

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



April 2017	C-1	J.B. Sims Inflow Design Flood Control System Plan
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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.

Signature

Date of Report Certification



Tiffany D. Johnson, PE

6201049160

Michigan P.E. #





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Table of Contents

CERTIF	FICATIONC	-1
1.	INTRODUCTION	. 1
1.1	Background	. 1
1.2	Purpose	.2
2.	FLOOD CONTROL SYSTEM	.3
2.1	External Floodwater Protection	. 3
2.2	Internal Flood Control	. 3
3.	PLAN REVISION AND RECORDKEEPING	.5
4.	REFERENCES	.6

List of Figures

Figure 1	Site Location Map
Figure 2	Overall Site Plan

List of Appendices

Appendix A	FEMA Flood Elevations
Appendix B	Rainfall Data



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





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

IT	YYYY-MM-DD	2017-03-20	
<u></u>	DESIGNED	JJS	
Golder	PREPARED	JJS	
	REVIEWED	DML	
	APPROVED	TDJ	



REV.

PROJECT CCR RULE COMPLIANCE

TITLE OVERALL SITE PLAN

PROJECT NO. CONTROL 1775461 IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MO

FIGURE

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





OTTAWA COUNTY, MICHIGAN

Community

(ALL JURISDICTIONS)

Co	mmunity Name	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	260006
	(Allegan and Ottawa Counties)	
	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 S	OURCE	FLOODWAY				1-PERCENT-ANNUAL-CHANCE FLOOD WATER SURFACE ELEVATION				
	DIGTANOP	WIDTH	SECTION MEAN WIDTH REDUCED AREA VELOCITY FROM PRIOR VIDTH (SQUARE (FEET PER STUDY			WITHOUT	WITH			
CROSS SECTION	DISTANCE	(FEET)	FEET)	SECOND)	(FEET)	REGULATORY	FLOODWAY	FLOODWAY	INCREASE	
GRAND RIVER	0.10	282	10.022	6.1		594.2	$590 c^2$	500 (0.0	
A	0.19	383	10,023	6.1		584.3	580.0	580.6	0.0	
В	0.38	417	11,698	5.2		584.3	580.9	580.9	0.0	
C	0.75	595	14,211	4.3		584.3	581.2	581.2	0.0	
	0.98	008	14,500	4.2		584.3	581.5	581.5	0.0	
	1.10	473	11,700	4.8		584.3	581.4	581.4	0.0	
r C	1.57 2.12	132	13,209	4.2		<mark>- 384.3</mark> - 594.2	581.9	581.9	0.0	
G	2.13	595	12,291	4.0		584.3	582.5	582.5	0.0	
н	2.47	505	9,193	0.1		584.3	582.3	582.5	0.0	
l	2.51	523	9,674	5.8	50	584.3	582.7	582.7	0.0	
J	2.55	463	10,151	5.5	59	584.3	582.9	582.9	0.0	
K	2.64	887	13,049	4.3		584.3	585.2	583.2	0.0	
	2.91	1,791	16,757	3.3		584.3	584.1 ²	585.7	0.0	
IVI N	3.28	3,042	20,550	2.3		584.5	594.1	584.1	0.0	
N	4.00	3,900	33,780	1.8		584.0	584.0	584.0	0.0	
D	4.30	5,925	50,420 22,422	2.0		585.2	585.2	585.2	0.0	
P	4.75	2,407	22,422	2.7		585.6	585.2 585.6	585.6	0.0	
Q D	5.52	3,580	26 717	1.9		505.0	505.0	595.0	0.0	
K S	5.55	2,920	20,717	2.3		586 3	586 3	5863	0.0	
ы Т	6.45	2,100	24,902	2.4		586.5	586.5	586.5	0.0	
I	0.4J 6.07	2,904	27,505	2.2		587.0	587.0	587.0	0.0	
V	7 38	3,170	28,950	2.1		587.3	587.3	587.3	0.0	
v W	7.30	3 382	20,041	2.1		587.8	587.8	587.9	0.0	
v	9.60	3,362	29,203	3.4 4.4		588.5	588 5	588.6	0.1	
	9.00	3,179	27,204	4.4		580.8	580.8	580.0	0.1	

¹ Miles above mouth at Lake Michigan

TABLE

13

² Elevation computed without consideration of backwater effects from Lake Michigan

FEDERAL EMERGENCY MANAGEMENT AGENCY

FLOODWAY DATA

OTTAWA COUNTY, MI

(ALL JURISDICTIONS)

GRAND RIVER

	Peak Elevation (feet NAVD88)				
	10%	<u>2%</u>	<u>1%</u>	0.2%	
	<u>Annual</u>	<u>Annual</u>	<u>Annual</u>	<u>Annual</u>	
Flooding Source and Location	Chance	Chance	Chance	Chance	
Lake Macatawa					
Charter Township and City of	582.8^{1}	583.9^{1}	584.3 ¹	585.2^{1}	
Holland and Township of Park					
Lake Michigan					
Entire shoreline	<mark>582.8</mark>	<mark>583.9</mark>	<mark>584.3</mark>	<mark>585.2</mark>	
Lloyd's Bayou					
Township and Village of	582.8 ¹	583.9 ¹	584.7 ²	586.6 ²	
Spring Lake					
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	584.4^2	586.3^2	587.1^2	589.1 ²	
Grand Haven					
Rushmore Lake					
Charter Township of Georgetown	*	*	606.8	*	
Spring Lake					
City of Ferrysburg and Township	582.8^{1}	583.9^{1}	584.3 ¹	585.2^{1}	
and Village of Spring Lake					
Waterfront Lake					
Charter Township of Georgetown	*	*	606.7	*	
West Georgetown Shores Lake					
Charter Township of Georgetown	*	*	608.9	*	

TABLE 8 – Summary of Stillwater Elevations (continued)

* 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.

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: 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)									
Duration	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)	<mark>11.4</mark> (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.

Back to Top

NOAA Atlas 14, Volume 8, Version 2

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Maps & aerials

Large scale terrain

Back to Top

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