2.6 DAM/LEVEE FAILURE

DAM FAILURE

A dam is defined as an artificial barrier that is usually constructed across a stream channel to impound water. A dam failure is defined as an uncontrolled release of that impounded water. The causes of dam failures can be divided into three groups: dam overtopping, excessive seepage, and structural failure of a component. Despite efforts to provide sufficient structural integrity and to perform inspection and maintenance, problems can develop that can lead to failure. While most dams have storage volumes small enough that failures would have little or no consequences, dams with large storage amounts could cause significant flooding downstream.

Dam failures can result from any one or a combination of the following causes:

- Prolonged periods of rainfall and flooding;
- Inadequate spillway capacity, resulting in excess overtopping flows;
- Internal erosion caused by embankment or foundation leakage or piping;
- Improper maintenance, including failure to remove trees, repair internal seepage problems, replace lost material from the cross section of the dam and abutments, or maintain gates, valves, and other operational components;
- Improper design, including the use of improper construction materials and construction practices;
- Improper operation, including the failure to remove or open gates or valves during high flow periods;
- Failure of upstream dams on the same waterway that release water to a downstream dam;
- Earthquakes, which typically cause longitudinal cracks at the tops of the embankments that can weaken entire structures.

In terms of emergency management, dam failures are categorized as either sunny day failures or rainy day failures. Sunny day failures occur during a non- flooding situation with the reservoir near normal pool level. Rainy day failures usually involve periods of rainfall and flooding, and can exacerbate inadequate spillway capacity. Improper design of a spillway or operation of gates during high flows can lead to excessive water pressure and subsequent failure as well. Even though both types of failures can be disastrous, it can be assumed that a sunny day failure would be more catastrophic due to its unanticipated occurrence and the lack of time to warn residents downstream.

Dams are complicated structures, and it can be difficult to predict how a structure will respond to distress "… the modes and causes of failure are varied, multiple, and often complex and interrelated, i.e., often the triggering cause may not truly have resulted in failure had the dam not had a secondary weakness. These causes illustrate the need for careful, critical review of all facets of a dam" (Safety of Existing Dams, 1983).

LEVEE FAILURE

A levee is any artificial barrier together with appurtenant works that will divert or restrain the flow of a stream or other body of water for the purpose of protecting an area from inundation by flood waters. Generally, a levee is subjected to water loading during a few days or weeks in a given year; unlike a dam that is retaining water most days in the same year.

A levee breach results when a portion of the levee breaks away, providing an opening for water to flood the landward side of the structure. Such breaches can be caused by surface erosion due to water velocities, or they can be the result of subsurface actions. Subsurface actions usually involve sand boils whereby the upward pressure of water flowing through porous soil under the levee exceeds the static pressure of the soil weight above it (i.e., under-seepage). These boils can indicate instability of the levee foundation given the liquefied substrate below it, leading way to breaching. Levee overtopping is similar to dam overtopping in that the flood waters simply exceed the design capacity of the structure, thus flowing over the lowest crest of the system. Such overtopping can lead to erosion on the landward side which, subsequently, can lead to breaching. In order to prevent this type landward erosion, many levees are reinforced or armored with rocks or concrete.

AUTHORITY AND RESPONSIBILITY

The Ohio Department of Natural Resources, Division of Water Resources - Dam Safety Program (DSP) has the responsibility to ensure that human life, health and property are protected from dam and levee failures. The program achieves its core purpose by performing the following main functions:

- Emergency response – Assessing the conditions of dams during severe floods and emergency's, taking action to correct dams that pose an immediate threat to public safety, providing timely and best-available information to other agencies and the public during disasters, and supporting mandate Ohio Revised Code (ORC) Section 1521.062;
- Construction permits – Ensuring that dams and levees are designed and constructed in accordance with proper engineering standards and OAC rules, reviewing construction plans and specifications, performing calculations and investigations, issuing permits, and monitoring/approving construction;
- Repairs and modifications -- Ensuring that dams and levees are repaired in accordance with proper engineering standards and OAC rules, reviewing construction plans and specifications, performing calculations and investigations, issuing permits, and monitoring/approving construction, and supporting mandate ORC Section 1521.062;
- Periodic safety inspections –Inspecting Class I-III dams once every five years, monitoring the overall condition of Ohio's dams, providing data for the National Performance of Dams Program (NPDP), and supporting mandate ORC Section 1521.062;
- Enforcement – Requiring dam and levee owners to improve safety when efforts for voluntary compliance have been unsuccessful and focusing on Class I dams with dense populations downstream; and
- Public information – Providing data security for Ohio EMA, US Army Corps of Engineers (USACE), the National Guard, Ohio EPA, as well as the state and federal legislatures, providing dam and levee owners and engineers with technical information and access to division files, educating the public about dam safety and providing quality data, and giving presentations for EPA, Water Management Association of Ohio (WMAO), and the Ohio Lake Communities Association (OLCA).

The ORC provides the authority for the program to regulate dam and levee safety, and dictates the responsibilities of the program as well as the responsibilities of the dam and levee owners. The program has jurisdiction over approximately 2,749 dams in Ohio, of which 362 are Class I (highest hazard); DSP does not have jurisdiction over Federal dams. USACE presides over most of those Federal dams, and ensures they are operated and maintained properly.

Many levees in Ohio are owned and maintained by local communities, with a few levees being owned and maintained by the USACE. While a federal inventory of levees is complete, the methodology for evaluating the effects of levees on flood hazards is in flux. This will be discussed later in this section.

RISK ASSESSMENT

DAMS—LOCATION

In Ohio, there are 5,874 known existing structures that retain or detain water, and these are included in ODNR's inventory of dams (DSP data, June 2018). The volume of water impounded, and the density, type, and value of development downstream determine the potential severity and potential classification of dam. The USACE's National Inventory of Dams (NID) represented only a portion of the dams regulated by the State of Ohio. Therefore, a more complete list was obtained from ODNR's inventory for this 2019 Update.

The ODNR DSP classifies dams as Class I, Class II, Class III, and Class IV dams, with Class I being the highest risk and Class IV the lowest risk (Table 2.6.a). The classification of a dam is based on three factors: the dam's height, storage capacity, and potential downstream hazard. The height of the dam is the vertical distance from the crest to the downstream toe. The storage capacity is the volume of water that the dam can impound at the top of dam (crest) elevation. The downstream hazard consists of roads, buildings, homes, and other structures that would be damaged in the event of a dam failure. Potential for loss of life is also evaluated. Various dam failure scenarios must be considered, and they include failures when the dam is at normal pool level (sunny day) and failures during significant flood events (rainy day). Each of the three factors is evaluated, and the final classification of the dam is based on the highest individual factor. The classification of a dam can change based on future development along the downstream channel. It is important to note all classes are required to have Emergency Action Plans (EAPs) and Class I dams are required to include dam failure inundation mapping.

Table 2.6.a

Ohio and Federal Dam Classification Systems		
Ohio Dam Classification	**Description**	**Corresponding Federal Classification**
Class I	Probable loss of life, serious hazard to health, structural damage to high value property (i.e., homes, industries, major public utilities)	High
Class II	Flood water damage to homes, businesses, industrial structures (no loss of life envisioned), damage to state and interstate highways, railroads, only access to residential areas	Significant
Class III	Damage to low value non- residential structures, local roads, agricultural crops and livestock	Significant
Class IV	Losses restricted mainly to the dam	Low

Source: http://water.ohiodnr.gov/safety/dam-safety

This update will focus on Class I dams as they are deemed as having the most potential for loss of life, greatest hazards to health, and causing the most structural damage should any of them fail. Classes II and III also will be evaluated to a slight degree since their failure would most likely result in damages to homes, businesses, infrastructure, but no loss of life is likely.

As mentioned, there are 402 Class I dams, 1089 Class II and III, and 1049 Class IV dams in Ohio. Additionally, there are approximately 3,374 "other" structures throughout the state that are proposed, unclassified, exempt, and/or abandoned. (Table 2.6.b).

Table 2.6.b

Dam Inventory by County and Dam Classification											
Region 1											
County	I	II+III	IV	Other	Total	County	I	II+III	IV	Other	Total
Allen	5	7	10	24	46	Marion	0	2	4	4	10
Auglaize	1	2	2	8	13	Mercer	2	5	1	2	10
Champaign	0	9	7	11	27	Miami	3	4	6	26	39
Clark	2	6	6	9	23	Ottawa	0	2	3	6	11
Crawford	5	5	12	19	41	Paulding	1	1	6	9	17
Darke	0	5	7	25	37	Preble	5	12	16	38	71
Defiance	2	8	6	11	27	Putnam	1	2	3	12	18
Erie	0	2	4	13	19	Sandusky	3	0	2	4	9
Fulton	5	5	0	4	14	Seneca	2	5	4	10	21
Hancock	9	3	0	11	23	Shelby	2	4	10	23	39
Hardin	0	3	6	10	19	Van Wert	3	0	1	5	9
Henry	0	1	1	12	14	Williams	1	8	14	24	47
Huron	10	12	10	24	56	Wood	4	4	0	8	16
Logan	3	8	12	22	45	Wyandot	0	6	7	22	35
Lucas	1	4	0	18	23						
TOTAL: 779 (I: 70, II+III: 135, IV: 160, Other: 414)											

Region 2											
County	I	II+III	IV	Other	Total	County	I	II+III	IV	Other	Total
Ashland	5	19	20	42	86	Lorain	5	21	20	101	147
Butler	7	15	22	74	118	Madison	1	3	1	3	8
Clinton	8	12	13	18	51	Medina	14	51	64	133	262
Cuyahoga	7	12	4	40	63	Montgomery	6	6	6	38	56
Delaware	16	13	24	36	89	Morrow	3	13	18	28	62
Fairfield	13	34	15	39	101	Pickaway	2	10	10	21	43
Fayette	1	3	1	6	11	Portage	8	16	27	151	202
Franklin	3	15	11	40	69	Richland	3	11	11	31	56
Geauga	9	22	24	68	123	Stark	5	30	29	93	157
Greene	4	9	16	26	55	Summit	18	30	23	115	186
Hamilton	9	23	15	84	131	Union	1	2	5	21	29
Knox	5	12	10	36	63	Warren	10	33	48	74	165
Lake	2	9	4	23	38	Wayne	3	14	10	50	77
Licking	1	16	40	63	120						
TOTAL: 2568 (I: 169, II+III: 454, IV: 491, Other: 1454)											

Region 3											
County	**I**	**II+III**	**IV**	**Other**	**Total**	**County**	**I**	**II+III**	**IV**	**Other**	**Total**
Adams	3	12	10	38	63	**Jefferson**	7	21	18	47	93
Ashtabula	6	26	24	78	134	**Lawrence**	5	6	3	41	55
Athens	8	4	10	40	62	**Mahoning**	6	14	14	58	92
Belmont	9	12	28	68	117	**Meigs**	2	7	7	24	40
Brown	2	17	16	42	77	**Monroe**	2	9	8	33	52
Carroll	3	17	28	50	98	**Morgan**	2	18	10	38	68
Clermont	8	30	23	63	124	**Muskingum**	5	36	22	71	134
Columbiana	7	36	21	67	131	**Noble**	3	9	4	22	38
Coshocton	3	15	13	23	54	**Perry**	9	23	8	41	81
Gallia	4	9	4	35	52	**Pike**	5	4	3	41	53
Guernsey	4	26	12	30	72	**Ross**	8	16	6	27	57
Harrison	11	23	14	68	116	**Scioto**	8	9	4	59	80
Highland	3	8	9	28	48	**Trumbull**	4	18	12	93	127
Hocking	4	23	10	80	117	**Tuscarawas**	7	19	13	63	102
Holmes	2	3	11	13	29	**Vinton**	3	6	9	19	37
Jackson	5	12	13	94	124	**Washington**	5	12	11	12	40
TOTAL: 2567 (I: 163, II+III: 500, IV: 398, Other: 1506)											

Source: DSP Dam Inventory, June 2018

Region 1 has many fewer dams than regions 2 and 3. This may be largely due to the topography as Region 1 is relatively flatter than Regions 2 and 3. Region 1 has a total of 779 dams consisting of 70 Class I, 135 Class II and III, 160 Class IV, and 414 "Other" dams. Region 2 has a total of 2568 dams consisting of 169 Class I, 454 Class II and III, 491 Class IV, and 1454 "Other" dams. Region 3 has a total of 2567 dams consisting of 163 Class I, 500 Class II and III, 398 Class IV, and 1506 "Other" dams.

LEVEES—LOCATION

There are two primary sources of levee data for the State of Ohio- The US Army Corp of Engineers National Levee Database (NLD) and the Ohio Department of Natural Resources Dam Safety Program. The National Levee Database is dynamic in nature, it does provide static information regarding levee location and attributes, which can aid in decision making and better flood risk management. This database was recently released to the public so individuals would have the ability to conduct custom queries and get information pertinent to their situation and their community. However, gaps remain in some qualitative and quantitative data for levees, which will affect a community's ability to gauge risk and implement successful risk communication. Such data gaps exacerbate existing state and community-specific levee safety issues, such as estimating levee maintenance costs, which affect future funding priorities; and completing accurate risk assessments among the various counties containing such structures in their jurisdictions. The National Levee Database identifies that there are 257 levees in Ohio (Table 2.6.d).

Table 2.6.c

USACE NLD Levee Inventory by County											
Region 1				Region 2				Region 2			
County	Region	Levee Count	Leveed Area (Sq. Miles)	County	Region	Levee Count	Leveed Area (Sq. Miles)	County	Region	Levee Count	Leveed Area (Sq. Miles)
Erie	1	2	0.16	Butler	2	10	4.12	Clermont	3	1	0.08
Erie/Sandusky	1	1	0.53	Cuyahoga	2	1	0.01	Columbiana	3	1	0.45
Lucas	1	5	4.12	Fairfield	2	2	0.89	Guernsey	3	2	0.12
Lucas/Monroe	1, 3	1	0.50	Franklin	2	3	4.82	Hocking	3	1	0.03
Lucas/Ottawa	1	6	3.68	Hamilton	2	10	5.39	Lawrence	3	2	2.35
Marion	1	2	0.80	Knox	2	5	0.79	Muskingum/Perry	3	1	0.11
Miami	1	6	0.28	Lake	2	1	0.03	Pike	3	4	1.81
Ottawa	1	146	16.62	Licking	2	1	0.16	Ross	3	1	2.15
Ottawa/Sandusky	1	4	0.97	Lorain	2	1	0.25	Scioto	3	1	2.99
Sandusky	1	3	1.30	Montgomery	2	20	10.28	Tuscarawas	3	1	0.11
				Richland	2	1	0.00				
				Stark	2	5	0.78				
				Stark/Carroll	2, 3	1	0.11				
				Warren	2	5	0.45				
Region 1 Total:		176	28.96	Region 2 Total:		66	26.75	Region 3 Total:		15	10.21

Source: USACE National Levee Database

The ODNR DSP levee database classifies the hazard potential for levees as Class I, Class II, and Class III levees (Table 2.6.c), depending on what is identified as the landward risk. Under these classifications, ODNR DSP identifies 36 levees including four unclassified levees (Table 2.6.d).

Table 2.6.c

Ohio Levee Classification Systems	
Hazard Classifcation	**Description**
Class I	Probably loss of human life, structural collapse of at least one residence or one commerical or industrial business
Class II	Disruption of a public water supply or wasterwater treatment facility, or other health hazards; flooding of residential, commerical, industrial, or publically owned structures; flooding of high-value property; damage or disruption to major roads including but not limited to interstate and state highways, and the only access to residential or other critical areas such as hospitals, nursing homes, or correctional facilities as determined by the chief; damage or disruption to railroads or public utilities
Class III	Property losses including but not limitied to rural buildigs not otherwise described in this rule; damage or disruption to local roads including but not limited to roads not otherwise listed as major roads in this rule

Source: http://water.ohiodnr.gov/safety/dam-safety

Table 2.6.d

ODNR DSP Levee Inventory				
NAME	OWNER TYPE	COUNTY	STREAM	CLASS
SHADYSIDE WWTP LEVEE	PUBLIC, LOCAL	BELMONT	OHIO RIVER	II
HAMILTON SOUTH WATER TREATMENT LEVEE	PUBLIC, LOCAL	BUTLER	PLEASANT RUN	II
BANKER DRIVE LEVEE	PUBLIC, LOCAL	BUTLER	PLEASANT RUN	III
WINDISCH ROAD LEVEE	PRIVATE	BUTLER	EAST FORK OF MILL CREEK	III
HAMILTON LEVEE	PUBLIC, C.D.	BUTLER	GREAT MIAMI RIVER	UNCLASS
WELLSVILLE LEVEE	PUBLIC, LOCAL	COLUMBIANA	OHIO RIVER	I
CERRI LEVEE	PRIVATE	CUYAHOGA	CHAGRIN RIVER	III
AGG ROK REACH LEVEE	PRIVATE	FRANKLIN	SCIOTO BIG RUN	I
KING AVENUE LEVEE	PUBLIC, LOCAL	FRANKLIN	OLENTANGY RIVER	II
NATIONAL LIME & STONE SHADEVILLE LEVEE	PRIVATE	FRANKLIN	SCIOTO RIVER	UNCLASS
SUN VALLEY LEVEE	PRIVATE	GALLIA	UNNAMED TRIBUTARY TO CHICKAMAUGA	EXEMPT
KYGER CREEK LEVEE	PUBLIC, STATE	GALLIA	KYGER CREEK	II
SOUTHGATE DIKE	PUBLIC, LOCAL	GUERNSEY	WILLIS CREEK	I
MUDDY CREEK WWTP LEVEE	PUBLIC, LOCAL	HAMILTON	ALONG OHIO RIVER	I
LITTLE MIAMI WWTP LEVEE	PUBLIC, LOCAL	HAMILTON	OHIO RIVER	II
SYCAMORE CREEK WWTP LEVEE	PUBLIC, LOCAL	HAMILTON	SYCAMORE CREEK	II
HILLSBORO WWTP LEVEE	PUBLIC, LOCAL	HIGHLAND	CLEAR CREEK	UNCLASS
LOGAN WATER TREATMENT PLANT LEVEE	PUBLIC, LOCAL	HOCKING	HOCKING RIVER	II
WARNER LEVEE	PRIVATE	LAKE	CHAGRIN RIVER	III
HEATH WWTP FLOOD PROTECTION LEVEE	PUBLIC, LOCAL	LICKING	SOUTH FORK LICKING RIVER	II
SWANEY LEVEE	PRIVATE	MARION	SCIOTO RIVER TRIBUTARY	III
GRUSENMEYER LEVEE	PRIVATE	MIAIMI	GREAT MIAMI RIVER	III
FULTON LEVEE	PRIVATE	MIAMI	LOST CREEK	III
MORAINE LEVEE AND FLOODWALL	PUBLIC, LOCAL	MONTGOMERY	GREAT MIAMI RIVER	I
ARNOLD LEVEE	PRIVATE	NOBLE	SALT RUN	UNCLASS
WESTFALL LEVEE	PRIVATE	PICKAWAY	BIG DARBY CREEK	III
GREEN ACRES LEVEE	PUBLIC, LOCAL	PIKE	CROOKED CREEK	I
WAVERLY WWTP LEVEE	PUBLIC, LOCAL	PIKE	SCIOTO RIVER	I
MILLS PRIDE LEVEE	PRIVATE	PIKE	SCIOTO RIVER - OFFSTREAM	I
YELLOWBUD CREEK LEVEE	PRIVATE	ROSS	YELLOWBUD	III
SIDNEY LEVEE	PUBLIC, LOCAL	SHELBY	GREAT MIAMI RIVER	II
SWARTZ DITCH LEVEE	PUBLIC, LOCAL	SUMMIT	SWARTZ DITCH	III
SWARTZ DITCH DETENTION DAM	PUBLIC, LOCAL	SUMMIT	SWARTZ DITCH	III
FRAL1 LEVEE	PUBLIC, C.D.	WARREN	GREAT MIAMI RIVER	I
WOOSTER LEVEE RELOCATION	PUBLIC, LOCAL	WAYNE	KILLBUCK CREEK	II
PERRYSBURG WWTP LEVEE	PUBLIC, LOCAL	WOOD	MAUMEE RIVER	I

LHMP DATA

Stark County: According to flood studies on file with the Stark County EMA, many communities in the county could be affected by a dam failure event. In an event that the Dover and Bolivar dams are at the emergency spillway, back up flooding along the Tuscarawas River through Stark County would significantly impact the Village of Navarre, as well as affect the cities of Massillon and Canal Fulton. Flooding in Navarre would far surpass 500-year flood levels, placing much of the village's downtown under water. Similar studies for Atwood Lake and the Beach City Dam, on file with the county EMA, indicate similar concerns. After an extensive examination of spreadsheet calculations, vulnerability assessments show that 28,288 structures could be damaged with an estimated loss of $1,019,132,000.

Delaware County: Dam failure is a significant concern for Delaware County. As of June 2018, there are 88 dams and reservoirs located within the county that could result in significant losses if they were to fail or become overtopped. These include 16 Class I dams, 13 Class II and III dams, and 24 Class IV dams. The Hoover Dam structure is located within Blendon Township in Franklin County, but a significant portion of its reservoir exists within Delaware County and should be considered a potential hazard to Delaware County residents (see Section 2.2). The Dams located within Delaware County are regulated by the U.S. Army Corp of Engineers (USACE), Ohio Department of Natural Resources (Division of Water) (ODNR) and Federal Energy Regulatory Commission (FERC).

For the 2013 Delaware County Hazard Mitigation Plan, local GIS inundation maps for all of the dams, except for the Sunbury and Ashley reservoirs, were overlaid onto the Auditor's parcel data and this determined the number of structures at-risk within each jurisdiction. Delaware, Powell, and Shawnee Hills are the only cities or villages that contain at-risk populations or structures due to their proximity to crucial rivers and reservoirs. Delaware City contains a staggering 1,458 vulnerable structures valued at over $300 million because the densely populated city lies directly south of the dam, in the direct pathway of the water's direction. In addition, there are over 2,000 vulnerable structures that lie outside of the county's municipalities, particularly since the majority of the dams and reservoirs are a sizeable distance from them. The 2013 Delaware County Multi-Hazard Mitigation Plan estimates that a total of 3,734 structures could be damaged with an estimated loss of $909,122,500.

PAST OCCURRENCES

The 2008 State Hazard Mitigation Plan Update referenced "The National Performance of Dams Partnership," a cooperative effort of engineers and dam safety professionals in the U.S. who retrieve, archive, and disseminate information on dam performance in order to list dam incidents and failures throughout the state. According to this database, Ohio experienced 273 dam incidents from 1882 to 2001. Because dam classification can be dynamic, a more complete database was developed by DSP for a span of years ranging from 1852 to 2014. (Please note the DSP data list incidents/failures dating back to 1852, However, the DSP was not created until 1963. Therefore, not all data provided to Ohio EMA were collected by DSP). Table 2.6.e lists the dam failures and incidents for Class I and II dams throughout the state. Due to limitations in data, incidents since 2014 could not be obtained when updating the 2019 State Hazard Mitigation Plan.

There has been little property damage that has resulted from a dam failure alone, as dam failures are few in Ohio. However, there has been property damage due to a combination of downstream flooding from excessive precipitation and dam failure. Unfortunately, it is difficult to assess which property damage was

a direct result of the dam failure and which damage was a result of downstream flooding due to excessive precipitation. There has been some infrastructure loss in terms of roads washing away, but there has been no loss of critical facilities due to dam failure to date. It should be noted that DSP does not have much data showing property damages and losses; such data are generally unavailable as there has not been a large dam failure in Ohio for many years. The comments associated with each incident or failure in Table 2.6.e rarely contains such loss information.

There are no documented instances of levee breaches whereby structures or properties were damaged in Ohio as such data are generally unavailable and undocumented. This does not mean there is minimal risk behind these levees; it means more effort needs to be exerted in the collection of such data. However, according to DSP records, in 1997 the Green Acres Levee (Pike County) was overtopped by a flood estimated to be a 100-year event. Several homes were flooded as a result, but no specific damage data could be found for this update.

Table 2.6.e

Ohio High Hazard Dam Incidents/Failures From 1852 to 2014				
County	**DSP Class**	**Dam Name**	**Incident Year**	**Incident Description***
Region 1				
Huron	I	NORWALK LOWER RESERVOIR	1969	Dam failed; no damage downstream noted. Dam was rebuilt with berm and drainage.
Huron	I	GREENWICH RESERVOIR DAM	1969	Dam partially failed; no damage downstream noted.
Huron	I	HOLIDAY LAKE DAM	1982, 2007	Left sidewall failed in 1982. A shallow slide was noted in 2007.
Morrow	I	CANDLEWOOD LAKE DAM	1998	Approximately 3-4' noted in the emergency spillway.
Sandusky	I	BALLVILLE DAM	1913	Dam failed with 1913 flood; no damage downstream reported.
Williams	I	LAKE SENECA DAM	1973, 1996	Overflow spillway failed in 1973 and 1996; no damage downstream reported.
Wyandot	I	KILLDEER UPGROUND RESERVOIR	1979, 2004	Leak and slide indicated in 1979, and multiple slides indicated in 2004.
Defiance	II	INDEPENDENCE DAM	1982	Left abutment was overtopped and damaged.
Lucas	II	SWANTON UPGROUND RESERVOIR	1970	Dam failure in 1970, but was repaired.
Seneca	II	MOHAWK LAKE DAM	1910, 1963	Dam failure in 1910 resulted in replacement; dam failure in 1963 resulted in repairs. No damage downstream reported.
Region 2				
Ashtabula	II	GERLAT LAKE DAM	2011	Spillway failed. ODNR issued an order for the dam to be repaired or breached. The dam was breached.
Cuyahoga	I	BRIAR HILL LAKE DAM	2006	Dam possibly overtopped; no damage downstream noted.
Delaware	I	LEXINGTON GLEN DAM	1987	Dam failed due to erosion on the emergency spillway and four erosion rills on the downstream slope.
Delaware	I	SUNBURY UPGROUND RESERVOIR NO. 1	1960s	Dam overtopped; no downstream damage noted.
Fairfield	I	RUSHCREEK STRUCTURE NO. VI-A	1982	An abutment leakage was noted and repaired.
Fairfield	I	PINE LAKE ESTATES DAM	2013	Spillway failure

Geauga	II	KENSTON LAKE DAM	2010	Spillway clogged and the dam overtopped. ODNR issued an order for the dam to be repaired or breached. The dam was breached. Pipe jacked and bored through the dam, eliminating the reservoir and making the dam a roadway embankment.
Geauga	I	MONT-MERE LAKE DAM	2006	Water was 1-1.5' below top of dam; dam never overtopped.
Geauga	I	TANGLEWOOD LAKE DAM	1981	Spillway partially failed, but was repaired; no damage downstream noted.
Knox	I	KNOX LAKE DAM	1950	Seepage was noted and spillway failed.
Lake	I	HOOSE ROAD RETENTION DAM	2006	Water was 1-2' above emergency spillway elevation.
Lake	I	BRIGHTWOOD LAKE DAM	1985	A resident near the emergency spillway stated the dam overtopped; no damage downstream reported.
Lorain	II	BRENTWOOD LAKE DAM	2009	Spillway failed. ODNR issued an order for the dam to be repaired or breached. The dam was breached.
Medina	I	PISCHIERI POND DAM	1999	Dam was breached in controlled manner due to detection of void in dam; no damage downstream.
Medina	I	RAVENS WOOD LAKE DAM	1973	Original dam failed and was rebuilt in 1973.
Medina	I	RUSTIC HILLS LAKE DAM	1980, 2003	Dam failed in 1980, and emergency spillway failed in 2003 which caused overtopping; no damage downstream reported.
Portage	I	BRIMFIELD LAKE DAM	1979	Dam nearly failed due to overtopping; no damage downstream reported.
Richland	I	SHELBY UPGROUND RESERVOIR NO. 2	2001	Seepage was noted through reservoir due to field tile; repairs were made accordingly.
Summit	II	THE MEADOWS DAM	2012	Spillway failed. ODNR issued an order for the dam to be repaired or breached. The dam was breached.
Summit	I	LAKE LITCHFIELD DAM	1973	Embankment failed during construction.
Warren	I	PINE HILL LAKE DAM	2001	Emergency spillway flowed; no damage downstream reported.
Wayne	I	CHIPPEWA CREEK STRUCTURE VII-C	1973	Foundation failure during construction; no damage indicated downstream.
Ashtabula	II	ELKEM FLUID WASTE POND 3A	1980	Slide was noted in the downstream slope, and was fixed.
Cuyahoga	II	MARSHFIELD LAKE DAM	1973	Dam breached under order; no damages reported; rebuilt in 1977.
Franklin	II	TIMBERLAKE NO. 1 DAM	1984	Drain pipe failed, but was repaired.
Geauga	II	BURTON LAKE DAM	1970s, 1997	Dam breached in the 1970s, and seepage boils were noted in 1997.
Geauga	II	PAW PAW LAKE DAM	1941	Dam failed and was rebuilt in 1941; no damage downstream was reported.
Geauga	II	KENSTON LAKE DAM	1970s	Downstream face slipped.
Hamilton	II	HERMITAGE CLUB LAKE DAM	1982	Intense storm resulted in dam overtopping; no damage downstream reported.
Licking	II	GOSS LAKE DAM	1990	Floodwaters caused partial failure of principal spillway; no damage downstream noted.
Licking	II	NEWARK LOW HEAD DAM	1959	Dam washed out in 1959, but was rebuilt.
Medina	II	RPM LAKE DAM	1998	Principal spillway failure; repairs made in 1998.
Portage	II	AURORA POND DAM	1985	Dam failed and was rebuilt around 1985.
Stark	II	MORELLI POND DAM	2003	Causeway breached due to a compromise in left end of dam; no damage downstream reported.
Stark	II	WILLOWDALE LAKE DAM	1923	Original dam failed and was rebuilt in 1924, with multiple repairs through the present.
Summit	II	VIRGINIA KENDALL PARK DAM	2003	Dam failure in late 1970s, and was overtopped in 2003; no damage downstream noted.

Summit	II	CAMP JULIA CROWELL LAKE DAM	2006	Severe erosion was noted on the left side of the emergency spillway.
Summit	II	LAKE FOREST DAM	2003	Dam experienced a flood of record in 2003; no damage downstream reported.
Summit	II	CITY OF HUDSON UPPER LAKE DAM	2003	Dam overtopped; no downstream damage noted.
Summit	II	CITY OF HUDSON LOWER LAKE DAM	2003	Dam overtopped; no downstream damage noted.
Trumbull	II	NEWTON FALLS LOW HEAD DAM	1988	Hole was noted in spillway.
Warren	II	WATER'S EDGE DAM	1993	Dam was rebuilt in 1993 after failure.

Region 3				
Athens	I	ATHENS FISH AND GAME CLUB LAKE DAM	1975	Dam was deemed unsafe due to seepage and a slide and was breeched; no downstream damage reported. It was reconstructed in 1978.
Belmont	I	ST. CLAIRSVILLE RESERVOIR NO. 2 DAM	1980	A sinkhole was noted in the upstream slope.
Belmont	I	BARNESVILLE LAKE DAM	2005	A shallow slide was noted on the downstream slope.
Belmont	I	MEIGS-PHILLIPS I NO. 1 DAM	2004	Severe erosion was noted in the emergency spillway.
Brown	I	RUSSELLVILLE RESERVOIR DAM	1997	Dam was overtopped; no damage noted downstream.
Columbiana	I	GUILFORD LAKE DAM	1852	Dam breached; no downstream damage noted.
Guernsey	I	LUBURGH LAKE DAM	1979	A downstream slope slide was noted and repaired.
Guernsey	I	SALT FORK LAKE DAM	1998	Dam overtopped; no downstream damage noted.
Hocking	I	LAKE LOGAN DAM	1950	Dam was breached upon initial filling; no damage downstream noted. Dam was redesigned in 1952 and rebuilt in 1954.
Hocking	I	LAKE OF THE FOUR SEASONS DAM	2013	Upstream slope earth slide.
Jackson	I	WELLSTON RESERVOIR DAM	1937	A slide was noted.
Jackson	I	OAK HILL UPGROUND RESERVOIR	1986	Multiple slides were noted.
Jefferson	I	JEFFERSON LAKE DAM	2004	Dam was within 0.5' of overtopping two times in one year.
Jefferson	I	WILLIAMS LAKE DAM	2004	Dam overtopped twice in same year; no damage downstream reported.
Morgan	I	CROOKSVILLE RESERVOIR NO. 1 DAM	1950	Dam noted as probably overtopping; no damage downstream indicated.
Morgan	I	CROOKSVILLE RESERVOIR NO. 2 DAM	1984	Slide was noted in the downstream slope, and was fixed.
Perry	I	SHELTON LAKE DAM	1990	Dam overtopped; no downstream damage noted.
Perry	I	ALTIERS LAKE DAM	2004	Flood event resulted in pool being 3-4' above normal; dam did not overtop.
Pike	I	LAKE WHITE DAM	1964, 1994	Dam overtopped in 1964 and 1994; no damage downstream reported.
Ross	I	CALDWELL LAKE DAM	1994	Sink hole was noted and repaired.
Ross	I	KNOLES POND DAM	1979	Lake was drained for repairs.
Scioto	I	ROOSEVELT LAKE DAM	1997	Dam overtopped; no downstream damage noted.
Athens	II	RAINBOW LAKE DAM	1979	Slide was noted in the downstream slope near right abutment, and was fixed.
Carroll	II	ROHR DAM	1975	Failure indicated at right end of dam; no damage downstream reported.
Carroll	II	BOY SCOUT DAM	1984	Upstream slope failed during construction.
Clermont	II	BECKJORD ASH POND C DAM	1999	Elbow of pipe and riser collapsed.

Columbiana	II	WESTVILLE LAKE DAM	1980, 1982, 1994	Breach in the south dike indicated in 1980; another breach indicated in 1982; portion of replacement spillway washed out during construction in 1994. No damage downstream was reported.
Columbiana	II	SEVAKEEN COUNTRY CLUB LAKE DAM	1930s	Dam breached and rebuilt; no downstream damage noted.
Columbiana	II	SLATES LAKE DAM	1965	Dam failed during initial filling of lake due to seepage around spillway pipe; no damage downstream indicated.
Columbiana	II	WOODLAND LAKE DAM	2003	Dam overtopped; no downstream damage noted.
Columbiana	I	Buckeye Water District Reservoir	2008	
Harrison	II	SELESKI LAKE NO. 2 DAM	1989	Dam overtopped at left end; no damage downstream reported.
Jefferson	II	LAKE HENRY DAM	1993	Original principal spillway was blocked.
Lawrence	II	SMITH HOLLOW DAM	1989	Spillway failed; no damage downstream reported.
Morgan	II	MUSKINGUM RIVER LOCK AND DAM NO. 7	1959	Dam failed in 1959; no damage downstream reported.
Muskingum	II	MUSKINGUM RIVER LOCK AND DAM NO. 10	1951	Dam failed in 1951; no damage downstream reported.
Perry	II	MERKLE DAM	1972	Dam washed out but was rebuilt in 1972.
Perry	II	TECUMSEH LAKE DAM	1990	Dam was overtopped by 1-2'; no damage downstream was reported.
Scioto	II	ELKS COUNTRY CLUB LAKE DAM	1980	33' long slide on the downstream slope; repaired, but slipped again.
Scioto	II	LAKE MARGARET DAM	1997	Dam overtopped in 1997, but repaired in 2002. No damage downstream noted.
Tuscarawas	I	SUGARCREEK SPORTSMAN CLUB Dam	2010	Seepage.
Washington	II	CHOPPER'S LAKE DAM	1994	Dam breached due to heavy rainfall with erosion of earth adjacent to spillway; no downstream damage noted.

Source: ODNR—Division of Soil and Water Resources, Dam Safety Program, Dam Inventory Data.

PROBABILITY OF OCCURRENCE

From 1852 to 2014, there were 103 documented Class I and II dam incidents/failures that were generally minor and resulted in little property damage (Table 2.6.e). Based on these figures, there is a 64% (103 incidents/162 years observed) annual chance of Class I/II dam incident/failure in any given year.

There are no documented instances of levee breaches whereby structures or properties were damaged in Ohio as such data are generally unavailable and undocumented. This does not mean that there is a zero percent chance of levee failure within the state, but more effort needs to be exerted in the collection of such data in order to produce a more accurate probability statement. For reasons previously mentioned, and some of which are uncontrollable by humans, it is possible a dam or levee can fail at any time, given the right circumstances. However, the probability of future occurrence is reduced due to proactive preventative action on the part of ODNR, DSP and individual dam and levee owners. As previously discussed in this section, the DSP provides oversight to dam/levee repairs, oversees and issues construction permits, enforces safety standards and mandates, conducts periodic safety inspections, and provides public information to levee owners, engineers, and the general public. This proactive approach to managing dam and levee safety in Ohio reduces the number of losses to property and life as a result of dam or levee failures or near failures.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

DAMS – METHODOLOGY

It should be noted that many dams throughout the state do not possess inundation mapping, including some Class I dams. However, a portion of these high hazard dams have draft or final inundation mapping available through the ODNR- DSP and the local Emergency Management Agencies in which the dams reside. Much of this data is subjected to agreements where it cannot be published. In respect to these agreements, much of the inundation data could not be obtained while updating the 2019 State of Ohio Hazard Mitigation Plan.

Assessing the hazard that a dam poses to downstream areas can be divided into three analyses: (1) analysis of an uncontrolled release of the reservoir, (2) analysis of the inundation from the uncontrolled release, and (3) analysis of the consequence of the release. In other words, a dam fails, the failure causes flooding downstream, and the flooding has negative impacts on people or property. Each of these analyses includes substantial uncertainty. Legitimate estimates of discharge from a breach can differ by over 200%. Discharge from a dam breach is usually several times the one-percent-annual-chance flood, and, therefore, typical flood studies are of limited use in estimating the extent of flooding. Dam failure inundation studies require specialized hydraulic modeling software and experience. Determining the impact of flooding is also difficult to accomplish, especially for estimating loss of life. Loss of life is a function of the time of day, warning time, awareness of those affected, and failure scenario. Many dam safety agencies have used “population at risk” (PAR), a more quantifiable measurement of the impact to human life, rather than “loss of life.” PAR is the number of people in structures within the inundation area that would be subject to significant, personal danger, if they took no action to evacuate.

Another factor in assessing the hazard that a dam poses is the dam’s condition. Assessing the condition of a dam can be an extensive and expensive process. ODNR’s Dam Safety Program inspects all regulated dams once every 5 years. As part of that inspection, the dam’s history is reviewed including original construction plans, previous inspection reports, investigations and studies, “Operation, Maintenance, and Inspection Manuals”, “Emergency Action Plans”, calculations, and any other available information. During

the inspection, an assessment of the downstream area is made to verify the classification of the dam. If the inspection, combined with the dam's history and potential downstream impacts, reveal concerns with the dam's condition, the DSP takes enforcement action through the Ohio Attorney General's office as needed.

As mentioned at the beginning of this section, emergency managers usually categorize dam failures as either sunny-day failures or rainy-day failures. Sunny day failures occur during a non-flooding situation with the reservoir near normal pool level. Rainy day failures usually involve periods of rainfall and flooding. Improper design of a spillway or careless operation of gates during high flows can lead to excessive water pressure and subsequent failure as well. Even though both types of failures can be disastrous, it can be assumed that a sunny day failure would be more catastrophic due to its unanticipated occurrence and the lack of time to warn residents downstream.

The impacts of a dam failure are contingent on many factors and, therefore, cannot be concisely described. Table 2.6.f contains rough estimates of the downstream impacts of dam failures for the Class I dams that have an estimated Sunny Day PAR greater than 50. The condition of the dams in table 2.6.f is not a factor of the estimated damage or PAR levels. Because of the uncertainty of determining precisely who and what will be impacted by a dam failure, a scale was developed by the DSP to categorize dams based on their estimated impact to lives and structures downstream. The "Very high, high, medium, and low" scale is based on the PAR and was developed using experience with flood modeling, aerial photographs, field observations, and engineering judgment. The Damage and PAR levels are periodically updated by DSP staff as new data is obtained.

DAMS – RESULTS **Table 2.6.f**

Class I Dams, Estimated Downstream Damage Level and Estimated Population At-Risk (PAR) by County					
Region 1					
County	**Dam**	**Sunny Day Damage Level**	**Sunny Day PAR Level**	**Rainy Day Damage Level**	**Rainy Day PAR Level**
Allen	Ferguson Upground Reservoir	High	Medium	Very High	Medium
Allen	Metzger Upground Reservoir	Medium	Medium	Very High	Medium
Allen	Lost Creek Upground Reservoir	Medium	Low	Medium	Low
Crawford	Bucyrus Reservoir No. 1 Dam	Medium	Low	Medium	Low
Hancock	Veterans Memorial Reservoir	Medium	Low	Medium	Low
Huron	Willard City Upground Reservoir	Medium	Low	Medium	Low
Huron	Norwalk Memorial Reservoir	High	Low	High	Low
Huron	Norwalk Upper Reservoir – Erosion and drainage repairs completed in 2012.	High	Low	High	Low
Huron	Norwalk Lower Reservoir	High	Low	High	Low
Shelby	Lockington Dam – Extensive dam foundation repairs completed in 2012.	--	Low	Very High	Medium
Shelby	Lake Loramie Dam – Extensive spillway improvements completed in 2018.	Medium	Low	Medium	Low

Region 2					
County	**Dam**	**Sunny Day Damage Level**	**Sunny Day PAR Level**	**Rainy Day Damage Level**	**Rainy Day PAR Level**
Butler	Fairfield Detention "A" Dam	--	Low	Medium	Low
Butler	Fairfield Detention "C" Dam	--	Low	Medium	Low
Butler	Acton Lake Dam - Extensive dam repairs completed in approximately 2016.	High	Low	High	Low
Clinton	Wilmington Upground Reservoir No. 2	Medium	Low	Medium	Low
Cuyahoga	Lakeview Cemetery Flood Control Dam	--	Low	High	Medium
Delaware	Alum Creek Upground Reservoir	High	Low	High	Low
Delaware	O'Shaughnessy Reservoir Dam	Very High	Low	Very High	Low
Franklin	Hoover Dam	Very High	High	Very High	High
Franklin	Julian Griggs Dam	High	Low	High	Low
Geauga	Bridge Creek Dam	Very High	Medium	Very High	Medium
Greene	Huffman Dam	--	Low	Very High	Medium
Knox	Apple Valley Lake Dam	High	Low	High	Low
Licking	Buckeye Lake Dam – Extensive dam repairs were completed in 2019.	Very High	High	Very High	Medium
Montgomery	Germantown Dam	--	Low	Very High	Medium
Montgomery	Taylorsville Dam	--	Low	Very High	Medium
Montgomery	Englewood Dam	--	Low	Very High	High
Portage	Mogadore Reservoir Dam	High	Medium	High	Medium
Portage	Lake Rockwell Dam	High	Medium	Very High	Medium
Richland	Clear Fork Reservoir Dam	Medium	Low	High	Medium
Summit	West Reservoir Dam – Extensive dam repairs completed in 2013.	High	Low	High	Low
Summit	Wolf Creek Dam	Very High	High	Very High	High
Summit	Tuscarawas River Diversion Dam – Extensive dam repairs completed in 2016.	Medium	Low	High	Low
Summit	North Reservoir Dam	Medium	Low	Medium	Low
Summit	East Reservoir Dam – extensive dam repairs are currently in construction expected to be completed in 2019.	Medium	Low	Medium	Low
Summit	Lake Dorothy Dam	Medium	Low	High	Low

Region 3					
County	**Dam**	**Sunny Day Damage Level**	**Sunny Day PAR Level**	**Rainy Day Damage Level**	**Rainy Day PAR Level**
Ashtabula	Roaming Rock Shores Lake Dam	High	Medium	High	Medium
Belmont	Belmont Lake Dam	Medium	Low	High	Medium
Clermont	Stonelick Lake Dam	High	Medium	Medium	Low

Columbiana	Guilford Lake Dam	High	Medium	Medium	Low
Gallia	Gavin Bottom Ash Pond	Medium	Low	Medium	Low
Gallia	Stingy Run Fly Ash Dam	Very High	Medium	Very High	High
Guernsey	Salt Fork Lake Dam – dam repairs completed in 2012.	Very High	Medium	Very High	Medium
Highland	Rocky Fork Lake Dam	Very High	High	Very High	High
Holmes	Lake Buckhorn Dam	Medium	Low	Medium	Low
Jefferson	Cardinal Fly Ash No. 2 Dam	Very High	Low	Very High	Low
Jefferson	Lake Austin Dam – Extensive dam and spillway repairs completed in 2018.	High	Low	High	Low
Mahoning	Evans Lake Dam	High	Medium	Very High	Medium
Mahoning	McKelvey Lake Dam	High	Medium	High	Medium
Mahoning	Lake Hamilton Dam	Medium	Low	High	Low
Mahoning	Lake Milton Dam	Very High	High	Very High	High
Noble	Wolf Run Lake Dam	Very High	Medium	Very High	Medium
Noble	Caldwell Lake Dam	High	Medium	High	Medium
Scioto	Turkey Creek Lake Dam	High	Medium	Medium	Low
Trumbull	Mineral Ridge Dam	Very High	High	Very High	High
Washington	Eramet Waste Retention Dam	High	Medium	High	Medium

Source: Ohio Department of Natural Resources Dam Safety Program, “Population at Risk” Evaluation

LEVEES – METHODOLOGY

Levee vulnerability was included as "Risk Characteristics" for each Levee system in the US Army Corp of Engineers National Levee Database (NLD). A risk classification was not assessed for each levee, however the Risk Characteristic assessed FEMA FIRM maps to estimate the number of people and structures at risk, as well as the property value exposed. The risk characteristics are as summarized in table 2.6.e below.

Table 2.6.e

National Levee Database: Vulnerability by County						
County	**Region**	**Levee Count**	**Leveed Area (Sq. Miles)**	**People at Risk**	**Structures at Risk**	**Property Value at Risk**
Erie	**1**	2	0.16	340	198	$ 67,000,000.00
Erie/Sandusky	**1**	1	0.53	240	99	$ 21,600,000.00
Lucas	**1**	5	4.12	2015	875	$ 334,600,000.00
Lucas/Ottawa	**1**	6	3.68	7	6	$ 9,114,000.00
Marion	**1**	2	0.80	60	43	$ 375,200,000.00
Miami	**1**	6	0.28	8501	3011	$ 1,838,530,000.00
Ottawa	**1**	146	16.62	465	547	$ 163,790,000.00
Ottawa/Sandusky	**1**	4	0.97	23	10	$ 2,538,000.00
Sandusky	**1**	3	1.30	2742	1340	$ 481,900,000.00
Butler	**2**	10	4.12	7582	267.6	$ 1,252,140,000.00
Cuyahoga	**2**	1	0.01	148	32	$ 10,300,000.00
Fairfield	**2**	2	0.89	1067	453	$ 232,980,000.00
Franklin	**2**	3	4.82	14485	4695	$ 2,197,130,000.00
Hamilton	**2**	10	5.39	16289	1709	$ 2,709,870,000.00
Knox	**2**	5	0.79	1927	767	$ 302,460,000.00
Lake	**2**	1	0.03	183	75	$ 24,900,000.00
Licking	**2**	1	0.16	671	283	$ 61,400,000.00
Lorain	**2**	1	0.25	13	6	$ 2,000,000.00
Montgomery	**2**	20	10.28	20717	8114	$ 9,869,017,000.00
Stark	**2**	5	0.78	1821	671	$ 332,320,000.00
Warren	**2**	5	0.45	1717	595	$ 238,570,000.00
Clermont	**3**	1	0.08	6	4	$ 2,690,000.00
Columbiana	**3**	1	0.45	1868	113	$ 250,000,000.00
Guernsey	**3**	2	0.12	282	167	$ 147,400,000.00
Hocking	**3**	1	0.03	60	32	$ 10,200,000.00
Lawrence	**3**	2	2.35	9377	5043	$ 1,303,000,000.00
Muskingum/Perry	**3**	1	0.11	384	324	$ 85,700,000.00
Pike	**3**	4	1.81	37	14	$ 69,592,000.00

Levee Inventory by County						
County	Region	Levee Count	Leveed Area (Sq. Miles)	People at Risk	Structures at Risk	Property Value at Risk
Ross	3	1	2.15	9407	3999	$ 1,920,000,000.00
Scioto	3	1	2.99	11062	4717	$ 2,650,000,000.00
Tuscarawas	3	1	0.11	53	35	$ 23,400,000.00
Lucas/Monroe	1, 3	1	0.50	2364	1225	$ 275,000,000.00
Stark/Carroll	2, 3	1	0.11	303	141	$ 47,700,000.00

Source: US Army Corp of Engineers National Levee Database

Statewide, there are 257 levee systems in the National Levee Database that protect an area of about 56.50 square miles. Within this protected area resides an estimated 116,216 people, 42,019 structures, and an estimated property value of $27,312,041,000.

In Region 1, there are 146 levee systems that protect an area of about 28.96 square miles. Within this protected area resides an estimated 16,757 people, 7,354 structures, and an estimated property value of $3,569,272,000. One of these levee systems extend into Monroe County which is in Region 3.

In Region 2, there are 65 levee systems that protect an area of about 28 square miles. Within this protected area resides an estimated 66,923 people, 20,217 structures, and an estimated property value of $17,280,787,000. One of these levee systems extend into Carroll County which is in Region 3.

In Region 3, there are 15 levee systems that protect an area of about 9.42 square miles. Within this protected area resides an estimated 32,536 people, 14,448 structures, and an estimated property value of $6,461,982,000.

STATE-OWNED AND STATE-LEASED CRITICAL FACILITIES VULNERABILITY ANALYSIS & LOSS ESTIMATION

DAM VULNERABILITY METHODOLOGY

As discussed in Section 2.1, the Department of Administrative Services maintains a database of all state-owned and state-leased facilities. These data were obtained for this enhanced plan update, and facilities were categorized based on their critical and non-critical nature (per the definition provided in Section 2.1). For dam failures, inundation mapping is available for many Class I dams throughout the state. This mapping can be coupled with the georeferenced state-owned and state-leased facilities to determine which state holdings are at risk given a dam failure that matches the assumptions made during the inundation analyses.

This methodology was used for assessing state-owned and state-leased facilities vulnerable to Class I dams owned and operated by the USACE. Specifically, 16 dams were analyzed. The inundation area that was analyzed for each dam was specific to the spillway design flood with dam failure. While such an event is extremely remote in nature, it is within the realm of possibility given the right conditions. The USACE dams and the critical facilities that fall within their inundation zones are summarized in table 2.6.f below.

Table 2.6.f

USACE Dam Name	Structures	Value of Structures
MOSQUITO CREEK	3	$ 242,823
MOSQUITO CREEK UPSTREAM	20	$ 1,441,000
ALUM CREEK DAM	1	$ 60,600,000
ATWOOD DAM	4	$ 616,148
BEACH CITY DAM	5	$ 39,174,348
BLUESTONE DAM	8	$ 20,602,352
BOLIVAR DAM	52	$ 46,270,783
CAESAR CREEK LAKE DAM	2	$ 101,705
CLENDENING DAM	1	$ 226,644
DELAWARE DAM	56	$ 73,152,052
DILLON DAM	24	$ 2,357,385
DOVER DAM	30	$ 42,908,528
MICHAEL J KIRWAN DAM	3	$ 242,823
MOHAWK DAM	33	$ 4,904,058
TOM JENKINS DAM	1	$ 19,503,602
WEST FORK OF MILL CREEK LAKE DAM	1	$ 1,667,976

It should be noted the majority of dams throughout the state do not possess inundation mapping, many of which are Class I. However, a portion of these high hazard dams have draft or final inundation mapping available through the ODNR- DSP. Future updates to this plan will include analysis of these maps in coordination with the ODNR using the same methodology described previously.

RESULTS

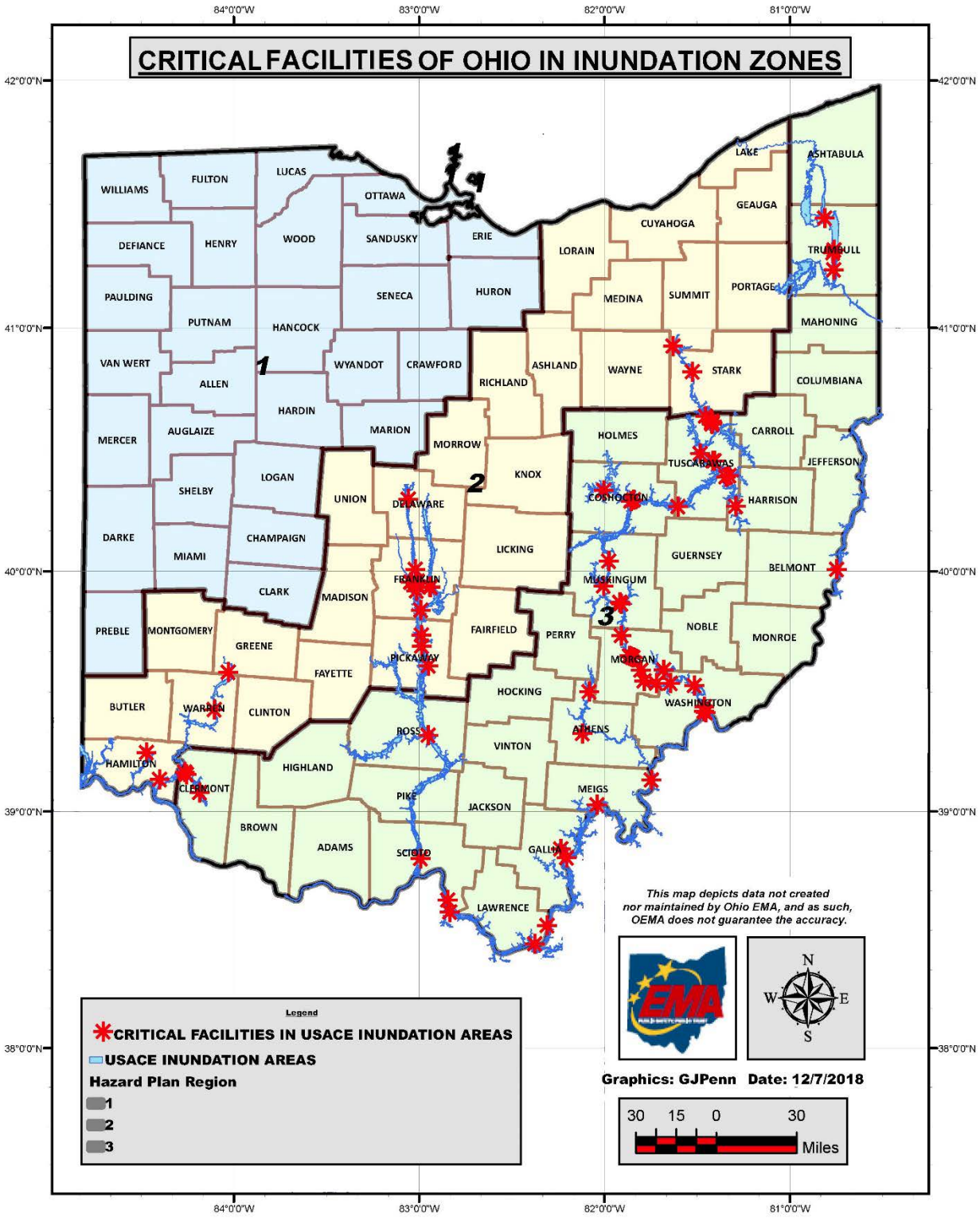
Table 2.6.g shows the numbers of state-owned and state-leased facilities potentially affected by an event equivalent to the spillway design flood with dam failure. Of the dams analyzed, Region 1 did not have any facilities within the spillway. In Region 2, there were an estimated 82 structures within the spillway with a total property value at risk at $460,473,098.00. Franklin County had the most with 58 structures at $435,759,205.00.

Region 3 contains the most state-owned and state-leased facilities within the inundation zones of the assessed dams. There were 240 structures throughout 15 counties in the region with a total property value of $151,752,451.00. Tuscarawas County had most of these counties, with 68 structures worth a total value of $54,290,414.00.

Table 2.6.g

Estimated Losses from Dam Failure for State-Owned and State-Leased Facilities					
Region 2			Region 3		
County	Structures with Levee Protection	Property Value at Risk	County	Structures with Levee Protection	Property Value at Risk
Clinton	1	$ 422,778.00	Athens	12	$ 24,853,315.00
Delaware	3	$ 736,213.00	Belmont	1	$ 22,108.00
Franklin	58	$ 435,759,205.00	Clermont	8	$ 1,675,283.00
Greene	4	$ 995,000.00	Coshocton	14	$ 4,588,245.00
Hamilton	3	$ 19,954,621.00	Gallia	5	$ 927,908.00
Pickaway	6	$ 2,140,011.00	Harrison	1	$ 873,000.00
Stark	2	$ 194,389.00	Lawrence	5	$ 1,862,205.00
Warren	5	$ 270,881.00	Meigs	22	$ 4,163,299.00
			Morgan	19	$ 1,275,120.00
			Muskingum	9	$ 1,263,707.00
			Ross	1	$ 937,500.00
			Scioto	11	$ 33,423,194.00
			Trumbull	42	$ 2,837,882.00
			Tuscarawas	68	$ 54,290,414.00
			Washington	22	$ 18,759,271.00
Region 2 Total:	82	$ 460,473,098.00	Region 3 Total:	240	$ 151,752,451.00

Map 2.6.c


CRITICAL FACILITIES OF OHIO IN INUNDATION ZONES
84°0'0"W
83°0'0"W
82°0'0"W
81°0'0"W
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
WILLIAMS
FULTON
LUCAS
OTTAWA
LAKE
ASHTABULA
GEAUGA
CUYAHOGA
ERIE
SANDUSKY
WOOD
HENRY
DEFIANCE
LORAIN
TRUMBULL
PORTAGE
MEDINA
SUMMIT
SENECA
HURON
PAULDING
PUTNAM
HANCOCK
MAHONING
VAN WERT
ALLEN
WYANDOT
CRAWFORD
RICHLAND
ASHLAND
WAYNE
STARK
COLUMBIANA
HARDIN
MERCER
AUGLAIZE
MARION
MORROW
HOLMES
CARROLL
TUSCARAWAS
JEFFERSON
SHELBY
LOGAN
UNION
DELAWARE
KNOX
COSHOCTON
HARRISON
DARKE
MIAMI
CHAMPAIGN
LICKING
GUERNSEY
BELMONT
CLARK
MADISON
FRANKLIN
MUSKINGUM
PREBLE
MONTGOMERY
GREENE
FAIRFIELD
PERRY
NOBLE
MONROE
FAYETTE
PICKAWAY
MORGAN
HOCKING
BUTLER
WARREN
CLINTON
WASHINGTON
ROSS
ATHENS
VINTON
HAMILTON
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CLERMONT
PIKE
MEIGS
JACKSON
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
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This map depicts data not created nor maintained by Ohio EMA, and as such, OEMA does not guarantee the accuracy.
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CRITICAL FACILITIES IN USACE INUNDATION AREAS
USACE INUNDATION AREAS
Hazard Plan Region
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LEVEE VULNERABILITY METHODOLOGY

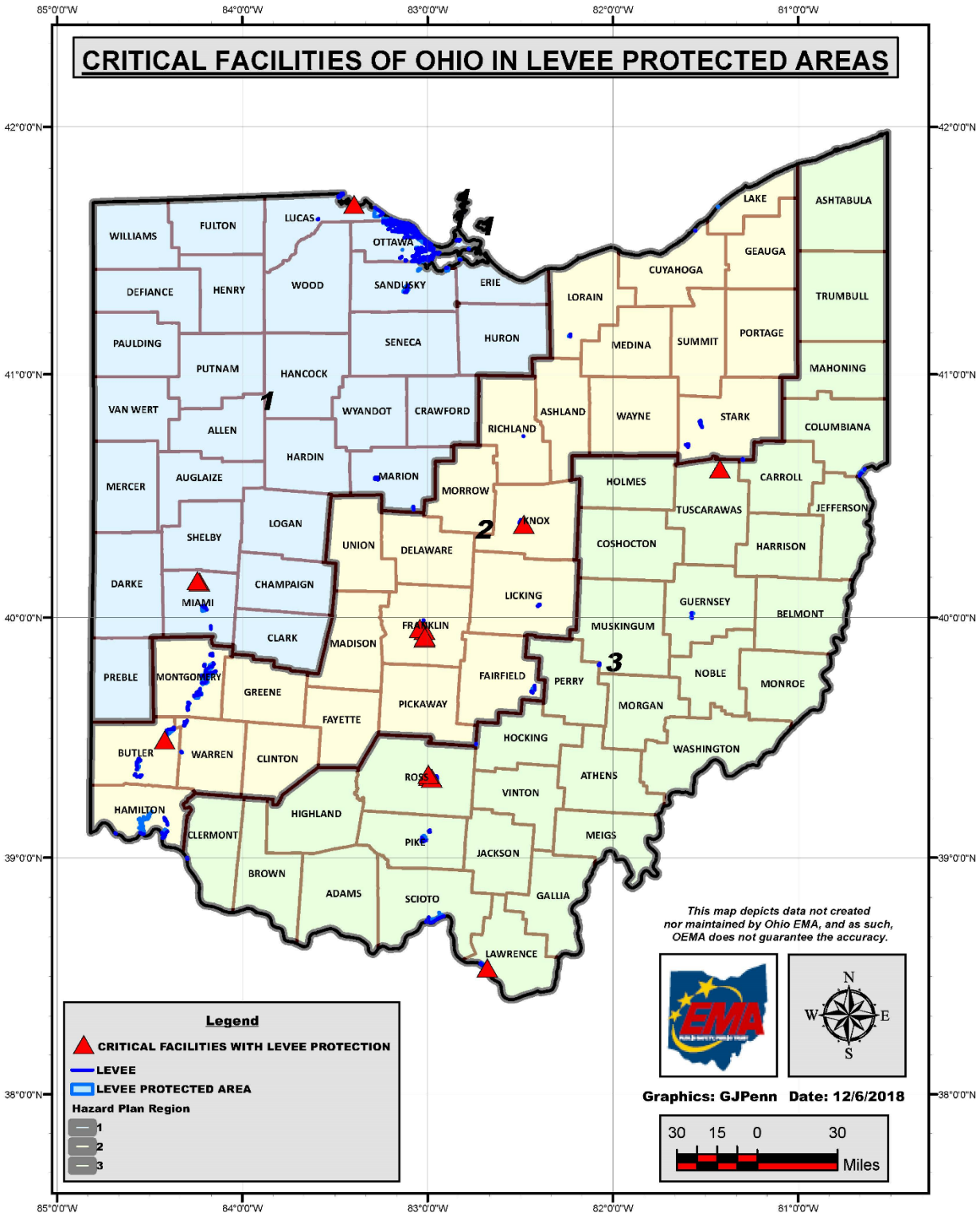
As referenced in Table 2.6.d, the National Levee Database lists 257 levee systems in Ohio. Each one of these levees protects a defined area as determined from FEMA FIRM maps. Each of these leveed areas were used to intersect with the list of State-owned and State-leased critical facilities in Ohio.

RESULTS

Table 2.6.h shows that there are 102 State-owned and State-leased critical facilities in Ohio that are protected by levees listed in the National Levee Database. The total value of these structures amount to approximately $87.82 million. Region 1 had the least number of structures with four—one in Lucas County and three in Miami County. The total value of these four structures in Region 1 is approximately $1.55 million. Region 2 has the second most number of structures at 57 but had the highest property value at risk by far at approximately $68.39 million. 54 of the 57 structures are in Franklin County. Region 3 had the highest number of structures at 68—51 of which are in Ross County. The total value of these 68 structures in Region 3 is approximately $17.88 million.

Table 2.6.h

State-Owned and State-Leased Facilities within Leveed Areas (NLD)								
Region 1			Region 2			Region 3		
County	Structures with Levee Protection	Property Value at Risk	County	Structures with Levee Protection	Property Value at Risk	County	Structures with Levee Protection	Property Value at Risk
Lucas	1	$ 22,000.00	Butler	1	$ 1,447,035.51	Lawrence	1	$ 705,010.77
Miami	3	$1,523,856.86	Franklin	54	$66,332,254.38	Ross	51	$13,770,711.88
			Knox	2	$ 608,285.67	Tuscarawas	16	$ 3,408,608.69
Region 1 Total:	4	$ 1,545,856.86	Region 2 Total:	57	$ 68,387,575.56	Region 3 Total:	68	$ 17,884,331.34


CRITICAL FACILITIES OF OHIO IN LEVEE PROTECTED AREAS
85°0'0"W
84°0'0"W
83°0'0"W
82°0'0"W
81°0'0"W
42°0'0"N
41°0'0"N
40°0'0"N
39°0'0"N
38°0'0"N
WILLIAMS
FULTON
LUCAS
OTTAWA
WOOD
SANDUSKY
ERIE
LAKE
ASHTABULA
GEAUGA
CUYAHOGA
LORAIN
TRUMBULL
DEFIANCE
HENRY
PAULDING
PUTNAM
HANCOCK
SENECA
HURON
MEDINA
SUMMIT
PORTAGE
MAHONING
VAN WERT
ALLEN
WYANDOT
CRAWFORD
RICHLAND
ASHLAND
WAYNE
STARK
COLUMBIANA
HARDIN
MERCER
AUGLAIZE
MARION
MORROW
HOLMES
CARROLL
TUSCARAWAS
JEFFERSON
SHELBY
LOGAN
UNION
DELAWARE
KNOX
COSHOCTON
HARRISON
DARKE
MIAMI
CHAMPAIGN
LICKING
GUERNSEY
BELMONT
CLARK
MADISON
FRANKLIN
MUSKINGUM
PREBLE
MONTGOMERY
GREENE
FAIRFIELD
PERRY
NOBLE
MONROE
FAYETTE
PICKAWAY
MORGAN
HOCKING
WASHINGTON
BUTLER
WARREN
CLINTON
ROSS
ATHENS
VINTON
HAMILTON
CLERMONT
HIGHLAND
PIKE
MEIGS
JACKSON
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
1
2
3
Legend
CRITICAL FACILITIES WITH LEVEE PROTECTION
LEVEE
LEVEE PROTECTED AREA
Hazard Plan Region
1
2
3
This map depicts data not created nor maintained by Ohio EMA, and as such, OEMA does not guarantee the accuracy.
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Miles