	12.5 (9.04-16.9)	14.2 (9.85-19.2)
20-day	5.45 (4.74-6.25)	5.99 (5.20-6.88)	6.94 (6.00-7.99)	7.79 (6.70-9.02)	9.06 (7.59-10.9)	10.1 (8.25-12.4)	11.2 (8.84-14.1)	12.5 (9.38-16.1)	14.2 (10.2-18.8)	15.5 (10.9-20.9)
30-day	6.64 (5.79-7.59)	7.34 (6.39-8.40)	8.50 (7.38-9.75)	9.49 (8.19-10.9)	10.9 (9.08-13.0)	12.0 (9.75-14.5)	13.1 (10.3-16.3)	14.2 (10.7-18.2)	15.8 (11.4-20.8)	17.0 (11.9-22.8)
45-day	8.18 (7.15-9.31)	9.05 (7.90-10.3)	10.4 (9.10-11.9)	11.6 (10.0-13.3)	13.1 (11.0-15.5)	14.3 (11.7-17.2)	15.4 (12.2-19.0)	16.6 (12.5-21.1)	18.0 (13.1-23.6)	19.1 (13.5-25.6)
60-day	9.51 (8.33-10.8)	10.5 (9.19-11.9)	12.1 (10.5-13.7)	13.3 (11.6-15.3)	15.0 (12.5-17.6)	16.2 (13.3-19.4)	17.4 (13.8-21.4)	18.6 (14.1-23.6)	20.1 (14.6-26.2)	21.2 (15.0-28.3)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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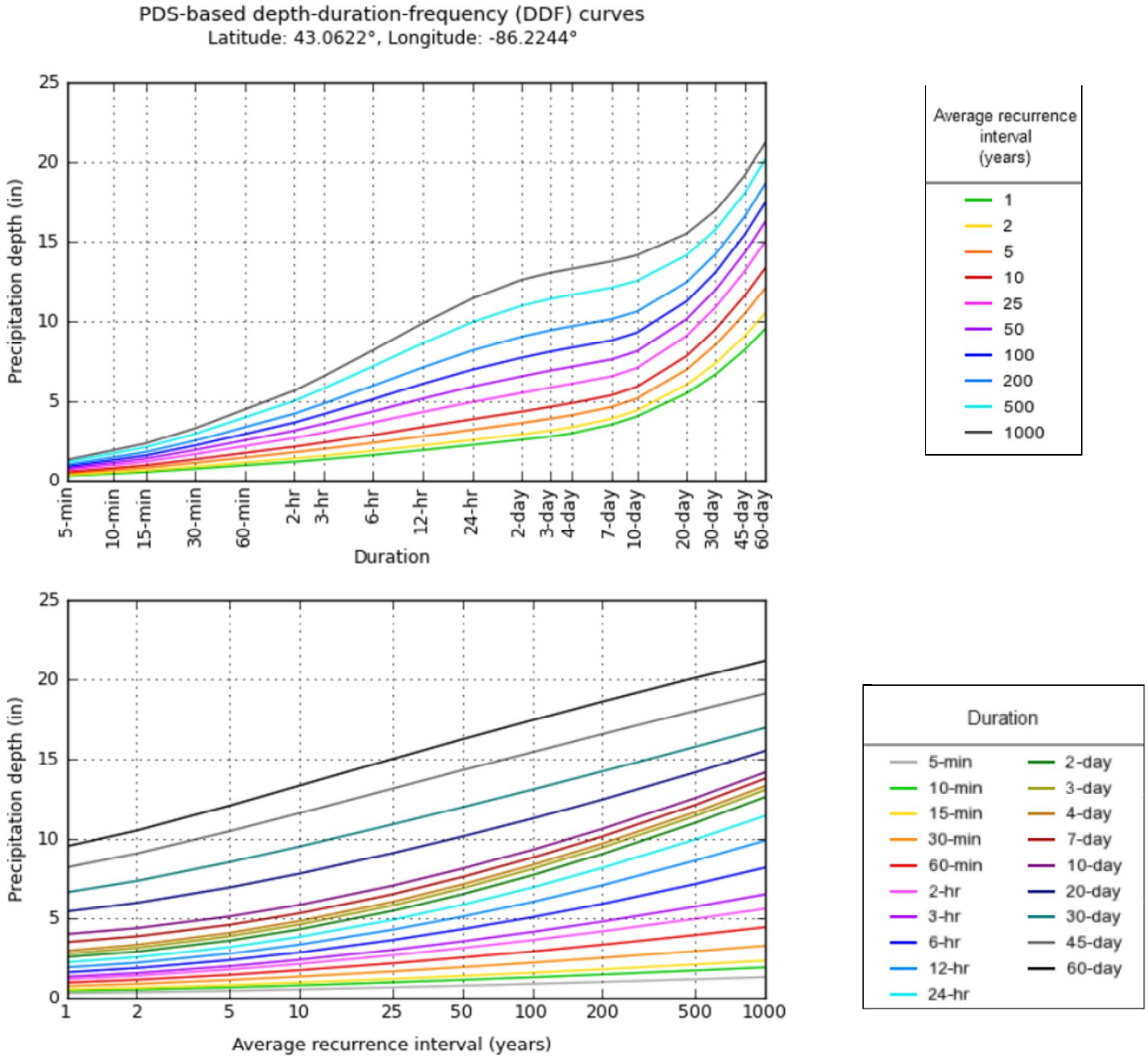
PF graphical



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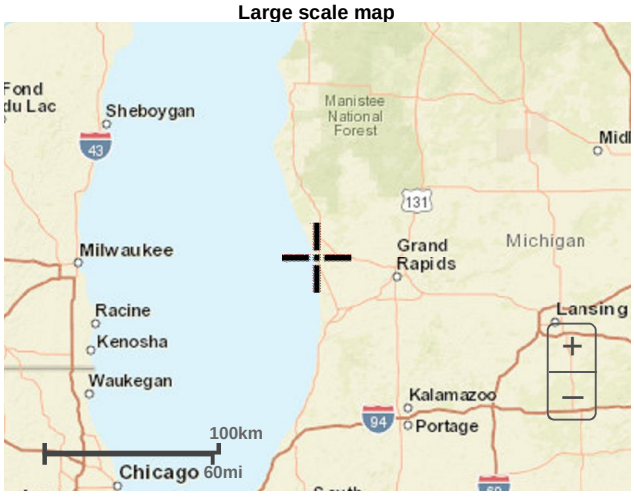
Maps & aerials

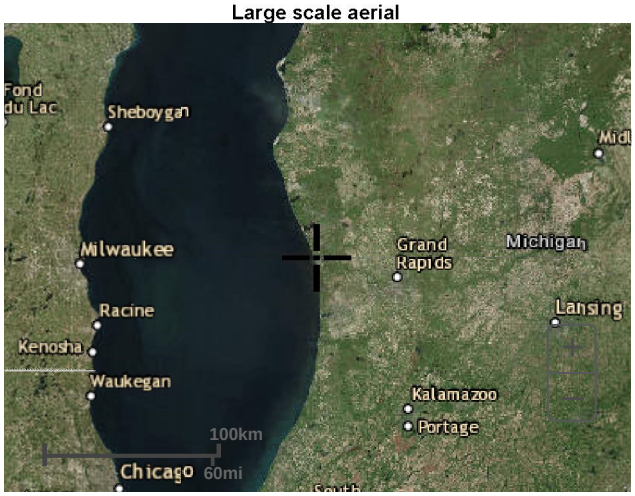
Small scale terrain

Large scale terrain

Large scale map



Large scale aerial



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