SECTION 2:
RISK ANALYSIS

2.1 RISK ANALYSIS OVERVIEW

The State of Ohio is prone to many natural, manmade, and technological hazards. Ohio has experienced thousands of hazard events, resulting in millions of dollars in losses and casualties, and 48 Presidential disaster declarations. The Risk Analysis (RA) in Section 2 of this plan draws data and analysis from many different sources in order to analyze and mitigate impacts from the state's highest risk hazards.

In order to meet FEMA state mitigation planning requirements in 44 CFR 201.4(c) (2) and (d), a state mitigation plan risk assessment must:

- Include an overview of the type and location of all natural hazards that can affect the state,
- Provide an overview of the probabilities of future hazard events,
- Address the vulnerability of state assets located in hazard areas and estimate the potential dollar losses to these assets,
- Include an overview and analysis of the vulnerability of jurisdictions to the identified hazards and the potential losses to vulnerable structures, and
- Reflect changes in development

HAZARD IDENTIFICATION

The State of Ohio Hazard Identification and Risk Analysis (HIRA) provides an overview of the type and location of all natural hazards that can affect the state (see Appendix I). The HIRA is maintained by the Ohio EMA Plans Branch and is the authoritative source of hazard identification and analysis that informs all state plans related to emergency management. However, the SOHMP does not include an in-depth analysis of all thirty-one (31) hazards listed in the HIRA for several reasons some of which include:

- The hazard is human-caused or technological and the impacts of the hazard are more appropriately addressed in preparedness or law enforcement plans,
- The hazard probability is so low that an in-depth analysis is not justified or the data to conduct the analysis does not exist, and
- The State of Ohio has decided to focus limited mitigation resources on the hazards that will have the highest probability and greatest documented impact to people and property.

To support the hazards selected for a detailed analysis in the SOHMP, the state has applied multiple HIRA models that use different methodologies. The results of these analyses can be found in the 2014 SOHMP. All of the HIRA models applied concurred that flooding, tornado/windstorms, and winter storms are the highest threat hazards in Ohio. In the 2019 SOHMP update, the following hazards are analyzed in detail:

- Flooding (includes areal, riverine and flash flooding)
- Tornado
- Winter Storms (includes snow, ice, hail, and sleet)
- Landslide (includes mudslides)
- Dam/Levee Failure
- Wildfire
- Seiche / Coastal Flooding
- Earthquake
- Coastal Erosion
- Severe Summer Storms (includes windstorms and hail)
- Invasive Species
- Land Subsidence (includes abandoned mines)

Each hazard identified in this section includes an overview of the hazard and the probability of future hazard events. Each section also addresses, where appropriate, the vulnerability of state assets located in hazard areas and estimates the potential dollar losses to these assets. The methodology for estimating losses to state-owned critical facilities is different based on the characteristics of the hazard and data available to conduct the vulnerability analysis. The methodology used for each hazard is discussed in that section of the plan. Each section also contains an overview and analysis of the vulnerability of jurisdictions to the identified hazards and the potential losses to vulnerable structures based on analysis of data in local hazard mitigation plans.

STATE HAZARD ANALYSIS RESOURCE AND PLANNING PORTAL (SHARPP)

SHARPP is a repository for past, present, and future versions of all local natural hazard mitigation plans in Ohio. As local mitigation plans are updated they will be uploaded into SHARPP. There are seven factors for each hazard: Frequency, Response, Onset, Impact (magnitude), Impact on business, Impact on people, and Impact on Property. This allows for an increased ability to "ground truth" local priorities with respect to the SOHMP HIRA. For the 2019 SOHMP update, 57 local hazard mitigation plans were reviewed as part of this analysis. These 57 plans were the plans that were approved and not expired as of April 2018. Table 2.1.k shows the ranking of the top ten hazards based on local priorities. For more information regarding SHARPP entry and rankings, see Section 4.3.

Table 2.1.k

Overall Hazard Ranking		
Hazard	**Score**	**Rank**
Flooding	21.09	1
Winter Storms	20.54	2
Severe Summer Storms	18.44	3
Tornado	18.04	4
Drought	16.91	5
Earthquake	15.67	6
Dam/Levee Failure	14.71	7
Invasive Species	12.02	8
Landslide	11.97	9
Land subsidence	11.97	10
Wildfire	11.21	11
Coastal Erosion	10.39	12

Section 2.15 titled, Future Potential Areas of Risk, contains an analysis of future projected growth areas in the state in relation to known hazard risk. This section also evaluates activities with the potential to amplify the effects of existing hazards such as climate change and hydraulic fracturing for oil and gas, and Harmful Algal Blooms (HAB).

ASSESSING VULNERABILITY OF STATE FACILITIES

44 CFR 201.4 (c) (2) (ii) – The risk assessment shall include "an overview and analysis of the state's vulnerability to the hazards described in this paragraph (c) (2), based on estimates provided in local risk assessments. State-owned or operated critical facilities located in the identified hazard areas shall be addressed." The methodology for this section varies by hazard due to available data and their attributes, and is more thoroughly discussed below.

The State of Ohio Department of Administrative Services (DAS) Risk Management Section currently maintains a listing of state-owned and state-leased facilities. State leased buildings are only tracked if the lease requires that the state also insure the building. Both the state-owned and state-leased facility datasets are attributed and contain a geo-referenced point for each facility. The data includes facilities ranging from small salt buildings owned by the Department of Transportation (ODOT) to multi-story office buildings owned by DAS. While the previous state plans only evaluated structures whose values exceeded $1 million, this plan evaluates all state-owned structures as many facilities crucial to response are worth much less than $1 million. Additionally, the state leases nearly 300 facilities around the state, and a significant percentage of those are critical in nature. Therefore, it was deemed necessary to evaluate all state-owned and state-leased structures, and parse out those that are critical in nature.

A critical facility is defined as any facility whose services are necessary to the response and/or recovery operations following a disaster. Such facilities include (but are not limited to) administration office buildings, transportation facilities, highway patrol posts, armories, radio antenna towers etc. Also, numerous facilities exist at correctional institute complexes that are used for sheltering purposes immediately following a disaster, and such facilities include structures appurtenant and necessary to their function.

The state-owned and state-leased datasets are sufficient for vulnerability assessments, the state-owned dataset included estimated values for building and contents replacements and the state-leased dataset include estimated values for contents replacement. However, assumptions made for vulnerability using these datasets must be fairly general since additional attributed information is not complete. The majority of the datasets include year of construction, construction type, square footage, number of stories, etc. However, not all dataset include these pieces of information since the data were compiled through multi-agency efforts. As the data is refined and becomes more complete in the future, updates will be made to the methodologies used here for vulnerability assessments.

An additional dataset was acquired from the National Geospatial-Intelligence Agency in cooperation with FEMA. During DR-4002 recovery efforts, Ohio EMA worked with FEMA to gain access to the Homeland Security Infrastructure Program (HSIP) Gold Dataset 2011. The datasets are the products of collaborative efforts of various stakeholders in the Defense, Intelligence, and Homeland Security Communities. The data provides national critical infrastructure sectors as defined by Homeland Security. Much of the data is populated in major metropolitan areas, but gaps exist between highly populated areas. Additionally, replacement costs are not provided for various facilities, limiting the discussion on vulnerability in terms of dollars. The datasets are used to supplement the data obtained from DAS, especially for non-geographic hazards.

ESTIMATING POTENTIAL LOSSES OF STATE FACILITIES

44 CFR 201.4 (c) (2) (iii) – The risk assessment shall include “an overview and analysis of potential losses to identified structures, based on estimates provided in local risk assessments. The state shall estimate the potential dollar losses to state-owned or operated buildings, infrastructure, and critical facilities located in the identified hazard areas.”

As mentioned above, the state-owned and state-leased datasets are sufficient for loss estimations, as all state-owned and state-leased datasets include estimated values for replacement costs. However, assumptions made for losses using these datasets must be fairly general since additional attributed information is not complete. Many of the datasets include year of construction, construction type, square footage, number of stories, etc. However, not all of the data includes these pieces of information since the data was compiled through multi-agency efforts. As these datasets are refined and become more complete in the future, updates will be made to the methodologies used here for loss estimations.

A summary of the state-owned and state-leased facilities by county and agency is provided in Appendix C. It should be noted that facility specifics (i.e., facility name, location, etc.) are not listed in this plan due to increased security. Further information can be obtained from the Ohio DAS-Risk Management Section.

Tables 2.1.a – 2.1.c list state-owned critical and non-critical facility numbers and replacement values within each county. Currently, there are a total of 6,514 state-owned facilities (3,454 critical and 3,060 non-critical) throughout Ohio worth an estimated $7.8 billion. For Region 1 there are 827 critical and 802 non-critical worth approximately $974 million and $235 million, respectively. The county with the largest dollar exposure of state-owned facilities is Lucas County with $311 million. Lucas County also has the highest dollar exposure of critical facilities at $275 million.

Presently, there are a total of 2,367 (1,586 critical and 781 non-critical) state- owned facilities in Region 2, worth an estimated $5.3 billion. The estimated worth for the critical facilities is over $4.3 billion, and non-critical is over $1 billion. As would be expected, Franklin County, which contains the state capital, represents the majority of the dollar value with $2.3 billion in state-owned facilities that include 230 critical in nature, worth approximately $2.1 billion. The total number of state-owned facilities located in Region 3 is 2,518, representing over $1.2 billion in worth. The estimated worth for critical facilities is $1 billion, and $262 million in non-critical facilities. Ross County has the highest dollar exposure of any county in the Region ($272 million).

Tables 2.1.d – 2.1.f list state-leased critical and non-critical facility numbers and their respective replacement costs within each county. Currently, there is a total of 301 state facilities that are leased annually, of which 49 are critical to response and recovery following a disaster. For Region 1, there are 4 critical and 39 non-critical with approximately $258,945 and $3.1 million in replacement costs. Region 2 has 35 critical and 176 non-critical leases with replacement costs of $53 million and $76 million. In Region 3 has 10 state-leased critical facilities ($3.9 million) and 46 state-leased non-critical facilities ($3.9 million).

Table 2.1.a

Region 1 State-Owned Critical and Non-Critical Facilities						
County	**Number of State-Owned Critical Facilities**	**Replaced Value of All State-Owned Critical Facilities**	**Number of Non-Critical State-Owned Facilities**	**Replacement Value of All Non-Critical Facilities**	**Total Number of State-Owned Facilities**	**Replaced Value of All State-Owned Facilities**
Allen	117	$89,669,386	16	$31,275,411	133	$120,944,797
Auglaize	20	$11,036,162	65	$9,296,282	85	$20,332,444
Champaign	23	$4,627,441	33	$2,305,453	56	$6,932,894
Clark	16	$8,087,767	62	$17,344,481	78	$25,432,248
Crawford	12	$9,677,920	0	_	12	$9,677,920
Darke	24	$6,650,078	4	$41,246	28	$6,691,324
Defiance	11	$7,562,674	8	$197,450	19	$7,760,124
Erie	51	$61,223,935	37	$13,080,766	88	$174,304,701
Fulton	14	$3,170,048	34	$465,870	48	$3,635,918
Hancock	22	$15,577,393	29	$4,470,945	51	$20,048,338
Hardin	10	$3,013,095	5	$137,500	15	$3,150,595
Henry	13	$2,547,412	25	$2,642,000	38	$5,189,412
Huron	21	$9,763,256	4	$239,989	25	$10,003,245
Logan	0	_	82	$11,386,440	82	$11,386,440
Lucas	45	$275,774,293	59	$55,854,581	104	$331,628,874
Marion	99	$127,860,942	15	$13,623,059	114	$141,484,001
Mercer	24	$5,649,522	2	$349,500	26	$5,999,022
Miami	22	$9,293,386	20	$3,809,669	42	$13,103,055
Ottawa	74	$64,951,967	114	$34,016,339	188	$98,968,306
Paulding	2	$577,267	0	_	2	$577,267
Preble	23	$4,624,095	88	$21,542,629	111	$26,166,724
Putnam	15	$2,763,489	0	_	15	$2,763,489
Sandusky	14	$4,765,069	7	$1,426,250	21	$6,191,319
Seneca	47	$32,793,980	8	$1,165,000	55	$33,958,980
Shelby	34	$26,176,043	25	$2,835,996	59	$29,012,039
Van Wert	12	$6,521,545	9	$770,598	21	$7,292,143
Williams	10	$4,071,906	6	$3,013,200	16	$7,085,106
Wood	34	$66,951,677	21	$1,962,240	55	$68,913,917
Wyandot	18	$9,513,296	24	$2,676,850	42	$12,190,146
REGIONAL TOTALS	827	$974,895,044	802	$235,929,744	1,629	$1,210,824,788

Table 2.1.b

Region 2 State-Owned Critical and Non-Critical Facilities						
County	**Number of State-Owned Critical Facilities**	**Replaced Value of All State-Owned Critical Facilities**	**Number of Non-Critical Facilities**	**Replacement Value of All Non-Critical Facilities**	**Total Number of State-Owned Facilities**	**Replaced Value of All State-Owned Facilities**
Ashland	139	$62,683,519	1	$28,000	140	$62,711,519
Butler	21	$17,563,033	10	$1,239,500	31	$18,802,533
Clinton	21	$10,968,912	47	$4,684,708	68	$15,653,620
Cuyahoga	75	$241,066,599	4	$2,792,701	79	$243,859,300
Delaware	36	$45,323,205	70	$22,471,765	106	$67,794,970
Fairfield	77	$85,858,500	11	$1,014,200	88	$86,872,700
Fayette	20	$4,117,291	18	$2,346,501	38	$6,463,792
Franklin	230	$2,107,432,879	58	$680,900,915	288	$2,788,333,794
Geauga	21	$6,690,893	50	$11,133,092	71	$17,823,985
Greene	20	$8,473,508	14	$162,640,206	34	$171,113,714
Hamilton	31	$169,769,037	3	$1,344,677	34	$171,113,714
Knox	31	$38,333,377	2	$58,750	33	$38,392,127
Lake	20	$5,337,835	30	$6,301,773	50	$11,639,608
Licking	58	$152,379,393	30	$11,446,588	88	$163,825,981
Lorain	88	$108,829,615	31	$2,474,957	119	$111,304,572
Madison	108	$320,905,230	27	$3,954,638	135	$324,859,868
Medina	19	$16,321,114	11	$1,205,776	30	$17,526,890
Montgomery	67	$76,369,896	12	$5,274,420	79	$81,644,316
Morrow	20	$6,306,221	15	$497,625	35	$6,803,846
Pickaway	131	$194,421,509	76	$37,335,516	207	$231,757,025
Portage	20	$6,530,887	79	$16,047,980	99	$22,578,867
Richland	71	$108,516,010	47	$12,081,234	118	$120,597,244
Stark	37	$99,410,340	4	$3,781,250	41	$103,191,590
Summit	64	$198,041,224	46	$8,907,138	110	$206,948,362
Union	51	$87,458,961	6	$341,758	57	$87,800,719
Warren	107	$147,595,469	70	$8,755,970	177	$156,351,439
Wayne	3	$5,646,013	9	$1,549,085	12	$7,195,098
REGIONAL TOTALS	1586	$4,332,350,470	781	$1,010,610,723	2367	$5,342,961,193

Table 2.1.c

Region 3 State-Owned Critical and Non-Critical Facilities						
County	**Number of State-Owned Critical Facilities**	**Replaced Value of All State-Owned Critical Facilities**	**Number of Non-Critical Facilities**	**Replacement Value of All Non-Critical Facilities**	**Total Number of State-Owned Facilities**	**Replaced Value of All State-Owned Facilities**
Adams	19	$3,210,607	9	$1,033,950	28	$4,244,557
Ashtabula	58	$18,061,398	152	$18,178,461	210	$36,239,859
Athens	25	$42,563,462	41	$5,068,078	66	$47,631,540
Belmont	59	$51,854,471	27	$2,347,130	86	$54,201,601
Brown	12	$31,554,442	14	$2,662,140	26	$34,216,582
Carroll	15	$2,290,075	1	$1,112,000	16	$3,402,075
Clermont	37	$17,540,161	52	$9,058,025	89	$26,598,186
Columbiana	34	$11,011,455	24	$5,814,746	58	$16,826,201
Coshocton	14	$8,669,467	10	$1,002,473	24	$9,671,940
Gallia	67	$32,190,875	13	$1,617,576	80	$33,808,451
Guernsey	50	$37,763,292	123	$48,231,119	173	$85,994,411
Harrison	26	$6,944,911	15	$2,002,170	41	$8,947,081
Highland	6	$8,833,500	53	$5,612,487	59	$14,445,987
Hocking	13	$2,902,923	147	$13,748,241	160	$16,651,164
Jackson	23	$8,964,361	17	$7,466,364	40	$16,430,725
Jefferson	35	$7,162,401	20	$3,654,238	55	$10,816,639
Lawrence	24	$8,724,700	4	$275,125	28	$8,999,825
Mahoning	63	$71,570,175	16	$10,976,579	79	$82,546,754
Meigs	13	$3,986,061	28	$1,539,230	41	$5,525,291
Monroe	18	$7,714,545	7	$201,319	25	$7,915,864
Morgan	8	$3,101,447	88	$20,026,230	96	$23,127,677
Muskingum	21	$7,726,690	84	$8,508,136	105	$16,234,826
Noble	30	$49,441,152	9	$554,025	39	$49,995,177
Perry	14	$3,266,059	2	$82,500	16	$3,348,559
Pike	8	$2,620,816	70	$9,446,266	78	$12,067,082
Ross	134	$259,985,420	125	$12,209,032	259	$272,194,452
Scioto	47	$166,624,490	69	$21,485,873	116	$188,110,363
Trumbull	57	$53,145,813	57	$4,746,863	114	$57,892,676
Tuscarawas	49	$53,883,450	50	$8,970,141	99	$62,853,591
Vinton	16	$3,074,322	124	$21,690,842	140	$24,765,164
Washington	46	$21,811,660	26	$13,208,305	72	$35,019,965
REGIONAL TOTALS	1041	$1,008,194,601	1477	$262,529,664	2518	$1,270,724,265

Table 2.1.d

Region 1 State-Leased Critical and Non-Critical Facilities						
County	**Number of State-Leased Critical Facilities**	**Total Value of Building/Contents of All State-Leased Critical Facilities**	**Number of State-Leased Non-Critical Facilities**	**Total Value of Building/Contents of All State-Leased Non-Critical Facilities**	**Total Number of State-Leased Facilities**	**Total Value of Building/Contents of All State-Leased Facilities**
Allen	1	$106,416	2	$856,366	3	$962,782
Auglaize	0	$0	1	$46,913	1	$46,913
Champaign	0	$0	1	$37,988	1	$37,988
Clark	0	$0	2	$72,425	2	$72,425
Crawford	0	$0	1	$30,487	1	$30,487
Darke	0	$0	1	$27,080	1	$27,080
Defiance	0	$0	1	$24,259	1	$24,259
Erie	0	$0	1	$34,154	1	$34,154
Fulton	0	$0	1	$67,554	1	$67,554
Hancock	0	$0	1	$37,171	1	$37,171
Hardin	1	$20,000	1	$49,005	2	$69,005
Henry	0	$0	1	$54,378	1	$54,378
Huron	0	$0	1	$45,858	1	$45,858
Logan	0	$0	1	$32,372	1	$32,372
Lucas	1	$203,366	10	$1,121,270	11	$1,324,636
Marion	0	$0	1	$87,996	1	$87,996
Mercer	0	$0	1	$32,253	1	$32,253
Miami	0	$0	1	$49,112	1	$49,112
Ottawa	0	$0	1	$67,529	1	$67,529
Paulding	0	$0	1	$38,342	1	$38,342
Preble	0	$0	1	$52,707	1	$52,707
Putnam	0	$0	1	$43,687	1	$43,687
Sandusky	0	$0	1	$54,183	1	$54,183
Seneca	0	$0	1	$50,077	1	$50,077
Van Wert	0	$0	1	$28,524	1	$28,524
Williams	0	$0	1	$30,022	1	$30,022
Wood	1	$199,166	1	$47,231	2	$246,397
Wyandot	0	$0	1	$50,678	1	$50,678
REGIONAL TOTALS	4	$528,948	39	$3,169,621	43	$3,698,569

Table 2.1.e

Region 2 State-Leased Critical and Non-Critical Facilities						
County	**Number of State-Leased Critical Facilities**	**Total Value of Building/Contents of All State-Leased Critical Facilities**	**Number of State-Leased Non-Critical Facilities**	**Total Value of Building/Contents of All State-Leased Non-Critical Facilities**	**Total Number of State-Leased Facilities**	**Total Value of Building/Contents of All State-Leased Facilities**
Ashland	0	$0	1	$27,322	1	$27,322
Butler	0	$0	4	$198,726	4	$198,726
Clinton	0	$0	1	$419,685	1	$419,685
Cuyahoga	1	$203,366	13	$3,966,473	14	$4,169,839
Delaware	0	$0	2	$129,094	2	$129,094
Fayette	5	$608,500	1	$44,150	6	$652,650
Franklin	13	$34,492,382	100	$68,636,110	113	$103,128,492
Geauga	0	$0	1	$50,737	1	$50,737
Greene	4	$1,366,335	1	$75,729	5	$1,442,064
Hamilton	3	$3,167,336	5	$1,590,142	8	$4,757,478
Knox	0	$0	1	$36,976	1	$36,976
Lake	0	$0	2	$117,015	2	$117,015
Licking	2	$13,363,695	2	$128,831	4	$13,492,526
Lorain	0	$0	4	$160,728	4	$160,728
Madison	0	$0	1	$54,644	1	$54,644
Medina	1	$200,000	3	$35,664	4	$235,664
Montgomery	2	$248,600	7	$912,612	9	$1,161,212
Morrow	0	$0	1	$25,707	1	$25,707
Pickaway	0	$0	1	$65,219	1	$65,219
Portage	3	$234,600	1	$61,748	4	$296,348
Richland	0	$0	3	$913,831	3	$913,831
Stark	0	$0	5	$1,157,612	5	$1,157,612
Summit	0	$0	10	$646,677	10	$646,677
Union	0	$0	1	$67,647	1	$67,647
Warren	0	$0	3	$108,011	3	$108,011
Wayne	1	$31,907	2	$84,626	3	$116,533
REGIONAL TOTALS	35	$53,916,721	176	$79,715,716	211	$133,632,437

Table 2.f

Region 3 State-Leased Critical and Non-Critical Facilities						
County	**Number of State-Leased Critical Facilities**	**Total Value of Building/Contents of All State-Leased Critical Facilities**	**Number of State-Leased Non-Critical Facilities**	**Total Value of Building/Contents of All State-Leased Non-Critical Facilities**	**Total Number of State-Leased Facilities**	**Total Value of Building/Contents of All State-Leased Facilities**
Adams	0	$0	1	$55,406	1	$55,406
Ashtabula	0	$0	1	$51,787	1	$51,787
Athens	1	$203,366	2	$140,711	3	$344,077
Belmont	0	$0	2	$65,489	2	$65,489
Brown	1	$625,000	1	$59,053	2	$684,053
Carroll	0	$0	1	$198,726	1	$198,726
Clermont	0	$0	3	$135,681	3	$135,681
Columbiana	0	$0	1	$48,841	1	$48,841
Coshocton	1	$1,250,000	1	$30,605	2	$1,280,605
Gallia	0	$0	1	$38,043	1	$38,043
Guernsey	1	$165,562	2	$492,525	3	$658,087
Harrison	0	$0	1	$46,382	1	$46,382
Highland	1	$145,600	1	$39,235	2	$184,835
Hocking	1	$172,150	1	$12,685	2	$184,835
Holmes	0	$0	1	$36,342	1	$36,342
Jackson	0	$0	1	$46,916	1	$46,916
Jefferson	0	$0	2	$82,088	2	$82,088
Lawrence	0	$0	1	$34,434	1	$34,434
Mahoning	1	$15,434	1	$15,434	2	$30,868
Meigs	0	$0	1	$39,508	1	$39,508
Monroe	0	$0	1	$48,917	1	$48,917
Morgan	0	$0	1	$41,739	1	$41,739
Muskingum	0	$0	1	$65,613	1	$65,613
Noble	0	$0	1	$40,702	1	$40,702
Perry	0	$0	1	$41,314	1	$41,314
Pike	0	$0	1	$24,534	1	$24,534
Ross	1	$937,500	2	$162,488	3	$1,099,988
Scioto	1	$122,770	3	$560,551	4	$683,321
Trumbull	1	$300,300	4	$1,082,976	5	$1,383,276
Tuscarawas	0	$0	2	$71,722	2	$71,722
Vinton	0	$0	1	$47,161	1	$47,161
Washington	0	$0	2	$134,233	2	$134,233
REGIONAL TOTALS	10	$3,937,682	46	$3,991,841	56	$7,929,523

2.2 FLOOD

Floods are natural and beneficial functions of stream and lacustrine systems. Floods occur when streams or lakes overflow their banks and spill onto the adjoining land area, which is called a floodplain. Loss of life and property can result when people build structures and develop in flood hazard areas. Numerous factors can cause or exacerbate flooding in Ohio including: heavy and/or prolonged periods of rainfall, snowmelt, soil saturation, ground freeze, severe wind events, and inadequate drainage systems. Floods damage private and public property and infrastructure in Ohio every year. Flooding is the most frequently occurring natural disaster in Ohio and the United States.

RISK ASSESSMENT

The two major drainage basins in Ohio are the Lake Erie and Ohio River basins. Streams in the northern third of the state flow into Lake Erie and eventually into the Atlantic Ocean. Streams in the southern two-thirds of the state flow into the Ohio River and eventually into the Gulf of Mexico.

There are many types of flooding that occur in Ohio including: riverine, flash flooding, coastal flooding, and shallow flooding. Riverine flooding is generally characterized by slower rising water, which allows for increased warning time, but has the potential to last for longer periods of time. Ohio communities experience riverine flooding on both large basins and smaller tributary streams throughout the state. Major sources of riverine flooding in Ohio include the Ohio River, Scioto River, Great Miami River, Muskingum River, Hocking River, Maumee River, Blanchard River, Sandusky River, Cuyahoga River, Grand River, Little Miami River, the Mahoning River and their larger tributaries.

Flash flooding can occur when a severe storm produces large amounts of rainfall in a short time. Flash flooding is generally characterized by high-velocity water that rises and recedes quickly allowing little or no warning time to evacuate. Ohio’s Appalachian Region is particularly vulnerable to flash flooding because of the steep terrain and narrow stream valleys. Ohio’s urban areas also experience flash flooding that may be attributed to inadequate or poorly maintained stormwater infrastructure, increased impervious area, and lost wetland areas. The U.S. Geological Survey (USGS) has concluded that urbanization generally increases the size and frequency of floods and may increase a community’s flood risk.

Coastal flooding generally occurs in the counties that border Lake Erie. Flooding in coastal areas can be caused by stream overflow, wave run-up caused by strong winds, and higher than normal lake levels. Annual fluctuations in Lake Erie water levels are the result of seasonal changes and the amount of water flowing into and out of the lake. In-flow for Lake Erie includes drainage from the upper portion of the Great Lakes basin through the Detroit River, water from streams flowing directly into the lake, groundwater, and precipitation falling directly into the lake. Out-flow includes discharge into Lake Ontario through the Niagara River, evaporation, and any diversion or other withdrawals. Lake Erie levels also exhibit a wide range of long-term fluctuations that are the result of prolonged and persistent deviation from average climatic conditions.

Shallow flooding occurs in flat areas with inadequate channels that prevent water from draining easily. There are four types of shallow flooding: sheet flow, ponding, urban drainage, and rural drainage. Sheet flow flooding occurs in areas where channels are not defined. Sheet flow flooding moves downhill and covers a large area under a relatively uniform depth.

Ponding occurs in flat areas where runoff collects in depressions and cannot drain. Ponding can occur where glaciers carved out depressions in the landscape, and where manmade features such as roads have blocked drainage outlets.

Urban drainage systems can include combinations of ditches, storm sewers, detention ponds, house gutters, and yard swales. When a rainfall event exceeds the design capacity of the drainage system, it can result in the system's back-up and overflowing ditches. Basements are highly susceptible to flood damage caused by overloaded sewer and drainage systems. Urban drainage flooding can also occur behind levees when rainfall amounts exceed the capacity of pumps or other manmade systems designed to drain the landward side of the levees.

Rural drainage flooding in northwest Ohio is similar to urban drainage flooding in Ohio's cities and villages. Most of northwest Ohio was covered by a large swamp prior to European settlement that was subsequently drained for agriculture. The flat topography of this area is drained by an extensive system of ditches, swales, and small meandering streams. Rural drainage flooding occurs when rainfall exceeds the design capacity of the drainage system.

Ohio's river systems offer many benefits that have contributed to the development of the state such as: transportation, waste disposal, energy, commerce, recreation, and water supply. As a result, most major communities include development in flood hazard areas. Wetland areas have been developed, streamside forests have been removed, and streams have been straightened and channelized resulting in faster and increased runoff. After two centuries, these development patterns have drastically changed Ohio's riparian ecosystems, and resulted in escalating flood damages.

Historically, efforts to manage flooding can be divided into three major eras according to the Federal Interagency Floodplain Management Task Force. The Frontier Era (Pre-1917) is characterized by limited federal involvement in flood control or relief. During this time, many federal policies and programs encouraged land development with the common goal being "to conquer the wild landscape and to promote productive use of the land." Flood hazards were the problem of the individual property owner or dealt with cooperatively at the local level.

The Structural Era (1917-1959) is characterized by attempts to modify and control floodwater and move water off the land as quickly as possible. The federal government began assuming the costs to construct dams, levees, reservoirs, and other large structural flood control projects. As this era came to an end, resource managers began to realize that flood control projects were not eliminating flood damage and may be harming the environment.

During the Stewardship Era (1960-present), people began to recognize the important benefits and natural functions provided by floodplain areas such as natural flood and erosion control, water quality maintenance, groundwater recharge, recreation, wildlife habitat, agricultural production, and many others. The responsibility of floodplain management began to shift from the federal government to the local level again. The federal government began to focus on providing financial assistance to reduce and recover from the impacts of flooding. Congress created the National Flood Insurance Program (NFIP) in 1968 as a response to mounting flood losses and increasing disaster relief costs. The intent of the program is to reduce future flood damage through community floodplain management regulations, and provide a federally-subsidized insurance alternative to federal disaster relief.

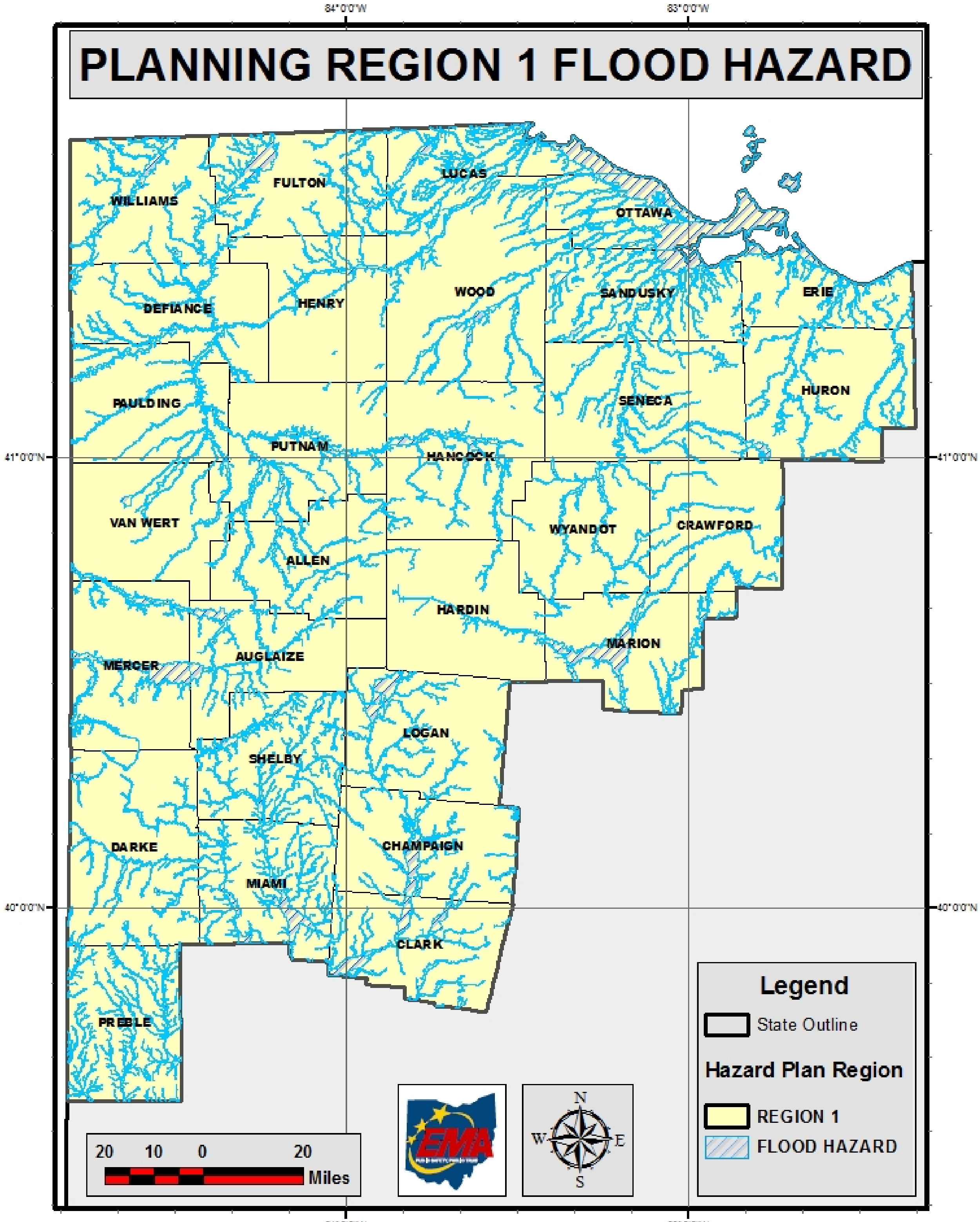
The political jurisdictions in Ohio that are eligible to participate in the NFIP include cities, villages, and unincorporated areas (through the county government). As of the 2010 Census, there are 247 cities, 686 villages, and 88 counties in Ohio. There are 754 Ohio communities that participate in the NFIP. The National Flood Insurance Program Community Status Book contains the complete list of communities in Ohio participating in the National Flood Program.

LOCATION

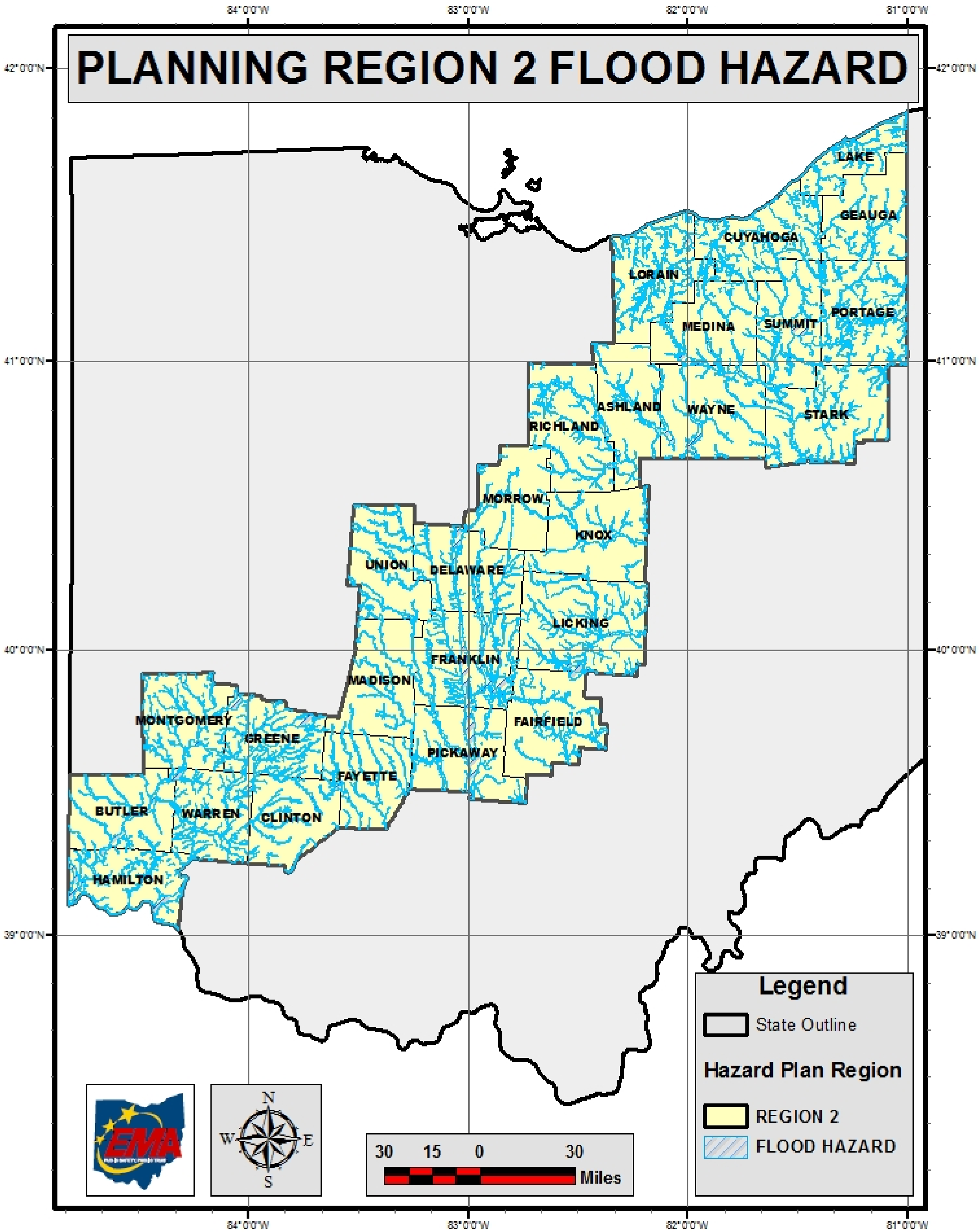
The four sources of information used to determine the location of flooding in Ohio are: FEMA flood maps and studies, NOAA data, information provided by the Ohio Department of Natural Resources - Division of Soil and Water Resources, and HAZUS analyses. Flood maps generated by FEMA to support the NFIP are the primary source of information on the location of special flood hazard areas (SFHAs) in the state. There are two main types of flood maps: the Flood Hazard Boundary Map (FHBM) and the Flood Insurance Rate Map (FIRM). The FHBM identifies approximate SFHAs based on the best available data at the time the map was created.

Generally, Flood Insurance Studies (FISs) and FIRMs are issued by FEMA following a detailed engineering analysis of flood hazard areas in participating communities. The FIS and FIRM identify 1%-annual-chance flood elevations and boundaries for selected stream reaches in the community. The FIRM will contain flood elevation information for various flood frequencies and may also delineate floodway boundaries. Flooding occurs in every county in Ohio. There are over 60,000 miles of named, unnamed, and intermittent streams in Ohio. FEMA has mapped approximately 2,777 square miles of flood hazard area in the state. Maps 2.2.a -2.2.c display FEMA's identified SFHAs in the State of Ohio for the designated Regions.

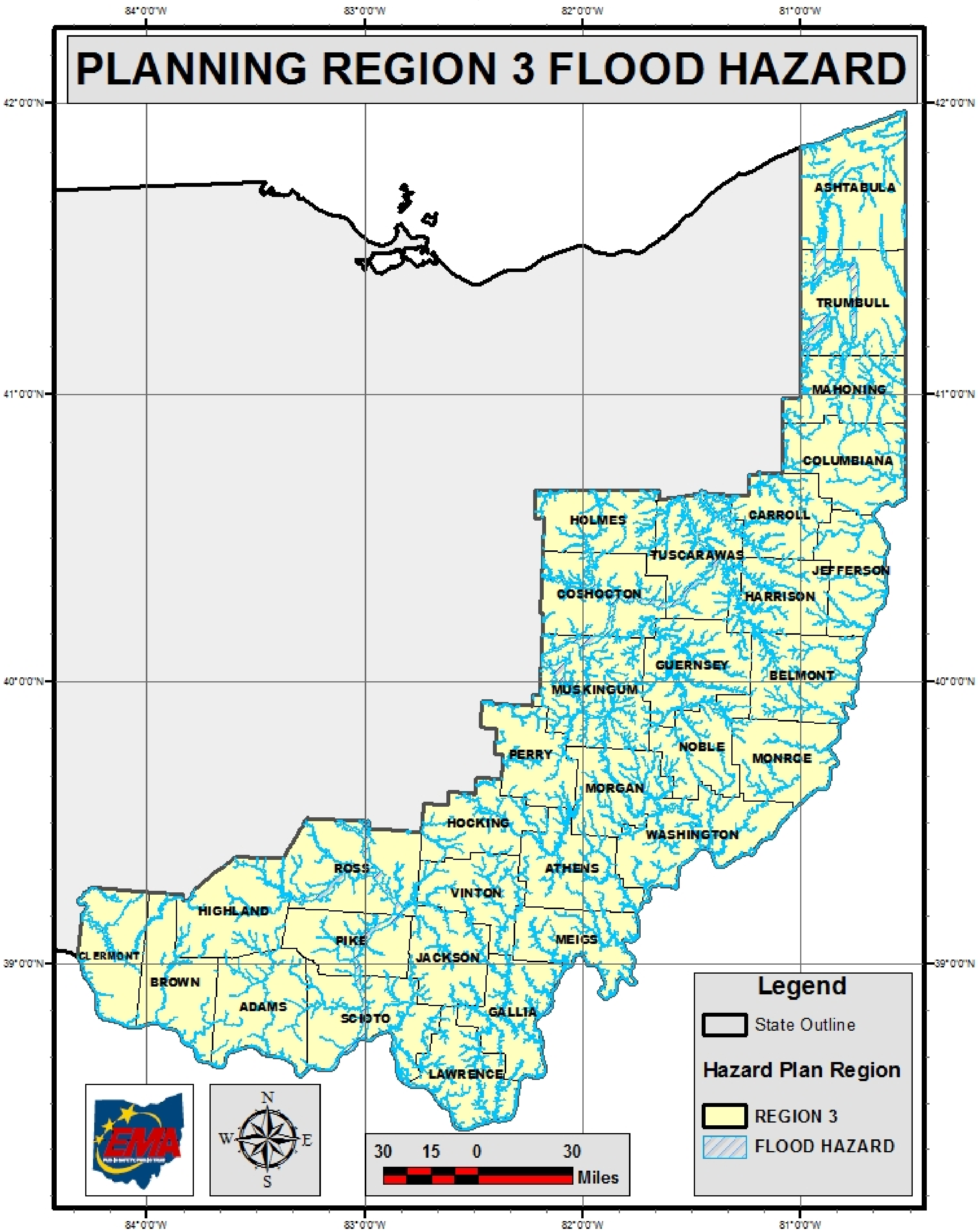
Map 2.2.a


PLANNING REGION 1 FLOOD HAZARD
WILLIAMS
FULTON
LUCAS
OTTAWA
DEFIANCE
HENRY
WOOD
SANDUSKY
ERIE
PAULDING
PUTNAM
HANCOCK
SENECA
HURON
VAN WERT
ALLEN
WYANDOT
CRAWFORD
HARDIN
MARION
MERCER
AUGLAIZE
LOGAN
SHELBY
DARKE
MIAMI
CHAMPAIGN
CLARK
PREBLE
Legend
State Outline
Hazard Plan Region
REGION 1
FLOOD HAZARD
20 10 0 20
Miles
N
S
E
W

Map 2.2.b


PLANNING REGION 2 FLOOD HAZARD
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
LAKE
GEAUGA
CUYAHOGA
LORAIN
MEDINA
SUMMIT
PORTAGE
ASHLAND
WAYNE
STARK
RICHLAND
MORROW
KNOX
UNION
DELAWARE
LICKING
FRANKLIN
MADISON
MONTGOMERY
GREENE
FAIRFIELD
PICKAWAY
FAYETTE
BUTLER
WARREN
CLINTON
HAMILTON
Legend
State Outline
Hazard Plan Region
REGION 2
FLOOD HAZARD
30 15 0 30
Miles
N
S
E
W

Map 2.2.c


PLANNING REGION 3 FLOOD HAZARD
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
ASHTABULA
TRUMBULL
MAHONING
COLUMBIANA
HOLMES
CARROLL
TUSCARAWAS
JEFFERSON
COSHOCTON
HARRISON
GUERNSEY
BELMONT
MUSKINGUM
NOBLE
PERRY
MONROE
MORGAN
HOCKING
WASHINGTON
ROSS
ATHENS
VINTON
HIGHLAND
PIKE
MEIGS
CLERMONT
JACKSON
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
Legend
State Outline
Hazard Plan Region
REGION 3
FLOOD HAZARD
30 15 0 30
Miles
N
S
E
W

The NOAA's National Climate Data Center (NCDC) Storm Events Database contains information on the location of flood events in Ohio. The database can be searched by county and includes a written description of the location of flood events reported in the state. The database also contains latitude and longitude values for some events and contains information on reported deaths, injuries, and estimated property and crop damage. The database can be found on the NCDC website.

The Ohio Department of Natural Resources, Division of Soil and Water Resources is mandated to be a state repository for flood hazard information (Ohio Revised Code Section 1521.13(C)(2)). The Floodplain Management Program maintains copies of flood hazard data generated by various federal, state, local, and private entities.

PAST OCCURRENCES

Profiling past occurrences of flooding at the state level involves gathering and compiling data from many different sources. The data sources used to profile the past occurrences of flooding include FEMA, the ODNR, the Ohio EMA, the NOAA, and the book Thunder in the Heartland by Thomas W. and Jeanne Applehans-Schmidlin, 1996. Table 2.2.a displays a summary of historic flooding information from 1860 to 1990 based on the chronicle Thunder in the Heartland: A Chronicle of Outstanding Weather Events in Ohio. More specific information on these events as well as events post 1990 can be found in the narrative of this section.

Table 2.2.a

Summary of Historic Flood Events 1860-1990			
Date of Event	**Affected Area(s)**	**Water Bodies Affected**	**Event Description**
8/12/1861	Columbiana County, Elkton, Lisbon	Beaver Creek, Elk Run	Every home in Elkton was damaged and four persons drowned when one home was washed off its foundation.
2/17/1867	Toledo, Maumee		Ice jams destroyed one bridge and damaged several others. Flooding in downtown Toledo.
2/11/1881	Toledo, Grand Rapids, Columbus, Findlay	Maumee River, Scioto River, Blanchard River	Four bridges were damaged by ice jams and debris in Toledo. Flooding in downtown Toledo.
2/1883	Statewide	Auglaize, Blanchard, Maumee, Portage, and Sandusky Rivers	A combination of snow melt, ice jams, frozen ground and heavy rains caused flooding statewide.
2/14/1884	Statewide	Ohio, Hocking, Maumee, and Muskingum Rivers	Second highest stage on the Ohio River in Cincinnati. Thousands were evacuated and 3000 buildings were submerged.
5/12/1886	Xenia	Shawnee Creek	Flash flooding washed away several homes killing 21 people and destroying one bridge.
1/23/1904	Lorain, Toledo, Waverly	Black, Scioto, Mahoning and Maumee Rivers	Ships, bridges, and structures were damaged by ice jams and flooding.
3/14-18/1907	Ohio River Watershed	Southern 2/3 of Ohio	Large scale flooding in the Ohio River Watershed resulted in 32 casualties, hundreds of flooded structures, utility and infrastructure damage.
3/23-27/1913	Statewide	Statewide	Described as "Ohio's Greatest Weather Disaster". Four days of heavy rain on saturated soils resulted in 467 casualties, over 2,200 homes destroyed, over 40,000 damaged, and over $2.5 Billion damage in 2003 dollars.

Table 2.2.a (Continued)

Summary of Historic Flood Events 1860-1990			
Date of Event	**Affected Area(s)**	**Water Bodies Affected**	**Event Description**
7/16/1914	Cambridge	Wills Creek Watershed	Over 7.09 inches of rain in 1.5 hours causing flash flooding.
8/16/1920	Toledo	Maumee River	Flash flooding in downtown Toledo damaged homes, businesses and infrastructure.
2/26/1929	Cleveland, Dayton, Mt. Vernon, Bridgeport, Springfield	Little Miami, Maumee, Miami, Rocky, Mad, and Kokosing Rivers, Wheeling and Buck Creeks	Two to three inches of rain, melting snow, and ice jams caused widespread flooding.
3/21/1933	Cincinnati and Southern Ohio	Ohio River	Two periods of heavy rain cause widespread minor flooding.
8/7/1935	Coshocton and surrounding counties	Tuscarawas Watershed	Heavy rain on saturated soils saturated soils caused flash flooding.
3/19/1936	Ohio River Communities from Pittsburgh to Steubenville	Upper Ohio River	Snow melt and heavy rains in Penn. and W. Virginia caused the Ohio River to rise 20 feet in two days.
1/26/1937	All Ohio River Communities	Ohio River	Described as the "Greatest Flood on the Ohio River". Record levels on the Ohio River from Gallipolis to the confluence with the Mississippi.
7/7/1943	Akron and Steubenville	Cuyahoga River, Cross and Wills Creeks	Six to seven inches of rain in several hours caused flash flooding and landslides.
6/16/1946	Wayne and Holmes Counties	Killbuck and Salt Creeks	Heavy rain caused flash flooding resulting in one death, a train wreck destroying 5 bridges and seriously damaging 55 others.
6/8/1947	Adams, Lawrence and Scioto Counties	South Fork of Scioto Brush Creek and other small tributaries to the south emptying into the Ohio River	Flash flooding damaged many homes, bridges, roads, and crops.
3/21/1948	Counties in the Lake Erie Watershed	Lake Erie Watershed	The most severe damage was reported in along the Chagrin River in Cleveland. Twenty buildings were destroyed and 153 were damaged.
6/16/1950	Crooksville, Roseville	Moxahala Creek Watershed	One of the most intense rainfalls ever known in Ohio caused severe flood damages to homes and businesses.
1/21/1959	Statewide	Statewide	Rainfall in January 1959 ranging from 3-6 inches on snow-covered, frozen ground caused the most severe statewide flooding since 1913. Streams reached flood stage from January 21-24 killing 16 people, forcing 49,000 people from their homes, and causing extensive damage to homes, businesses and infrastructure.
6/5/1963	Guernsey County	Wills Creek Watershed	Official records indicate 7.95 inches of rainfall in 16- hours in Cambridge. One railroad bridge was destroyed, all major highways were inundated, and water supplies were polluted.
3/10/1964	Southern and Central Ohio	All Streams in Southern and Central Ohio	Two periods of heavy rain cause widespread flooding resulting in eight deaths, thousands evacuated, 84 homes destroyed, and 8,200 damaged.
7/21/1964	Akron	Ohio Canal and Little Cuyahoga River	Official records indicate 3.05 inches of rain in 75 minutes, but rain distribution was variable. The resulting flooding caused a sewer line to collapse a large section of road killing 3 people.

Table 2.2.a (Continued)

Summary of Historic Flood Events 1860-1990			
Date of Event	**Affected Area(s)**	**Water Bodies Affected**	**Event Description**
4/27/1966	Communities Along Lake Erie's Western Basin	Lake Erie's Western Basin	Several hours of winds up to 55 mph from the northeast pushed the western end of Lake Erie to flood stage. Fifteen hundred were evacuated, hundreds of homes were damaged, and utility services were interrupted.
7/12/1966	Erie, Ottawa, and Huron Counties	Sandusky and Huron River Watersheds	Rainfall totals ranging from 9-12 inches of rainfall over and approximately one-day period. Total damages exceed $27 million in 2003 dollars, including damages to 12,000 homes and businesses in Sandusky.
5/23-27/1968	Central and Southern Ohio	Hocking, Scioto, Little Miami	Two periods of heavy rain within 5 days on already saturated soils caused flooding on many streams. Four deaths have been attributed to this event.
7/4/1969	Northern Ohio	Lake Erie Watershed	Severe thunderstorms moved from Lake Erie into Ohio's coastal communities on July 4, 1969. Flooding combined with strong wind and tornadoes caused 41 deaths and injured 559 people. Loss estimates for this event totaled $65 million dollars in 1969, or over $328 billion in 2003 dollars.
11/14/1972	Coastal communities from Toledo to Cedar Point	Lake Erie	Northeast wind setup caused Lake Erie to rise 3 feet at Toledo and fall 4 feet at Buffalo resulting in coastal flooding. Total damages were estimated at $22 million in 1972 dollars.
4/9/1973	Coastal communities from Toledo to Port Clinton	Lake Erie	Northeast winds caused 8 to 10 foot waves and flooding.
9/14/1979	Southeastern half of the state	N/A	The remains of Hurricane Frederic brought six inches of rain in a band from Cincinnati to Youngstown causing widespread flooding.
3/12/1982	Communities in the Maumee River Watershed	Maumee River Watershed	Two inches of rainfall on snow covered, frozen ground caused flooding. Loss estimates totaled $11 million in 1982 dollars with Defiance County being the hardest hit.
6/14/1990	Shadyside in Belmont County	Pipe Creek and Wegee Creek	Twenty-six people died in a flash flood near Shadyside. Approximately 80 homes were destroyed and 250 were damaged. An estimated that 3-4 inches of rain fell in a little over an hour.
12/31/1990	Widespread	Widespread	The wettest year on record ended with extensive flooding on New Year's Eve causing $50 million (1990 dollars) in damages.

Historically, significant floods in Ohio occurred in 1913, 1937, 1959, and 1969. Heavy rain on saturated soils caused flooding throughout Ohio during March 23rd to 27th, 1913, killing 467 people, destroying 2,200 homes, and flooding 40,637 residences. Losses were totaled at $113 million in 1913 (approximately $2.5 billion in 2010 dollars), including: $78 million to buildings and personal property, $12 million to roads and bridges, $12 million to railroad property, which includes lost profit, $6 million to the agricultural industry, and $4 million dollars to machinery. This flood set record water levels on many Ohio streams. The Miami River Watershed experienced the highest casualties and damages during this event.

The flood of record for the Ohio River occurred the last two weeks in January 1937. Normal January precipitation in Ohio is 2-3 inches. The statewide average rainfall in January 1937 was 9.57 inches, with some stations recording over 14 inches. Ohio River levels on January 26th and 27th were the highest ever recorded from Gallipolis, Ohio to the confluence with the Mississippi River. Every Ohio community along the river was flooded resulting in 10 casualties, 16 injuries, thousands of damaged structures, and over 54,000 evacuations statewide.

Rainfall in January 1959, ranging from 3-6 inches on snow-covered, frozen ground, caused the most severe statewide flooding since 1913. Streams reached flood stage from January 21-24, killing 16 people, forcing 49,000 people from their homes, and causing extensive damage to homes, businesses, and infrastructure. Loss estimates for this event totaled $100 million in 1959, or over $752 million in 2010 dollars. Some of the factors that reduced casualties and damages from the 1913 flood include: less intense rainfall amounts, the construction of flood-control reservoirs built after 1913, and improved emergency management procedures and capabilities.

Severe thunderstorms moved from Lake Erie into Ohio's coastal communities on July 4th, 1969. This line of storms became nearly stationary for more than eight hours, aligned from Toledo southeast to Wooster. Official records indicate over 10 inches of precipitation lasting over a two-day period. Flooding combined with strong winds and tornadoes caused 41 deaths and injured 559 people. Loss estimates for this event totaled $65 million dollars in 1969, or over $388 million in 2010 dollars. This flood caused extensive damage to homes, businesses, infrastructure, utilities, boats, and automobiles.

Twenty-six people died in a flash flood near Shadyside, Ohio on June 14th, 1990. The National Weather Service estimated that 3-4 inches of rain fell in a little over an hour near Pipe Creek and Wegee Creek. Total rainfall is estimated at 5.5 inches in three hours. The saturated soils and narrow, steep-sided valleys caused the water to drain quickly into the creeks. Flash flooding began at 9:30 PM and was over in 30 minutes. During that time, a wall of water six feet high (reported to be 20 feet in some areas) rushed through the valley at seven to ten miles-per-hour. Approximately 80 homes were destroyed and 250 were damaged.

Storms that produced heavy rains during March 1st and 2nd, 1997, resulted in severe flooding in southern Ohio. The largest accumulations of rainfall were recorded in southern Adams and Brown Counties and ranged from 10-12 inches over the two-day period. Generally, rainfall amounts of four or more inches fell on most of the counties along or near the southern border of Ohio. Widespread damages to private and public property occurred throughout the area. Preliminary loss estimates totaled nearly $180 million in 1997, or over $245 million in 2010 dollars. Approximately 20,000 people were evacuated and 6,500 residences and 833 businesses were affected. Five deaths were attributed to flooding; all of the fatalities were the result of attempts to drive through flooded roads.

Storms during June 26th through 30th, 1998, resulted in flooding and widespread damage throughout much of central, east-central and southeastern Ohio. More than 10 inches of rain fell during a four-day period in parts of southeast Ohio. Twelve storm or flood-related fatalities were reported and infrastructure and utilities were heavily impacted. Loss estimates totaled nearly $178 million in 1998, or over $239 million in 2010 dollars.

PRESIDENTIAL DISASTER DECLARATION DATA

Flood vulnerability can also be expressed as historic expenditures on disaster recovery for flood events. Total expenditures for programs triggered by a Presidential Disaster Declarations are tracked and summarized by Ohio EMA (Appendix A). Between the 2005 and 2019 plan updates, six flood events resulted in Presidential disaster declarations. These six events are described below.

<u>DR-1651-OH declared July 2, 2006</u>

Severe thunderstorms and tornado touchdowns caused two deaths and widespread damage in northern Ohio from June 21st and 23rd, 2006. The primary causes of damage in this event were flash flooding, which overwhelmed urban stormwater infrastructure, and riverine flooding. Huron County and the City of Brecksville were especially impacted. The communities of Toledo, Norwalk, Valley View, and Independence also experienced significant flooding.

The USGS estimated flood recurrence intervals for gaged streams based on flood stage for this event. The flooding on the Vermilion River was estimated to be a 50-year event. The flooding on the Cuyahoga River and Tinkers Creek were estimated to be 25 to 50-year events.

<u>DR-1656-OH declared August 1, 2006</u>

Two separate weather systems produced storms resulting in more than 11 inches of rain in parts of Lake County, Ohio on July 27th and 28th, 2006. As a result of the storms and ensuing flooding, the counties of Lake, Geauga, and Ashtabula were declared Federal Disaster Areas. The flooding caused one fatality and 600 evacuations in Lake County. Over all of Lake County, 100 homes and businesses were destroyed and an additional 731 homes and businesses were damaged. Flooding destroyed five bridges in Lake County and closed 13 roads. The City of Painesville experienced heavy damages.

The USGS streamflow-gaging station at the Grand River near Painesville, Ohio had record peak stream flow and peak stage. The recurrence interval for this event was estimated to be 500 years (Ebner, A.D.; Sherwood, J.M.; Astifan, Brian; and Lombardy, Kirk, 2007, Flood of July 27-31, 2006, on the Grand River near Painesville, Ohio: U.S. Geological Survey Open-File Report 2007-1164).

<u>DR-1720-OH declared August 26, 2007</u>

Heavy rainfall inundated multiple communities across northern Ohio during a two-day period. The rain developed along a nearly stationary frontal boundary that was oriented from west to east across north central Ohio. Moisture from the Gulf of Mexico, as well as the remnants of Tropical Depression Erin, was drawn northward resulting in tropical downpours. The heaviest rains redeveloped each night, starting Sunday night August 19th, 2007, into Monday morning and then again on Monday night into the early morning hours of Tuesday, August 21st, 2007.

Stream gage reports from four locations in the affected area indicated that 24-hour rainfall totals ending at 8 AM on August 21st, 2007, exceeded the 1,000 year/24-hour rainfall frequency. Peak flood stage of the Blanchard River in the City of Findlay was 0.04 less than the flood of record in 1913 (National Weather Service Forecast Office in Cleveland, Ohio). Communities in the Blanchard, Sandusky, and Mohican River watersheds were heavily impacted. There were approximately 2,500 flooded structures in the City of Findlay. The communities of Ottawa, Bucyrus, Shelby, Lima, Carey, and Bluffton also had many flooded structures.

DR-4002-OH declared July 13, 2011

Heavy rains and thunderstorms moved through the state on February 27th, 2011, as 3-4 inches of rain accumulated over a 24-hour period in already saturated areas across northern Ohio. This system exited the state and a second wave of precipitation moved through Southern Ohio. Warm temperatures, heavy snow pack, and snowmelt resulted in moderate to major flooding in many areas of the state. The State monitored river crests and falling temperatures over a 48-hour period for impacts, including potential issues with debris, wastewater, sewage, and shelters. Major to moderate flood river levels were recorded in Northern Ohio. The Cuyahoga River reached near-record flood levels.

In March and April, much of Ohio continued to experience heavy rain, severe storms, flooding, and flash flooding across the southern portion of the state. The cumulative effect of these conditions, coupled with flooding in neighboring states along the Ohio and Mississippi Rivers, resulted in dangerous conditions and damages, which affected the health, safety, and welfare in 21 southern Ohio counties. More severe storms moved across the south-central part of the state in May, producing heavy rain and high winds. These conditions further intensified the previously affected citizens in Gallia, Jackson, Lawrence, Pike, Ross, Scioto, and Vinton Counties. During this time, the Governor had issued two proclamations and requested a Presidentially-declared disaster for 13 counties along the Ohio River and 8 adjacent counties.

DR-4098-OH declared January 3, 2013

Hurricane Sandy brought heavy rainfall and significant flooding to northern portions of Ohio on October 29th and 30th, 2012. The flooding was the result of three consecutive weather events; a cold front, hurricane Sandy remnants, and lake enhanced showers. Rain started on October 26th as a slow moving cold front moved into the Ohio Valley. This front brought widespread 0.75 to 2.0 inches of rainfall to northern Ohio, highest near the lake.

By Monday, the remnants of Hurricane Sandy moved into Pennsylvania, and the pressure gradient between it and high pressure over Missouri produced storm force winds over Lake Erie. Moisture from Sandy moved into the region producing an additional rainfall of 2 to 3 inches by Tuesday the 30th. Rain continued at a rate averaging 0.10 inches per hour for the day, but increased to 0.75 inches per hour overnight and early Wednesday morning. This band of heavier rain caused the rivers, which were receding to once again rise. Areal flooding was limited to more northern counties; however, some small streams and creeks came out of their banks as far south as Ashland County. Numerous roads were closed due to flooding in Cuyahoga, Lake, and Medina Counties. In Ashtabula County, docks were damaged at the Port of Ashtabula due to severe wind and violent wave actions on Lake Erie, and marinas had to be dredged at the Port Authority of Conneaut. A flood watch was in effect for the lakefront counties and flood advisories were issued during the event.

A few dozen homes and businesses were impacted as water inundated basements or first floors. A number of homes affected were located in the floodplain of the rivers or along the shoreline where the raised lake level combined with the increased stream flows to produce flooding in areas not typically affected. Two rivers along the lakeshore reached major flood stage (based on NWS stage categories), the Cuyahoga and the Huron Rivers. The rest of the Lake Erie tributaries saw minor or moderate flooding. Many basements flooded further inland as sump pumps failed due to power outages. As the result of Hurricane Sandy, an estimated $17.8 Million in public assistance funds has been awarded to this point.

DR-4360-OH declared April 17, 2018

Beginning on February 14, 2018, and continuing through February 25, 2018, a persistent band of moderate to severe storms moved across Region V impacting Illinois, Indiana, Michigan, Ohio, and Wisconsin. While precipitation levels and storm-related damages varied, Ohio experienced a significant amount of flooding and subsequent damage along the southern portion of the state. The snowmelt and continued rain throughout the incident period, combined with the frozen soils, led to flooding along area streams, rivers, and low-lying areas. Numerous flood gauges in this area rose to moderate flood stage, and rainfall totals in the impacted areas during the incident period ranged from a total of five to nine inches. Following these storms, there were several road closures as well as reports of inaccessible areas throughout southern Ohio due to standing water.

Widespread flooding culminated February 26, 2018, when the Ohio River at Cincinnati rain gauge showed a crest of 60.53 feet, 8 feet above flood stage and the highest crest since 1997. Communities near the river and its tributaries incurred damages to roads, bridges, and public buildings, as well as basement flooding and sewage backup. According to the Governor, preventative steps on the part of state and local agencies, such as Ohio EMA, shielded the area from the worst possible damage. The SEOC was partially activated with Emergency Support Functions (ESFs). A FEMA Region V Liaison Officer was deployed to the SEOC from February 25, 2018, through February 27, 2018, and the SEOC returned to normal operations on February 27, 2018.

There were several local evacuations due to flooding and the American Red Cross opened three shelters in the impacted areas. There was one confirmed fatality (Shelby County) as a result of this event, and at its peak, there were 10,449 customers without power statewide. On March 6, the Governor requested a joint preliminary damage assessment (PDA) conducted by local, state, and federal emergency management officials. The joint PDA resulted in documentation of approximately $44 million worth of damages to county, village and township roads, bridges, and public buildings. On March 26, the Governor requested a Presidential Disaster Declaration. On April 17, 2018, a disaster was declared for the State of Ohio, due to severe storms, flooding, and landslides that occurred during the incident period of February 14, 2018, through February 25, 2018. As a result of that declaration, Public Assistance has been made available for Adams, Athens, Belmont, Brown, Columbiana, Gallia, Hamilton, Jackson, Lawrence, Meigs, Monroe, Muskingum, Noble, Perry, Pike, Scioto, Vinton, and Washington Counties. The Disaster impact data is fluid as only half of the Public Assistance projects have been awarded as of January 2019.

NOAA DATA SUMMARY

Table 2.2.b lists the number of reported floods in Ohio since the year 2000, and associated loss totals according to the NOAA's NCDC Storm Events Database. The information in this database comes from NWS, who receives their data from a variety of sources including: county, state, and federal emergency management officials, local law enforcement officials, weather spotters, NWS damage surveys, newspaper clipping service, and the insurance industry and the public. An effort is made to use the best available information, but because of time and resource constraints, information from these sources may be unverified by the NWS.

Table 2.2.b

Ohio Flood Data Summary from the National Climatic Data Center					
Year	**Number of Reported Flood Events [1]**	**Deaths**	**Injuries**	**Estimated Property Damage (2017 Dollars)**	**Crop Damage (2017 Dollars)**
2000	44	3	2	$11,727,310	None Reported
2001	37	3	1	$16,151,620	None Reported
2002	38	1	None Reported	$2,831,820	None Reported
2003	63	4	None Reported	$391,232,610	$3,263,460
2004	40	2	None Reported	$164,640,140	$1,073,650
2005	39	3	None Reported	$71,997,770	None Reported
2006	33	4	1	$620,812,770	$42,438,060
2007	115	None Reported	None Reported	$277,897,680	$18,256,410
2008	105	1	None Reported	$5,871,830	$50,140
2009	38	1	None Reported	$5,004,190	$58,860
2010	71	5	4	$14,985,320	$1,090
2011	47	2	None Reported	$48,788,400	$194,020
2012	25	None Reported	2	$340,692	None Reported
2013	31	None Reported	None Reported	$4,292,160	$105,200
2014	31	None Reported	None Reported	$72,226,440	$78,660
2015	37	5	3	$27,679,146	$284,350
2016	26	None Reported	None Reported	$4,733,356	None Reported
2017	39	None Reported	None Reported	$18,762,000	$1,500,000
Total:	**859**	**34**	**13**	**$1,759,975,254**	**$61,892,000**

1 - The number of reported flood events was calculated by adding one record for each date in the data set.

PROBABILITY OF FUTURE EVENTS

The probability of occurrence of flooding is the likelihood that a specific event will happen. The likelihood of a flood event happening is usually expressed in terms of frequency. The NFIP provides maps and studies that use the 1 percent annual chance floodplain area (area inundated during a 100-year flood) as the national standard for regulating floodplain development. It is critical to establish the probability of occurrence for flooding so that the state and local communities can make informed decisions about the sustainability of future development, and determine the feasibility of proposed mitigation projects.

The primary sources of data for determining the probability of occurrence of flooding are the FEMA FISs and FIRMs. Nearly every community that participates in the NFIP has a map that identifies at least some area of flood hazard in the community that has a 1 percent annual chance of being equaled or exceeded in any given year. This area is referred to as the 1%-annual-chance floodplain, or the 100-year floodplain, and is graphically represented on a FIRM or FHBM.

Communities that do not have FISs, usually have an FHBM or FIRM that shows the approximate area that would be inundated by the 1%-annual-chance flood. An FHBM was intended for interim use in most communities, until a FIS could be completed. FHBMs are still being used in some Ohio communities where a detailed FIS has yet to be produced.

Approximately 81 percent of Ohio communities that participate in the NFIP have a portion of their flood hazard areas identified in a FIS. The purpose of a FIS is to investigate the existence and severity of flood hazards in a certain geographic area. The information in a FIS is used to establish actuarial flood insurance rates and assist the community in its efforts to regulate flood hazard areas. A FIS contains data on: historical flood events, the area and flood sources studied, and the engineering methods employed to generate the flood hazard data. A FIS will have flood elevation profiles for the 100-year recurrence probability flood, and usually the 10-, 50-, and/or 500-year floods. It may also contain tables summarizing floodway data and other flood hazard information; however, it does not usually contain data for every flood hazard area in a community. The remaining areas may have approximate flood hazard data, or none at all.

There are several other possible data sources for determining the area affected by a particular probability flood event. The Ohio Department of Natural Resources, Division of Soil and Water Resources, is the state repository for flood hazard information and has copies of flood hazard information generated by various federal, state, local and private entities. The Floodplain Management Program maintains current copies of all FEMA FISs and flood maps in the state.

LHMP DATA

As stated at the beginning of Section 2, integration of LHMP data into the state HIRA is an ongoing effort. As local plans continue to expire and jurisdictions update their plans, vulnerability information and loss estimation are collected and assembled. Highlighted below is some of the more notable jurisdictional plan information that has been assembled and integrated into the state HIRA.

Hamilton County - The 2013 updated Multi-Hazard Mitigation Plan examined flash flooding, river flooding and urban flooding (categorized in their plan as Non- Flood Zone flooding). Since the previously approved plan in October 2006, Hamilton County has experienced 31 events with a total of $82,000 in property damage. Additionally, river flooding assessment is conducted for each of the major watersheds that affect the county: the Great Miami River, the Little Miami River, the Ohio River, and the Mill Creek watershed plus its tributaries. Each of the watersheds are mapped and analyzed to include properties, repetitive loss areas, and critical facilities. These analyses projected 2,377 residential structures at risk at a value of $72,428,000, an estimated 750 non-residential structures valued at $319,464,000 and 173 critical facilities valued at $30,404,000.

Belmont County - The 2013-2018 Belmont County Multi-Jurisdictional Hazard Mitigation Plan provides an analysis of riverine and flash flooding. Although it is considered a small, rural county, projections show potential losses approaching $2 billion. A Level-1 HAZUS-MH 100-year flood scenario estimated 10,469 residential structures at risk at a value of $1,388,080,000, an estimated 3,552 non-residential structures valued at $471,071,000 and 839 critical facilities valued at $113,140,000. Flooding continues to be a frequent and damaging hazard as a result of the Ohio River, several streams and creeks. There have been eight Presidential declarations due to flooding since 1980, three of which occurred in the month of June. However, riverine flooding occurs in the winter as well. In January 1996, floodwaters from the conveyance of two rivers in Pittsburgh caused the Ohio River to crest over 4 feet above flood stage. This caused 61 residences to be destroyed, 136 with major damage, 107 with minor damage and 14 residences to be affected. Belmont County also has 52 repetitive loss properties: 37 are residential with 36 losses while 15 are classified as non-residential with 87 losses. One of the residential properties is a Severe Repetitive Loss property with four losses. Flash flooding occurs more often than riverine flooding with 65 events recorded between 1996 and 2013 and damaging $7,159,000 in property and $5 million in crop losses. The most significant event was in June 1990, recorded as the most devastating flash flood to strike Ohio in recent years, resulting in 26 fatalities.

Jackson County - The Jackson County Natural Hazards Mitigation Plan of 2017 used HAZUS-MH to project damage in its most flood prone areas. These are identified as the Cities of Jackson and Wellston, and the Villages of Coalton and Oak Hill and various unincorporated jurisdictions. These areas experienced flooding in 1997 when the Little Salt Creek, Meadow Run, Little Raccoon Creek and other watersheds exceeded their banks. A Level-1 HAZUS- MH 100-year flood scenario performed in 2017, estimated the value of residential structures at risk at $453,142,000 (68.7%), and estimated the value of non-residential structures at $206,755,000 (31.3%). There were 24 essential facilities (fire stations, hospitals, police stations, and schools) at risk with one school expected to have loss of use.

SHARPP

Flood ranks highly amongst local hazard mitigation plans. It ranks in terms of frequency and response time, second in terms of impact on property, and third in impact (magnitude), and impact on business.

FLOOD SHARPP RANK AND SCORE							
Flood Rank	**1**	**1**	**6**	**3**	**3**	**4**	**2**
Criteria Score	**3.70**	**2.95**	**2.54**	**2.42**	**2.11**	**1.96**	**2.19**
	Hazard Frequency	Response Time	Onset Time	Impact	Impact on Business	Impact on Humans	Impact on Property

VULNERABILITY ANALYSIS

Flooding vulnerability is the likelihood of something to be damaged in a flood. A vulnerability analysis is a measurement of a community's flood risk. Vulnerability can be measured using many different methods. The method selected is highly dependent on the type and format of available data. If site-specific information on flood elevation, lowest floor elevation, structure type, and replacement value exist, a detailed vulnerability analysis can be performed using flood damage curves. The State of Ohio, and most communities in the state, lack all or a component of the data required for a detailed analysis and must use more simplified methods. Several different data sources are utilized in this discussion to help develop a clearer picture of Ohio's flood vulnerability including: HAZUS-MH analyses, the statewide Structure Inventory, NFIP repetitive loss data, and local data uploaded into SHARPP.

NFIP REPETITIVE LOSS PROPERTIES

The NFIP has identified a subset of structures covered by flood insurance policies that are referred to as "repetitive loss" and "severe repetitive loss" (see Appendix B). For this analysis, a repetitive loss structure is any property covered under an NFIP flood insurance policy with two or more losses of more than $1,000 each, in any 10-year rolling period, and at least two losses that are more than 10 days apart.

Severe repetitive loss (SRL) structures are defined as residential structures that are covered under an NFIP flood insurance policy and a) that have at least four NFIP claim payments (including building and contents) over $5,000 each, and the cumulative amounts of such claims payments exceed $20,000; or b) for which at least two separate claims payments (building payments only) have been made with the cumulative amount of the building portion of such claims exceeding the market value of the building. For both (a) and (b) above, at least two of the referenced claims must have occurred within any ten-year period, and must be greater than 10 days apart.

NFIP repetitive loss data can be used to identify some of the structures vulnerable to flooding throughout the state. In Ohio, it is estimated that approximately 63% of the structures in the SFHA are not covered by flood insurance for any number of reasons. Some reasons include: misinformation about flood insurance as a mitigation option; the structure is not required to be covered by flood insurance because there is no current mortgage; lack of resources to purchase coverage; and lack of enforcement by the mortgage holder.

The Ohio EMA Mitigation Branch examined repetitive flood loss data for all 88 counties and their affected communities. First, data were compiled and analyzed for the top twelve communities with the greatest number of repetitive flood loss structures. These counties were identified as Belmont, Cuyahoga, Erie, Franklin, Guernsey, Hamilton, Hancock, Lake, Lucas, Ottawa, Summit, and Washington. The Mitigation Branch discussed the significance of both categories, counties and jurisdictions, and decided that the focus should be on the top 12 counties with the highest number of repetitive loss structures. The counties are summarized in Table 2.2.c. The “Total Paid” column is the summed building and contents payments from the repetitive loss structures.

Table 2.2.c

RANK	COUNTY	LOSS STRUCTURES			Losses	Total Paid
		TOTAL RL/SRL STRUCTURES	REPETITIVE LOSS STRUCTURES	SEVERE REPETITIVE LOSS STRUCTURES		
1	Hancock	266	221	45	835	$ 19,786,550
5	Cuyahoga	148	117	31	557	$ 21,638,500
2	Washington	202	183	19	510	$ 11,975,540
4	Hamilton	141	123	18	437	$ 12,824,763
3	Ottaw a	130	125	5	375	$ 3,291,518
6	Erie	99	84	15	331	$ 3,533,345
8	Lucas	80	72	8	227	$ 2,753,382
9	Lake	78	71	7	225	$ 3,369,267
7	Summit	89	84	5	222	$ 5,517,466
10	Franklin	70	68	2	164	$ 2,123,454
11	Belmont	61	59	2	146	$ 2,604,347
12	Guernsey	57	55	2	139	$ 4,874,974
TOTAL		**1,421**	**1,262**	**159**	**4,168**	**$ 94,293,107**

Appendix B lists the repetitive loss properties by county and region, indicates the status of flood insurance, estimates the structure and content value, and demonstrates the number of flood losses per structure. As of August 2018, there are 2,661 repetitive and severe repetitive loss structures in Ohio with a total of 7,589 losses and $154,034,302 dollars paid.

Region 1 has the highest number of repetitive loss and severe repetitive structures in the state as identified by the NFIP at 931 structures, including 107 severe repetitive loss structures. The amount paid out for repair of these structures through August 2018, is $47,531,834 for structure repairs and contents replacement. Within Region 1, the most significant concentration of repetitive loss structures is located in the City of Findlay (Hancock County), which is along the Blanchard River. In total, Findlay has 253 repetitive loss structures identified with 801 losses, which have paid a total of $19,317,244 for structure repairs and contents replacements.

Region 2 is identified as having the second highest number of repetitive loss structures in the State. All of the counties within the region have identified repetitive loss structures. As a whole Region 2 has 880 repetitive loss structures identified, with the total of contents replacements and total payments equaling $65,459,581 in paid claims. There are two areas of significant loss identified within the region. The City of Cincinnati (Hamilton County) is located in the southwestern portion of the state on the Ohio River. It has 65 repetitive loss structures with 220 claims for $8,736,956 in repairs paid and contents replaced. The second area includes the City of Independence (Cuyahoga County). Independence has 20 identified repetitive loss structures with 114 claims for a total of $12,103,200.

Region 3 is third in the state for all statistics regarding repetitive loss structures. In total, there are 880 repetitive loss structures with 2,195 losses totaling $41,042,888 in repairs and contents paid. The City of Marietta (Washington County) has 120 repetitive loss structures with 298 reported claims representing $8,092,239 in repairs and contents replacements. The second highest RFC count in this region resides in the unincorporated area of Washington County, 54 structures with 139 losses totaling $2,625,547 in repairs and contents replacements.

NFIP COMMUNITY RATING SYSTEMS (CRS) PROGRAM

According to the October 2018 NFIP Flood Insurance Manual, the Community Rating System (CRS) is a voluntary program for communities participating in the National Flood Insurance Program (NFIP). The CRS offers flood insurance policy premium discounts in communities that develop and execute extra measures beyond minimum floodplain management requirements to provide protection from flooding. A community's eligibility for the CRS depends upon participating in the Regular Program and maintaining full compliance with the NFIP. CRS flood insurance policy premium discounts range from 0 percent to 45 percent depending on the community's floodplain management measures and activities.

The CRS recognizes measures for flood protection and flood loss reduction. The four main activity categories include Public Information, Mapping and Regulation, Flood Damage Reduction, and Flood Preparedness.

In order to participate in the CRS, a community must complete and submit an application to FEMA. Subsequently, FEMA reviews the community's floodplain management efforts and assigns the appropriate CRS classification based on credit points earned for various activities. A community's classification may change depending on the level of continued floodplain management efforts. Classifications range from one to ten and determine the premium discount for eligible flood insurance policies. All community assignments begin at Class 10 with no premium discount. Communities with a Class 1 designation receive the maximum 45 percent premium discount.

The table below highlights the available CRS premium discounts organized by class and flood zone. In addition to the Rate Class of the, the discount amount also varies depending on whether the insured property is in a Special Flood Hazard Area (SFHA), or not.

CRS Premium Discounts by Class and Flood Zone

Rate Class	Discount for SFHA*	Discount for Non-SFHA**	Credit Points Required
1	45%	10%	4,500 +
2	40%	10%	4,000–4,499
3	35%	10%	3,500–3,999
4	30%	10%	3,500–3,499
5	25%	10%	3,000–2,999
6	20%	10%	2,500–2,499
7	15%	5%	1,500–1,999
8	10%	5%	1,000–1,499
9	5%	5%	500–999
10	0	0	0–499

* Special Flood Hazard Area

** Preferred Risk Policies are available only in B, C, and X Zones for properties that are shown to have a minimal risk of flood damage. The Preferred Risk Policy does not receive premium rate credits under the CRS because it already has a lower premium than other policies. Although they are in SFHAs, Zones AR and A99 are limited to a 5% discount. Premium reductions are subject to change.

Source: 2018 National Flood Insurance Program (NFIP) Community Rating System (CRS): A Local Official's Guide to Saving Lives, Preventing Property Damage, Reducing the Cost of Flood Insurance

As of October 2018, 13 communities in Ohio are currently participating in the CRS program. The table below shows their current class and status.

CRS Communities in Ohio

Effective October 1, 2018

STATE	COMMUNITY NUMBER	COMMUNITY NAME	CRS ENTRY DATE	CURRENT EFFECTIVE DATE	CURRENT CLASS	% DISCOUNT FOR SFHA[1]	% DISCOUNT FOR NON SFHA	STATUS[2]
OH	390183	Delta, Village of	10/1/1992	10/1/2016	8	10	5	C
OH	390038	Fairfield, City of	10/1/1993	10/1/1998	8	10	5	C
OH	390110	Highland Heights, City of	10/1/1991	10/1/1992	10	0	0	R
OH	390412	Kettering, City of	10/1/1995	10/1/2000	8	10	5	C
OH	390328	Licking County	10/1/1993	5/1/2009	7	15	5	C
OH	390378	Medina County	5/1/2007	5/1/2012	8	10	5	C
OH	390071	New Richmond, Village of	10/1/1992	10/1/2002	8	10	5	C
OH	390176	Obetz, Village of	10/1/1996	10/1/2016	10	0	0	R
OH	390737	Orange, Village of	10/1/1991	10/1/2016	7	15	5	C
OH	390472	Ottawa, Village of	10/1/1995	10/1/1995	9	5	5	C
OH	390432	Ottawa County	10/1/1992	10/1/1992	9	5	5	C
OH	390460	Preble County	10/1/1998	10/1/1998	9	5	5	C
OH	390479	Shelby, City of	10/1/1992	5/1/2012	8	10	5	C
OH	390131	South Euclid, City of	10/1/1991	10/1/2016	8	10	5	C
OH	390419	West Carrollton, City of	5/1/2002	5/1/2009	8	10	5	C

1. For the purpose of determining CRS discounts, all AR and A99 Zones are treated as non-SFHAs.
2. Status: C = Current, R = Rescinded

OCTOBER 2018 NFIP FLOOD INSURANCE MANUAL

Source: October 2018 NFIP Flood Insurance Manual, Appendix F

Risk MAP

Not only is flooding one of the most common and costly disasters, flood risk can also change over time because of new building and development, weather patterns and other factors. Although the frequency or severity of impacts cannot be changed, FEMA is working with federal, state, and local partners across the nation to identify flood risk and promote informed planning and development practices to help reduce that risk through the Risk Mapping, Assessment and Planning (Risk MAP) program

Risk MAP provides high quality flood maps and information, tools to better assess the risk from flooding and planning and outreach support to communities to help them take action to reduce or mitigate flood risk. Each Risk MAP flood risk project is tailored to the needs of each community and may involve different products and services.

Risk MAP outreach and discovery meetings in Ohio

The FEMA, ODRN, Ohio EMA and the Strategic Alliance for Risk Reduction hosted outreach and discovery meetings with local officials and the public to discuss floodplain mapping needs and potential mitigation projects on the following dates. Those meetings highlighted in black led directly to a Hazard Mitigation Assistance project being developed and funded.

2014

- **Cuyahoga County Pilot Meeting – 05/22/14**
- City of Columbus – 9/17/14
- Marion County – 9/18/14
- Delaware County 9/23/14
- City of Columbus – 12/9/14
- City of Reynoldsburg – 12/9/14
- Marion County – 12/10/14
- City of Marysville – 12/10/14

2015

- City of Miamisburg – 4/28/15
- City of Oxford – 4/29/15
- City of Eaton – 4/29/15
- City of Clayton – 4/30/15
- City of Hamilton – 4/30/15
- Shelby County – 6/30/15
- Sandusky County – 7/7/15
- Lake County – 7/7/15
- City of Westlake – 7/8/15
- City of Toledo – 7/9/15
- Tuscarawas County – 9/16/15 & 12/2/15
- Stark County – 9/16/15 & 12/1/15
- Mercer County – 11/4/15
- Summit County – 12/1/15
- Morrow County – 1/6/15
- Delaware County – 1/6/15
- City of Circleville – 1/7/15
- City of Hilliard – 1/7/15
- City of Eaton – 1/21/15
- Butler County – 1/21/15

2016

- Portage County – 7/27/16

2017

- **Summit County – 6/22/17**
- City of Troy – 8/8/17
- Coastal Map Meetings – Lucas, Ottawa, Erie, Lorain, Cuyahoga, Lake, Ashtabula – 11/28/17 thru 12/7/17

HAZARDS U.S.-MULTI-HAZARD (HAZUS-MH)

Ohio EMA cooperated with the US Army Corps of Engineers (USACE) to undertake a HAZUS analysis project under the USACE's Silver Jackets program. In this project, the USACE completed Level 2 flood analysis for 24 counties. The Corps analyzed Ashland, Ashtabula, Butler, Cuyahoga, Delaware, Fairfield, Franklin, Geauga, Greene, Hamilton, Lake, Licking, Mahoning, Medina, Montgomery, Pickaway, Portage, Richland, Stark, Summit, Warren, and Wayne Counties. The remainder of the state was done with a Level 1 analysis and was completed by Ohio EMA from 2017 to 2018. The analyses completed for all counties in the state included the 100-year and 25-year flood intervals. Results of these and other HAZUS-MH runs are shared with counties and jurisdictions when possible to assist in updating local mitigation plans.

The results of the HAZUS-MH runs have been broken down by region and are reported by county for total building exposure, number of structures impacted by percentage damaged, number of critical facilities impacted, total business interruption losses, and the total building loss (Tables 2.2.d, 2.2.e, 2.2.f, 2.2.g, 2.2.h, and 2.2.i). Tables ending in d, e, and f contain the results based on a 100-year event while g, h, and i contain the 25-year results. **It is important to remember all the information reported via the state's HAZUS-MH analyses is an estimate and cannot be interpreted as precise losses**. Future HAZUS analyses will include more refined property, flood, and topographic data to reduce this uncertainty.

RESULTS

Table 2.2.d

Table 2.2c Estimate of Potential Losses from Flooding in the 100-Year Event, Region 1*										
County	2010 Population	Building Exposure Value (thousands)	1-10% Damage Count	11-20% Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	>50% Damage Count	Estimated Business Interrupt	Estimated Building Loss
Allen	106,331	$ 2,938,683	144	133	38	15	10	8	$ 125,540,000	$ 108,770,000
Auglaize	45,949	$ 1,263,355	68	72	33	15	6	3	$ 330,000	$ 70,570,000
Champaign	40,097	$ 993,906	73	30	1	0	0	0	$ 50,000	$ 22,590,000
Clark	138,333	$ 2,509,518	136	144	29	7	3	6	$ 122,410,000	$ 124,430,000
Crawford	43,784	$ 660,181	8	11	2	0	0	0	$ 15,030,000	$ 16,410,000
Darke	52,959	$ 1,340,402	40	20	4	1	1	5	$ 35,660,000	$ 50,680,000
Defiance	39,037	$ 1,187,341	12	17	11	2	5	7	$ 42,380,000	$ 49,550,000
Erie	77,079	$ 2,524,903	132	130	35	25	3	10	$ 145,000,000	$ 91,790,000
Fulton	42,698	$ 685,737	17	19	3	1	0	0	$ 19,900,000	$ 19,640,000
Hancock	74,782	$ 2,026,624	137	76	11	4	1	4	$ 181,950,000	$ 95,970,000
Hardin	32,058	$ 726,799	20	26	7	2	2	5	$ 23,080,000	$ 24,940,000
Henry	28,215	$ 983,530	30	12	1	0	0	0	$ 17,250,000	$ 19,710,000
Huron	59,626	$ 1,556,642	60	66	12	2	0	0	$ 26,200,000	$ 39,930,000
Logan	45,858	$ 1,325,213	69	55	13	3	0	0	$ 22,960,000	$ 29,120,000
Lucas	441,815	$ 9,520,884	376	414	138	63	46	75	$ 373,160,000	$ 530,890,000
Marion	66,501	$ 1,299,338	74	79	15	2	0	0	$ 43,990,000	$ 43,330,000
Mercer	40,814	$ 926,354	23	15	3	1	1	0	$ 17,540,000	$ 22,850,000
Miami	102,506	$ 3,131,471	400	463	188	79	34	18	$ 285,810,000	$ 285,920,000
Ottawa	41,428	$ 1,650,536	39	25	1	0	0	0	$ 21,740,000	$ 15,460,000
Paulding	19,614	$ 727,272	18	13	3	0	0	0	$ 8,980,000	$ 17,520,000
Preble	42,270	$ 1,455,992	63	80	16	3	1	1	$ 47,820,000	$ 86,270,000
Putnam	34,499	$ 1,124,245	47	57	15	3	1	0	$ 29,140,000	$ 43,590,000
Sandusky	60,944	$ 1,436,449	37	17	1	0	0	0	$ 16,950,000	$ 24,730,000
Seneca	56,745	$ 1,341,176	81	125	33	11	3	7	$ 65,430,000	$ 80,830,000
Shelby	49,423	$ 983,159	30	60	26	15	3	4	$ 28,120,000	$ 54,230,000
Van Wert	28,744	$ 680,518	37	41	8	4	2	0	$ 41,040,000	$ 32,330,000
Williams	37,642	$ 1,192,933	12	27	12	5	1	0	$ 26,340,000	$ 35,760,000
Wood	125,488	$ 4,489,872	625	178	23	5	1	2	$ 1,410,000	$ 124,400,000
Wyandot	22,615	$ 663,692	16	26	4	1	0	0	$ 23,680,000	$ 20,550,000

Table 2.2.e

Table 2.2d Estimate of Potential Losses from Flooding in the 100-Year Event, Region 2*										
County	2010 Population	Building Exposure Value (thousands)	1-10% Damage Count	11-20% Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	>50% Damage Count	Estimated Business Interrupt	Estimated Building Loss
Ashland*	53,139	$ 676,389	174	49	37	20	20	92	N/A	$ 21,640,944
Butler*	368,130	$ 752,889	1064	365	177	78	3	33	N/A	$ 113,773,231
Clinton	42,040	$ 1,194,907	12	25	18	12	5	7	$ 26,790,000.00	$ 43,700,000
Cuyahoga*	1,280,122	$ 3,934,170	446	282	148	89	46	58	N/A	$ 220,686,769
Delaware*	174,214	$ 1,519,539	180	97	55	237	41	117	N/A	$ 331,691,349
Fairfield*	146,156	$ 1,177,309	504	323	189	148	86	208	N/A	$ 89,832,202
Fayette	29,030	$ 890,747	29	45	4	1	0	0	$ 21,830,000.00	$ 31,220,000
Franklin*	1,163,414	$ 4,144,131	1195	423	183	91	40	39	N/A	$ 93,598,477
Geauga*	93,389	$ 428,036	90	78	41	17	12	37	N/A	$ 23,147,161
Greene*	161,573	$ 1,099,886	206	104	41	22	26	52	N/A	$ 55,160,646
Hamilton*	802,374	$ 3,963,959	385	441	383	264	244	771	N/A	$ 739,490,735
Knox	60,921	$ 2,193,096	132	161	38	7	1	1	$ 201,930,000.00	$ 131,690,000
Lake*	230,041	$ 1,416,495	254	259	136	109	66	138	N/A	$ 84,988,502
Licking*	166,492	$ 1,521,162	640	461	183	104	70	157	N/A	$ 108,353,322
Lorain	301,356	$ 10,061,999	435	247	34	13	5	8	$ 501,730,000.00	$ 324,900,000
Madison	43,435	$ 1,335,970	50	64	9	1	0	0	$ 31,630,000.00	$ 31,690,000
Medina*	172,332	$ 713,878	225	172	144	61	26	77	N/A	$ 66,018,995
Montgomery*	535,153	$ 1,646,665	744	479	222	139	68	161	N/A	$ 197,349,805
Morrow	34,827	$ 920,900	9	12	0	0	0	0	$ 15,560,000.00	$ 13,260,000
Pickaway*	55,698	$ 1,182,662	61	22	11	10	0	16	N/A	$ 13,169,415
Portage*	161,419	$ 1,196,404	248	127	57	33	19	58	N/A	$ 28,462,660
Richland*	124,475	$ 466,770	211	146	70	51	23	93	N/A	$ 30,230,452
Stark*	375,586	$ 1,399,265	621	312	161	89	69	171	N/A	$ 116,659,799
Summit*	541,781	$ 1,933,070	614	252	114	48	36	105	N/A	$ 73,402,447
Union	52,300	$ 1,539,110	54	64	9	2	0	0	$ 120,000.00	$ 39,540,000
Warren*	212,693	$ 168,782	177	159	134	94	119	203	N/A	$ 31,784,842
Wayne*	114,520	$ 564,231	201	52	23	20	19	45	N/A	$ 21,676,031

** The figures provided for the specific county was a result of a HAZUS level 2 run done in collaboration with the US Army Corp of Engineers*

Table 2.2.f

Table 2.2e Estimate of Potential Losses from Flooding in the 100-Year Event Region 3*										
County	2010 Population	Building Exposure Value (thousands)	1-10% Damage Count	11-20% Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	>50% Damage Count	Estimated Business Interrupt	Estimated Building Loss
Adams	28,550	$ 819,637	2	16	9	4	3	24	$ 24,130,000	$ 49,170,000
Ashtabula*	101,497	$ 95,107,200	146	91	49	45	38	217	N/A	$ 52,565,007
Athens	64,757	$ 3,090,060	103	378	224	102	50	72	$ 577,820,000	$ 847,830,000
Belmont	70,400	$ 1,654,807	32	118	84	41	23	25	$ 98,460,000	$ 132,800,000
Brown	44,846	$ 1,264,472	6	26	14	5	4	7	$ 25,990,000	$ 48,350,000
Carroll	28,836	$ 1,113,047	62	121	48	14	4	4	$ 87,810,000	$ 61,300,000
Clermont	197,363	$ 4,224,485	3	25	36	28	22	62	$ 236,870,000	$ 361,230,000
Columbiana	107,841	$ 2,277,996	26	63	22	8	2	3	$ 67,550,000	$ 105,060,000
Coshocton	36,901	$ 1,322,188	9	69	73	39	30	81	$ 167,820,000	$ 242,940,000
Gallia	30,934	$ 1,185,928	5	23	9	2	1	5	$ 43,060,000	$ 82,340,000
Guernsey	40,087	$ 1,775,911	38	140	41	15	7	27	$ 299,980,000	$ 265,770,000
Harrison	15,864	$ 649,649	14	61	16	4	2	0	$ 62,210,000	$ 44,760,000
Highland	43,589	$ 1,102,474	10	20	7	3	0	0	$ 24,920,000	$ 25,350,000
Hocking	29,380	$ 1,441,311	91	121	45	13	6	10	$ 95,880,000	$ 125,170,000
Holmes	42,366	$ 1,066,689	21	35	11	3	0	0	$ 64,600,000	$ 44,420,000
Jackson	33,225	$ 866,659	10	47	11	1	0	0	$ 65,000,000	$ 88,490,000
Jefferson	69,709	$ 1,710,340	28	153	74	21	5	2	$ 58,460,000	$ 97,500,000
Lawrence	62,450	$ 2,123,631	3	68	62	42	32	287	$ 127,390,000	$ 308,560,000
Mahoning*	238,823	$ 680,989	89	46	20	17	4	39	N/A	$ 17,951,013
Meigs	23,770	$ 836,887	1	23	22	8	5	4	$ 34,880,000	$ 65,520,000
Monroe	14,642	$ 447,990	0	3	0	0	0	0	$ 22,340,000	$ 22,990,000
Morgan	15,054	$ 706,463	14	19	8	4	4	5	$ 15,760,000	$ 31,170,000
Muskingum	86,074	$ 2,836,667	50	137	108	58	46	135	$ 192,490,000	$ 309,180,000
Noble	14,645	$ 543,754	2	22	10	3	0	1	$ 38,060,000	$ 38,140,000
Perry	36,058	$ 999,528	31	70	20	6	1	1	$ 66,990,000	$ 59,610,000
Pike	28,709	$ 1,269,590	14	71	32	10	1	9	$ 105,850,000	$ 109,830,000
Ross	78,064	$ 2,160,166	74	184	94	39	21	36	$ 81,710,000	$ 137,990,000
Scioto	79,499	$ 2,235,436	36	190	118	42	15	40	$ 162,570,000	$ 210,770,000
Trumbull	210,312	$ 4,827,376	211	346	174	74	38	43	$ 296,600,000	$ 445,240,000
Tuscarawas	92,582	$ 3,440,893	267	489	225	80	44	76	$ 396,730,000	$ 542,600,000
Vinton	13,435	$ 525,275	2	21	11	3	2	1	$ 23,360,000	$ 38,190,000
Washington	61,778	$ 2,286,270	22	51	38	28	21	53	$ 96,540,000	$ 215,390,000

** The figures provided for the specific county was a result of a HAZUS level 2 run done in collaboration with the US Army Corp of Engineers*

Table 2.2.g

Table 2.2f Estimate of Potential Losses from Flooding in the 25-Year Event Region 1*										
County	2010 Population	Building Exposure Value (thousands)	1-10% Damage Count	11-20% Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	>50% Damage Count	Estimated Business Interrupt	Estimated Building Loss
Allen	106,331	$ 2,854,063	140	114	29	13	7	2	$ 111,210,000	$ 92,100,000
Auglaize	45,949	$ 1,234,816	67	61	23	12	4	5	$ 250,000	$ 57,080,000
Champaign	40,097	$ 947,343	61	17	0	0	0	0	$ 40,000	$ 20,030,000
Clark	138,333	$ 2,757,199	144	109	17	4	3	7	$ 196,720,000	$ 123,160,000
Crawford	43,784	$ 660,181	7	8	2	0	0	0	$ 9,980,000	$ 9,760,000
Darke	52,959	$ 1,168,586	30	10	1	1	0	2	$ 29,960,000	$ 40,440,000
Defiance	39,037	$ 1,207,280	10	15	9	3	1	3	$ 34,220,000	$ 37,320,000
Erie	77,079	$ 2,926,531	129	135	30	20	3	8	$ 144,610,000	$ 93,310,000
Fulton	42,698	$ 662,743	14	14	2	0	0	0	$ 18,510,000	$ 16,320,000
Hancock	74,782	$ 1,785,086	121	61	9	4	0	1	$ 84,640,000	$ 81,020,000
Hardin	32,058	$ 668,841	12	17	6	1	2	6	$ 17,950,000	$ 20,850,000
Henry	28,215	$ 1,018,557	29	12	2	0	0	0	$ 16,840,000	$ 19,000,000
Huron	59,626	$ 1,498,457	61	55	5	0	0	0	$ 22,870,000	$ 30,630,000
Logan	45,858	$ 1,245,991	70	48	4	2	1	1	$ 20,710,000	$ 24,440,000
Lucas	441,815	$ 9,314,928	519	395	96	60	26	87	$ 381,250,000	$ 465,690,000
Marion	66,501	$ 1,138,768	69	59	5	0	0	0	$ 33,910,000	$ 30,380,000
Mercer	40,814	$ 935,039	20	16	3	1	1	0	$ 17,090,000	$ 19,740,000
Miami	102,506	$ 2,971,411	427	420	138	48	23	8	$ 227,060,000	$ 231,300,000
Ottawa	41,428	$ 1,524,829	45	17	0	0	0	0	$ 21,380,000	$ 13,950,000
Paulding	19,614	$ 715,293	14	8	1	1	0	0	$ 8,370,000	$ 15,180,000
Preble	42,270	$ 1,474,208	60	66	12	4	0	1	$ 44,040,000	$ 74,350,000
Putnam	34,499	$ 1,124,245	36	49	8	1	0	0	$ 25,250,000	$ 33,240,000
Sandusky	60,944	$ 1,436,449	23	11	1	0	0	0	$ 12,990,000	$ 17,790,000
Seneca	56,745	$ 1,341,176	79	76	16	5	1	4	$ 46,560,000	$ 55,280,000
Shelby	49,423	$ 983,159	23	49	18	8	3	2	$ 19,970,000	$ 38,370,000
Van Wert	28,744	$ 680,518	36	31	7	4	2	0	$ 37,390,000	$ 26,870,000
Williams	37,642	$ 1,131,286	11	22	9	3	0	0	$ 20,980,000	$ 25,270,000
Wood	125,488	$ 4,465,175	532	169	27	9	0	0	$ 1,190,000	$ 109,970,000
Wyandot	22,615	$ 651,674	18	26	3	2	0	0	$ 21,750,000	$ 18,510,000

Table 2.2.h

Table 2.2g Estimate of Potential Losses from Flooding in the 25-Year Event Region 2*										
County	2010 Population	Building Exposure Value (thousands)	1-10% Damage Count	11-20% Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	>50% Damage Count	Estimated Business Interrupt	Estimated Building Loss
Ashland*	53,139	$ 676,389	184	45	23	21	14	82	N/A	$ 17,946,325
Butler*	368,130	$ 752,889	1028	271	90	23	1	23	N/A	$ 65,543,481
Clinton	42,040	$ 1,194,907	10	23	17	9	5	3	$ 26,000,000	$ 38,490,000
Cuyahoga*	1,280,122	$ 3,934,170	422	253	107	58	21	43	N/A	$ 177,713,853
Delaware	174,214	$ 1,519,539	163	90	159	124	29	88	N/A	$ 125,570,218
Fairfield*	146,156	$ 1,177,309	526	293	165	106	90	136	N/A	$ 68,453,798
Fayette	29,030	$ 890,747	27	41	3	0	0	0	$ 19,990,000	$ 25,950,000
Franklin*	1,163,414	$ 4,144,131	1048	330	140	56	18	27	N/A	$ 65,380,387
Geauga*	93,389	$ 428,036	94	70	30	16	14	26	N/A	$ 18,474,542
Greene*	161,573	$ 1,099,886	208	72	27	23	18	36	N/A	$ 40,788,723
Hamilton*	802,374	$ 3,963,959	396	449	275	268	175	601	N/A	$ 592,195,632
Knox	60,921	$ 2,193,096	115	119	17	2	0	1	$ 238,890,000	$ 138,710,000
Lake*	230,041	$ 1,416,495	280	250	88	71	47	76	N/A	$ 59,442,599
Licking*	166,492	$ 1,521,162	731	356	173	76	36	92	N/A	$ 87,496,547
Lorain	301,356	$ 10,061,999	368	205	32	12	5	10	$ 451,210,000	$ 277,700,000
Madison	43,435	$ 1,335,970	46	39	5	0	0	0	$ 25,310,000	$ 23,660,000
Medina*	172,332	$ 713,878	238	160	142	43	24	63	N/A	$ 57,245,360
Montgomery*	535,153	$ 1,646,665	769	391	156	61	36	126	N/A	$ 157,825,299
Morrow	34,827	$ 920,900	10	10	0	0	0	0	$ 11,740,000	$ 9,990,000
Pickaway*	55,698	$ 1,182,662	57	17	8	6	3	9	N/A	$ 10,435,412
Portage*	161,419	$ 1,196,404	217	109	38	25	22	38	N/A	$ 21,273,296
Richland*	124,475	$ 466,770	231	119	62	25	23	61	N/A	$ 23,097,903
Stark*	375,586	$ 1,399,265	612	253	136	87	58	127	N/A	$ 91,000,581
Summit*	541,781	$ 1,933,070	595	192	100	36	30	79	N/A	$ 57,907,010
Union	52,300	$ 1,539,110	51	54	5	2	0	0	$ 110,000	$ 32,130,000
Warren*	212,693	$ 168,782	168	152	119	107	84	143	N/A	$ 25,556,553
Wayne*	114,520	$ 564,231	168	35	19	22	14	22	N/A	$ 12,835,621

** The figures provided for the specific county was a result of a HAZUS level 2 run done in collaboration with the US Army Corp of Engineers*

Table 2.2.i

Table 2.2h Estimate of Potential Losses from Flooding in the 25-Year Event Region 3										
County	2010 Population	Building Exposure Value (thousands)	1-10% Damage Count	11-20% Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	>50% Damage Count	Estimated Business Interrupt	Estimated Building Loss
Adams	28,550	$ 806,742	3	13	6	5	3	14	$ 22,260,000	$ 41,910,000
Ashtabula*	101,497	$ 95,107,200	154	87	48	42	33	170	N/A	$ 42,246,950
Athens	64,757	$ 2,970,685	125	357	175	79	32	42	$ 506,850,000	$ 690,570,000
Belmont	70,400	$ 1,641,711	49	116	70	29	14	17	$ 86,970,000	$ 107,760,000
Brown	44,846	$ 1,244,527	9	23	14	7	3	6	$ 24,350,000	$ 42,760,000
Carroll	28,836	$ 1,086,010	63	114	38	9	2	2	$ 82,760,000	$ 55,760,000
Clermont	197,363	$ 3,738,842	6	35	29	19	13	24	$ 180,520,000	$ 256,070,000
Columbiana	107,841	$ 2,019,902	26	50	13	3	1	1	$ 52,930,000	$ 76,820,000
Coshocton	36,901	$ 1,240,157	25	97	64	32	19	56	$ 152,680,000	$ 204,830,000
Gallia	30,934	$ 1,096,469	9	26	6	0	0	6	$ 34,480,000	$ 62,330,000
Guernsey	40,087	$ 1,446,710	31	95	26	7	7	20	$ 225,380,000	$ 163,920,000
Harrison	15,864	$ 567,174	15	40	9	2	0	0	$ 53,950,000	$ 33,040,000
Highland	43,589	$ 1,046,063	11	19	6	2	0	0	$ 21,180,000	$ 20,590,000
Hocking	29,380	$ 1,459,252	57	138	46	12	5	4	$ 100,380,000	$ 137,860,000
Holmes	42,366	$ 977,093	12	15	1	0	0	0	$ 50,610,000	$ 25,440,000
Jackson	33,225	$ 812,675	4	31	5	0	0	0	$ 62,450,000	$ 78,220,000
Jefferson	69,709	$ 1,665,524	25	151	54	124	4	3	$ 48,950,000	$ 81,560,000
Lawrence	62,450	$ 2,022,620	11	89	64	32	39	228	$ 112,640,000	$ 276,560,000
Mahoning*	238,823	$ 680,989	94	37	19	7	3	22	N/A	$ 12,850,170
Meigs	23,770	$ 745,723	4	24	18	8	2	1	$ 22,020,000	$ 45,340,000
Monroe	14,642	$ 386,960	0	2	2	0	0	0	$ 18,680,000	$ 19,150,000
Morgan	15,054	$ 668,989	9	12	5	4	0	4	$ 13,700,000	$ 25,800,000
Muskingum	86,074	$ 2,555,694	34	125	84	43	25	80	$ 149,160,000	$ 212,790,000
Noble	14,645	$ 546,848	2	24	7	2	0	0	$ 39,150,000	$ 34,800,000
Perry	36,058	$ 995,375	33	65	25	4	2	0	$ 62,050,000	$ 56,240,000
Pike	28,709	$ 992,569	8	39	9	3	0	0	$ 47,200,000	$ 50,540,000
Ross	78,064	$ 1,881,596	70	135	47	23	10	16	$ 75,070,000	$ 102,110,000
Scioto	79,499	$ 2,112,517	40	204	84	21	10	23	$ 119,590,000	$ 175,340,000
Trumbull	210,312	$ 4,577,649	170	274	123	51	25	21	$ 255,790,000	$ 360,200,000
Tuscarawas	92,582	$ 3,125,095	180	417	146	46	30	49	$ 319,120,000	$ 409,460,000
Vinton	13,435	$ 563,827	4	23	6	3	0	0	$ 22,180,000	$ 29,540,000
Washington	61,778	$ 2,143,932	12	42	41	27	16	22	$ 95,080,000	$ 172,360,000

** The figures provided for the specific county was a result of a HAZUS level 2 run done in collaboration with the US Army Corp of Engineers*

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

The estimates for losses to state-owned and state-leased critical facilities were developed using the DAS-maintained databases. The structures deemed critical facilities in Appendix C, were intersected with the 1-percent annual chance floodplain. Because first-floor elevations have not been collected for these structures, estimated damages cannot be calculated via depth/damage curves. Instead, an exposure analysis was used to determine the number of critical facilities in the floodplain and the value of these structures. For State-owned critical facilities, the full value of building and contents were assessed. For State-leased critical facilities, only the content value was assessed. A project being implemented by DAS in 2019-2022 will collect lowest floor data for all state-owned structures, which will enable a more accurate vulnerability analysis in the next plan update. Table 2.2.j lists the number and value of critical facilities in the floodplain by county.

RESULTS

In Region 1, there are 366 critical facilities within the 100-year floodplain with a total owned/leased value of $326,276,310.

- 165 of these facilities were in Ottawa County valued at $87,812,602.
  - 52 of these 165 are owned or leased by the Ohio Adjutant General's Department with a total value of $57,636,943.
  - 98 of these 165 are owned or leased by the Ohio Department of Natural Resources with a total value of $28,553,259.
- Erie County, however, had a larger value of critical facilities in the floodplain at $154,276,447 with only 39 critical facilities.
  - 21 of these 39 critical facilities are owned/leased by the Ohio Department of Veteran Services with a total value of $147,257,900.
  - 16 of these 39 critical facilities are owned/leased by the Ohio Department of Natural Resources with a total value of $3,752,121.

In Region 2, there are 159 critical facilities within the 100-year floodplain with a total owned/leased value of $365,023,256.

- The vast majority of critical facilities in the floodplain were in Franklin County at 56 facilities worth $300,571,406.
  - 2 of these 56 are owned or leased by the Capitol Square Review Board with a total value of $190,242,623.
  - 13 of these 56 are owned or leased by the Ohio Department of Rehabilitation and Correction with a total value of $37,404,034.

In Region 3, there are 244 critical facilities within the 100-year floodplain with a total owned/leased value of $126,000,433.

- The majority of critical facilities in Region 3 are in Tuscarawas with 44 facilities worth $50,705,402.
  - 35 of these 44 structures are owned or leased by the Ohio Department of Transportation with a total value of $45,976,154.

Table 2.2.j

State-Owned and State-Leased Critical Facilities in 100-Year Floodplain								
Region 1			Region 2			Region 3		
County	Critical Facilities in Floodplain	Value of CF in Floodplain	County	Critical Facilities in Floodplain	Value of CF in Floodplain	County	Critical Facilities in Floodplain	Value of CF in Floodplain
Allen	6	$ 216,859	Butler	4	$ 678,145	Athens	23	$ 28,215,959
Auglaize	2	$ 1,100,630	Fairfield	9	$ 1,011,336	Belmont	9	$ 907,461
Champaign	19	$ 498,450	Fayette	1	$ 392,391	Brown	1	$ 910,920
Clark	7	$ 1,172,191	Franklin	56	$ 300,571,406	Clermont	12	$ 1,346,611
Defiance	5	$ 176,750	Greene	4	$ 995,000	Coshocton	1	$ 1,250,000
Erie	39	$ 151,849,185	Knox	2	$ 58,750	Gallia	5	$ 927,908
Fulton	4	$ 407,208	Licking	12	$ 9,843,704	Guernsey	4	$ 328,064
Hancock	1	$ 37,171	Lorain	2	$ 691,715	Harrison	7	$ 966,956
Huron	2	$ 817,929	Medina	3	$ 131,288	Highland	1	$ 39,235
Logan	3	$ 112,000	Montgomery	2	$ 56,558	Holmes	1	$ 14,832
Lucas	59	$ 52,802,770	Morrow	1	$ 25,000	Jackson	5	$ 2,631,673
Marion	3	$ 864,811	Pickaway	29	$ 18,986,141	Jefferson	4	$ 402,000
Ottawa	165	$ 87,812,602	Portage	1	$ 1,400,000	Meigs	4	$ 2,902,674
Putnam	1	$ 43,687	Richland	1	$ 206,250	Monroe	9	$ 683,055
Sandusky	7	$ 1,426,250	Summit	16	$ 5,640,781	Morgan	3	$ 152,797
Seneca	38	$ 26,155,953	Warren	16	$ 24,334,791	Muskingum	51	$ 2,779,869
Shelby	3	$ 53,600	**Total**	**159**	**$ 365,023,256**	Noble	8	$ 4,117,405
Williams	1	$ 572,714				Pike	7	$ 2,585,816
Wyandot	1	$ 155,550				Ross	23	$ 19,816,292
Total	**366**	**$ 326,276,310**				Scioto	4	$ 1,002,216
						Tuscarawas	44	$ 50,705,402
						Vinton	8	$ 342,675
						Washington	10	$ 2,970,613
						Total	**244**	**$ 126,000,433**

2.3 TORNADO

National Oceanic Atmospheric Association (NOAA) defines a tornado as a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground. Because wind is invisible, it is hard to see a tornado unless it forms a condensation funnel made up of water droplets, dust and debris. Tornadoes are the most violent of all atmospheric storms and the most hazardous when they occur in populated areas. Tornadoes can topple mobile homes, lift cars, snap trees, and turn objects into destructive missiles. Among the most unpredictable of weather phenomena, tornadoes can occur at any time of day, in any state in the union, and in any season. While the majority of tornadoes cause little or no damage, some are capable of tremendous destruction, reaching wind speeds of 200 mph or more.

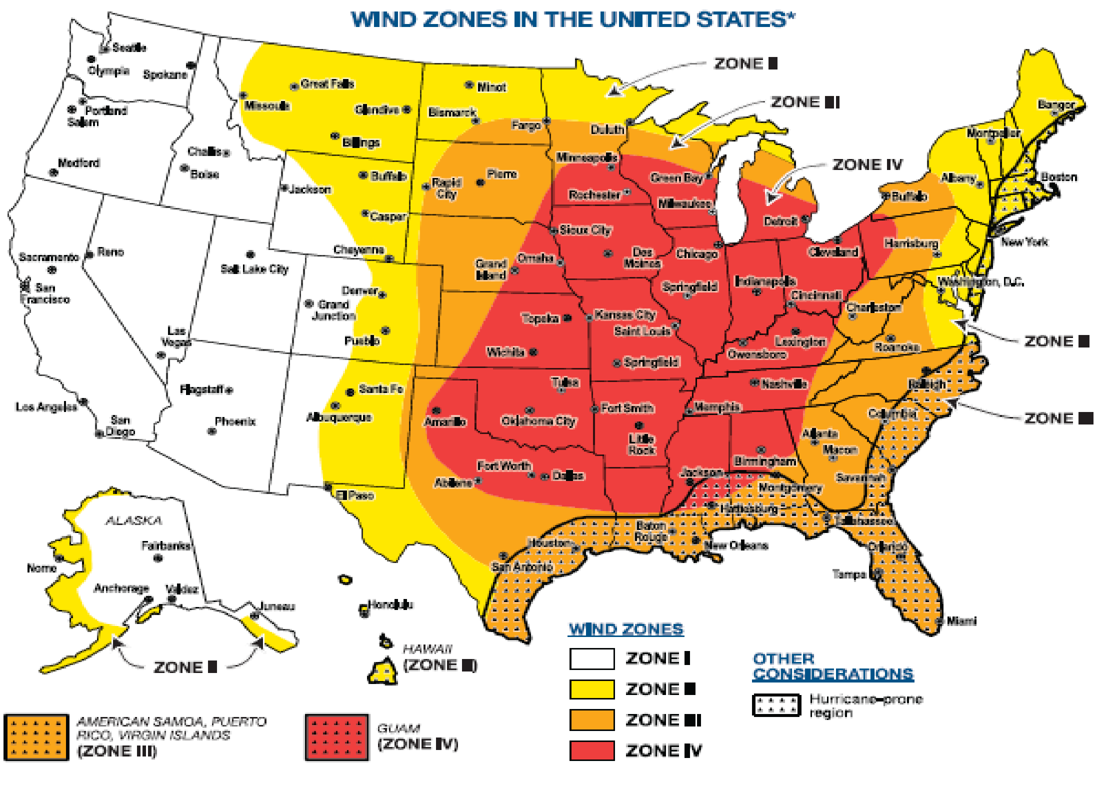


Figure 2-7: Wind Zones in the United States*

* If you are uncertain of your location because of the level of detail and size of the map, or if you live on or very near one of the delineation lines, use the highest adjacent wind zone.

Map 2.3.a

Tornadoes are non-spatial hazards; therefore, it is often difficult to profile tornadoes and determine the exact risk. However, estimations can be developed by analyzing historic occurrences and past declarations. While Ohio does not rank among the top states for the number of tornado events, it does rank within the top 20 states for fatalities, injuries, and dollar losses, indicating that it has a relatively high likelihood for damages resulting from tornadoes. Tornadoes are measured by damage scale based on their winds, with greater damage equating to greater wind speed. The original Fujita-scale (F-scale) was developed without considering a structure's integrity or condition as it relates to the wind speed necessary to damage it. The process of rating the damage was subjective with the original F-scale and arbitrary judgments were the norm. In order to reduce this subjectivity, the Enhanced F-scale (EF- scale) took effect February 1, 2007.

The Enhanced F-scale uses the original F-scale (i.e., F0-F5) and classifies tornado damage across 28 different types of damage indicators, which mostly involve building/structure type, and these are assessed at eight damage levels (1-8). Therefore, construction types and their strengths and weaknesses are incorporated into the EF classification given to a particular tornado. The most intense damage within the tornado path will generally determine the EF-scale given the tornado. Table 2.3.a. lists the classifications under the EF- and F-scale. It should be noted the wind speeds listed are estimates based on damage rather than measurements. Also, there are no plans by National Oceanic Atmospheric Administration or the National Weather Service to re- evaluate the historical tornado data using the Enhanced scale.

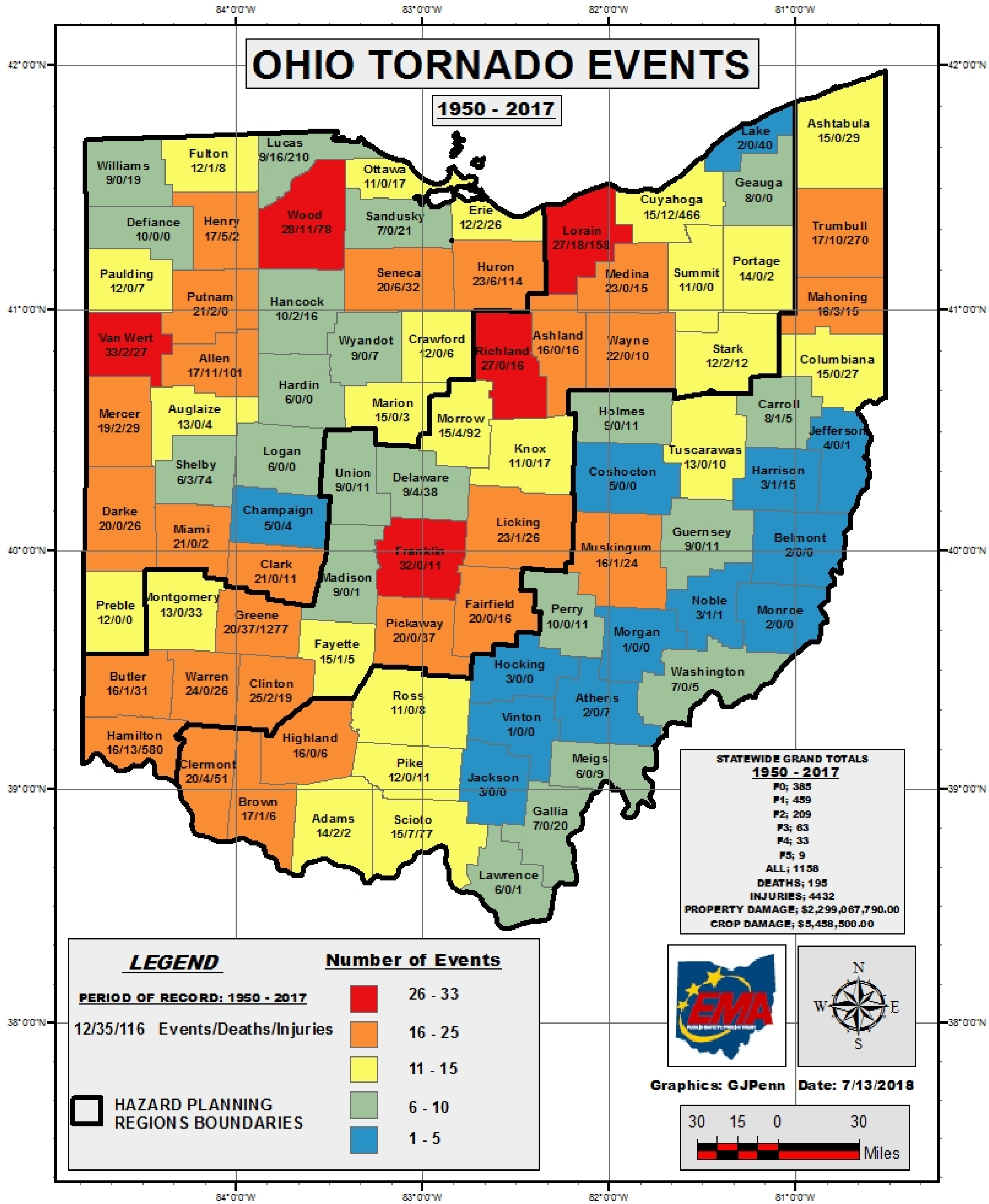
Fujita Scale 3-Second Gust (mph)		Damage Levels	Enhanced Fujita Scale 3-Second Gust (mph)	
F-0	45-78	Light - tree branches down	EF-0	65-85
F-1	79-117	Moderate - roof damage	EF-1	86-110
F-2	118-161	Considerable - houses damaged	EF-2	111-135
F-3	162-209	Severe - buildings damaged	EF-3	136-165
F-4	210-261	Devastating - structures leveled	EF-4	166-200
F-5	262-317	Incredible - whole towns destroyed	EF-5	Over 200

Table 2.3.a - Source*: http://www.spc.noaa.gov/faq/tornado/ef-scale.html*

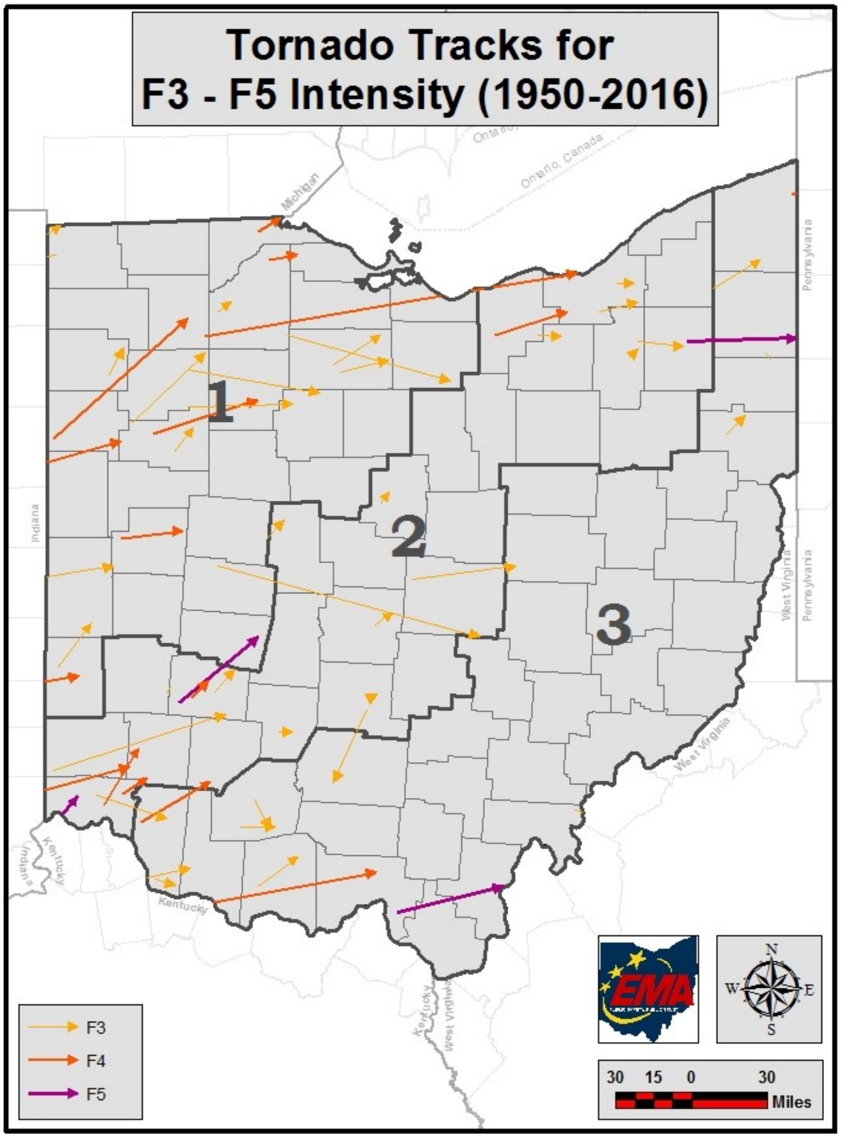
RISK ASSESSMENT

LOCATION

The wind zones in the United States map (Map 2.3.a) indicate that the entire state falls within the 250 mile per hour zone, but the frequency in which tornados occurs varies greatly depending on which county you are located. Ohio has a significant history of past tornado events. Map 2.3.b depicts the touchdowns of 1158 tornadoes that struck the State between 1950 and 2017. The counties in red have the greatest number of tornadoes touchdowns in that time period. In order, those counties are: Van Wert (33), Franklin (32), Wood (28), Lorain (27) and Richland (27). When looking at a regional perspective Region 1 (416) and Region 2 (454) have had significantly more tornados than Region 3 (288). Much of the variance in the number of tornados between Region 1 and 2, and Region 3 is due to the topography of Region 3.



Map 2.3.b – Source - NOAA Storm Database



Map 2.3.c indicates the tracks of the F 3 or greater tornados that have occurred in the state from 1950-2016. The tracks of these high intensity tornadoes are generally spread throughout the state with the exception of the southern and eastern portions of Region 3. The highest intensity, or F5 tornados tracks, are indicated in purple and have occurred in all of the regions in the state. Only one F5 tornado has occurred in Region 1, even though a large number of F 3 and F4 tornados occurred within that Region.

Map 2.3.c – Source - NOAA Storm Database

LHMP DATA

CLERMONT COUNTY

There were two events in 2012 that caused significant damages. The first was on March 2, 2012, and this tornado was categorized as an EF3. The Village of Moscow, parts of Franklin, Washington, & Tate Townships were all in the direct path, resulting in 353 structures damaged and 18 residential structures destroyed causing roughly $3,700,000 in damages with three lives lost and 13 injured. The second tornado event occurred on September 8, 2012. The Village of Moscow was hit the hardest with two homes destroyed. The location, frequency and impacts of tornadoes cannot be accurately predicted. However, an analysis of historic events can provide a reasonable understanding of expected future risks. Clermont County has had 18 tornadoes in 16 unique years since 1953, and they have sustained total losses of approximately $11.5 million. The annual chance of occurrence for a tornado is 23%. The annualized risk is approximately $190,883 with one injury and 3% chance of life loss.

GREENE COUNTY

Although tornadoes can occur throughout the state, the City of Xenia appears to be especially tornado-prone. According to the Greene County LHMP, "Nineteen tornadoes were reported in Greene County, Ohio since 1884. These tornadoes caused 43 deaths, 1,377 injuries and over $1 billion dollars of damage. Xenia was the location of seven tornadoes, responsible for the majority of the fatalities and caused the highest amount of damage." Greene County considers tornadoes major hazards with the potential of high damage, personal injury, and loss of life. They have conducted a number of studies involving tornadoes and have incorporated those studies into their LHMP.

CUYAHOGA COUNTY

The Cuyahoga County All-Hazards Mitigation Plan provides a comprehensive history of the tornado events that have occurred within Cuyahoga County from 1951-2015 including a tornado track map. According to the Cuyahoga County LHMP, fifteen tornadoes were reported in between 1951 and 2015. These tornadoes caused 12 deaths, 466 injuries and over 68 million dollars of damage. The Cuyahoga County LHMP states, while all County assets are considered at risk from this hazard, a particular tornado would only cause damages along its specific track. A high-magnitude tornado sweeping through densely populated portions of the County would have extensive injuries, deaths, and economic losses. There is no way to be sure how many people would be injured or killed due to the difference that time of day and year can make, but property values can provide an estimate of economic losses.

VAN WERT COUNTY

Per the 2014 Van Wert County LHMP, Van Wert County has the highest occurrences of tornados in the state. The most devastating event in recent history occurred on November 10, 2002, when a F4 tornado struck the City of Van Wert, killing 2 people and causing over $50 million dollars in damages and other economic losses. This event is ranked among the top 10 tornados to ever hit the northeastern United States. The Vulnerability Assessment in the Van Wert County LHMP provides the following estimates developed based on an EF 5 Tornado striking the heart Van Wert County, with a path 1-mile wide and 20-miles long. Using those assumptions, Van Wert County has a total exposure of 5,690 structures valued at $231,092,000.

PAST OCCURRENCES

XENIA – 1974

According to a Dayton Daily News article (April 2011), on April 3, 1974, an F-5 tornado tore through the heart of Xenia, killing 33 people and injuring more than 1,300 others. It bulldozed a path more than a half-mile wide, destroying or damaging more than 1,400 buildings, including 1,200 homes, dozens of businesses, 10 churches, and several schools. By the time it lifted into the sky near Cedarville, it left behind more than $100 million of damage in Greene County. The Xenia tornado was part of a super outbreak, when 148 twisters swept across several states, killing 335 people in a 16-hour period on April 3-4, 1974. It still ranks as one of the largest natural disasters in American history, with Xenia the hardest hit community.

The Xenia subdivision of "Arrowhead" was especially hard-hit, the tornado leaving it in ruins. The 4-year-old subdivision on the city's southwest side lost more than 300 homes, many on concrete slabs with no basements. Greene Memorial Hospital in northeast Xenia narrowly escaped the tornado's wrath, but lost its power and telephone service and its water quality was suspect. About 500 people were treated there in the first 24 hours, 34 of them being admitted with a number transferred to hospitals in nearby Dayton for treatment.

Photograph 2.3.a – Source - NWS

XENIA - 2000

Twenty-six years later another tornado (an F-4) struck at an unusual time – early autumn and after dark – on September 20, 2000. The tornado would follow an eerily familiar path of destruction through Xenia, killing one man and destroying or damaging more than 300 homes and 30 businesses.

Photograph 2.3.b – Source - Dayton Daily News

MAY TORNADO OUTBREAK - 1985

Per the NWS, on May 31, 1985, twenty-one tornadoes tracked across Northeast Ohio and Northwest Pennsylvania during that evening. Of these 21, one was rated an F5, and six were rated F4's. Tragically, these tornadoes killed 76 people in Ohio and Pennsylvania. In Ohio, this was the worst event since the April 3-4th, 1974 outbreak that killed 37 in Xenia.

The strongest of the tornadoes touched down at the Ravenna Arsenal in eastern Portage County around 6:35 p.m. The tornado intensified to an F5 as it tracked east across southern Trumbull County, devastating the communities of Newton Falls and Niles. Nine people were killed in the business district of Niles.

Photograph 2.3.c – Source - NWS

Photograph 2.3.d – Source - NWS

The residents of Ohio will long remember May 31, 1985. Rarely has such an outbreak of tornadoes been seen in this county and never before in this area. This day serves as a reminder that devastating tornadoes can occur in any month of the year at any time of the day and at any location in the country.

BLUE ASH TORNADO - 1999

Another notable tornado occurred in April 1999 in the counties of Clinton, Hamilton, and Warren. The tornadoes killed four people, injured 42, and damaged or destroyed 400 structures, causing about $82 million in losses (Ohio EMA 16). A lone supercell thunderstorm produced this F4 tornado, with winds between 207 and 260 mph.

Photograph 2.3.e – Source - Cincinnati Enquirer

DR-1444 - 2002 & DR-1484 - 2003

In more recent years, there have been two disaster declarations: DR-1444, which was for tornado-related damage, and DR-1484, which covered tornado and flood related damage. DR-1444 was in November 2002 and affected several counties throughout the state. Many of the residents of the impacted counties were left homeless or were trapped in debris, damage to commercial structures created localized unemployment, hundreds of injuries were reported, and multiple lives were lost.

Photograph 2.3.F – Source - OSHP

DR-1484 occurred in August 2003 and was the most recent declaration that included tornadic damage. The tornado was confirmed as an F-1 and affected part of the City of Youngstown and parts of the unincorporated areas of the County. The tornado was 50-100 yards wide and eight miles long. Sixty homes received major damage and 20 received minor damage. The estimated loss from this tornado was $900,000 and approximately 33% of the structures were insured.

2010 TORNADOS

The first event occurred in June 5 - 6, when a major tornado outbreak affected the Midwestern United States and Great Lakes Region. At least 46 tornadoes were confirmed from Iowa to southern Ontario and Ohio as well as northern New England. Tornadoes moved through northern Ohio affecting Fulton, Lucas, Wood, Ottawa, Richland, Holmes and Tuscarawas Counties. While all counties sustained heavy structural damage, the event resulted in seven people dead in Wood County. The Governor of Ohio issued an Emergency Proclamation for the event and requested a Presidential Declaration for the area, however, none was granted. Regardless, tornadoes ranged from EF-0 northeast of Lucas, Ohio in Richland County, to an EF-4 tornado that resulted in 78 homes with major damage and 97 with minor damage. The total residential loss was approximately $7,545,300. Thirty-two businesses had major damage and three had minor damage resulting in $4,661,000 in losses. The Counties experienced a total of $1,263,858 in infrastructure damage.

The second event occurred when severe weather and tornadoes swept across the state in the afternoon of September 16th. The National Weather Service confirmed 11 tornadoes in Wayne, Holmes, Fairfield, Athens, Perry, Meigs, Delaware and Tuscarawas Counties. The tornadoes ranged from EF-0 to EF-3, and Athens, Meigs, Pickaway, Perry and Wayne Counties declared a local state of emergency. Thirteen people were injured in Athens County, while six were injured in Meigs County. State and county teams assessed the damaged structures to be 62 destroyed, 77 with major damage, 113 with minor damage and 373 structures as affected. Residential loss equated to 2,227 claims amounting in $11,400,000, while business losses included 287 claims amounting in $4,700,000.

MOSCOW TORNADO - 2012

In March 2012, Brown and Clermont Counties experienced a devastating EF-3 tornado that came up from Kentucky and into Ohio. Thunderstorms developed during the afternoon in a high wind shear environment ahead of a strengthening low-pressure system. Many of these storms became severe, with large hail, damaging thunderstorm winds, and tornadoes all being the main threats. The tornado traveled seven miles in the Kentucky counties of Campbell and Pendleton. The tornado then moved into Clermont County, Ohio at 4:46 pm, where it hit the town of Moscow. It continued on the ground across Clermont County, crossing into Brown County around 4:58 pm. It then lifted south of Hamersville in western Brown County. This tornado caused extensive damage to structures and trees along its entire path on both sides of the Ohio River. Numerous homes were very heavily damaged or destroyed. Many homes lost their roofs, having complete exterior wall failure. Some modular homes were completely removed from their foundations, lifted, and thrown in excess of 100 yards where they were destroyed. The damage in Ohio from this tornado was consistent with maximum winds estimated at 160 miles per hour in Clermont County, and 100 miles per hour in Brown County. Clermont County experienced three deaths from the tornado. One fatality occurred in Moscow in Clermont County, while two others occurred in Bethel. Thirteen injuries were reported resulting from this storm. Property damage was estimated at $5,660,000.

Photograph 2.3.g – Source - OEMA

As this same system moved into Adams County, it caused an additional fatality. A tornado touched down just east of Highway 41, about 2 miles northeast of West Union. The tornado then traveled northeast for just over 11 miles, destroying at least 5 mobile homes and damaging two other houses. One of these homes was built of brick. A 99-year-old woman was in her mobile home in Tiffin Township when the tornado struck. She was injured from this tornado and passed away several days later. Two other people were also injured from this tornado. A dozen cattle were killed and major power transmission poles were knocked over. Numerous trees were snapped or uprooted. Based on the damage surveyed, the maximum estimated wind speed of this tornado was 125 miles per hour and caused an estimated $2 million in damage. The path of the tornado continued east into Pike and Scioto Counties causing an additional estimated $230,000 in damage, but no other fatalities or injuries were reported.

CEDARVILLE TORNADO - 2014

A narrow but intense tornado ripped through Greene County on May 14, 2014, while sparing the nearby town of Cedarville. The NWS in Wilmington confirmed an EF3 tornado hit the area, packing winds as high as 145 mph. Cedarville is nine miles northeast of Xenia, the site of a massive F5 tornado that killed dozens during the Super outbreak of April 4, 1974. The NWS says two people were injured and several homes were hit by the tornado. This includes completely destroying two homes and causing over $500,000 in damage.

Photograph 2.3.h - Source - NWS

PROBABILITY OF FUTURE EVENTS

Between 1950- 2017, Ohio has experienced 1,158 tornadoes, an average of 17.28 tornadoes annually. The majority of tornados that have occurred in the state have been between an EF-0 and EF-2 (90.1%). Table 2.3.b give a breakdown of the various EF tornado events that have occurred in the state from 1950-2017.

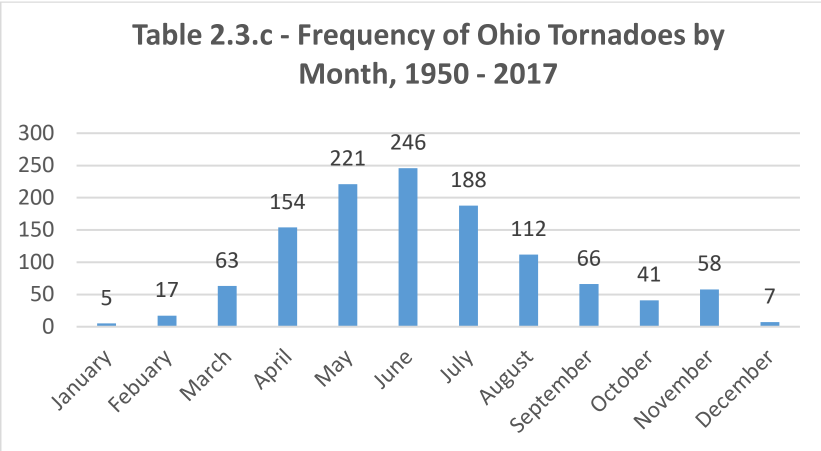
Probability of Future Tornado Events							
Year	**F0**	**F1**	**F2**	**F3**	**F4**	**F5**	**Total**
1951	0	1	2	0	0	0	**3**
1952	0	2	0	0	0	0	**2**
1953	0	1	1	0	6	0	**8**
1954	5	5	2	0	0	0	**12**
1955	0	2	2	2	0	0	**6**
1956	1	2	5	2	0	0	**10**
1957	0	1	3	0	0	0	**4**
1958	0	5	6	0	0	0	**11**
1959	5	2	2	1	0	0	**10**
1960	1	4	2	0	0	0	**7**
1961	4	6	4	3	1	0	**18**
1962	0	1	2	0	0	0	**3**
1963	2	8	6	0	0	0	**16**
1964	0	2	4	0	0	0	**6**
1965	2	14	12	3	8	0	**39**
1966	0	1	1	1	0	0	**3**
1967	0	3	3	0	0	0	**6**
1968	1	7	4	0	5	3	**20**
1969	1	11	1	8	0	0	**21**

1970	3	7	9	1	0	0	**20**
1971	1	3	7	4	0	0	**15**
1972	1	7	2	0	0	0	**10**
1973	17	17	11	10	0	0	**55**
1974	3	11	4	2	2	3	**25**
1975	2	6	4	0	0	0	**12**
1976	7	3	2	0	0	0	**12**
1977	5	15	3	1	0	0	**24**
1978	4	15	2	1	0	0	**22**
1979	1	2	1	0	0	0	**4**
1980	1	30	6	0	0	0	**37**
1981	6	14	6	1	0	0	**27**
1982	0	7	3	0	0	0	**10**
1983	0	6	2	2	0	0	**10**
1984	0	2	0	0	0	0	**2**
1985	2	11	5	4	2	3	**27**
1986	3	13	11	0	0	0	**27**
1987	2	3	1	0	0	0	**6**
1988	0	0	0	0	0	0	**0**
1989	4	11	4	0	0	0	**19**
1990	13	8	7	0	4	0	**32**
1991	6	2	0	1	0	0	**9**
1992	26	20	12	4	1	0	**63**
1993	2	3	0	0	0	0	**5**
1994	4	5	0	0	0	0	**9**
1995	1	2	0	0	0	0	**3**
1996	6	4	0	0	0	0	**10**
1997	7	6	1	1	0	0	**15**
1998	17	6	3	0	0	0	**26**
1999	10	9	1	1	1	0	**22**
2000	9	10	7	0	1	0	**27**
2001	4	2	2	1	0	0	**9**
2002	8	12	8	5	1	0	**34**
2003	7	4	2	0	0	0	**13**
2004	4	5	0	0	0	0	**9**
2005	2	2	0	0	0	0	**4**
2006	22	11	4	0	0	0	**37**
2007	8	5	0	0	0	0	**13**
2008	12	2	1	0	0	0	**15**
2009	10	3	0	0	0	0	**13**
2010	20	23	5	2	1	0	**51**
2011	24	14	2	0	0	0	**40**
2012	11	2	1	1	0	0	**15**

2013	20	14	3	0	0	0	**37**
2014	16	4	0	1	0	0	**21**
2015	5	2	0	0	0	0	**7**
2016	14	7	3	0	0	0	**24**
2017	13	11	2	0	0	0	**26**
Total	**385**	**459**	**209**	**63**	**33**	**9**	**1158**

Table 2.3.b - Source - NOAA Storm Database

Considering more tornadoes have formed in June than any other month, there is approximately a 20.8 percent chance of a tornado on any day in June. The likelihood of a tornado is lower during the winter and higher during the summer, as indicated in Graph 2.3.a.



Graph 2.3.a – Source NOAA Storm Database

Every County in the state of Ohio has experienced at least one tornado from 1950-2017, and six counties have each recorded at least 25 tornadoes (see table 2.3.d). Van Wert and Franklin Counties have had the most tornados with 33 and 32 respectively. Note that prior to 1900 tornados were not documented and rarely reported.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHODOLOGY

The tables shown in this section were compiled using historic data from the NWS, and NOAA's National Centers for Environmental Information Storm Event Database. For each county in the State, information on tornadoes was entered in a spreadsheet using a time period of January 1, 1950, through December 31, 2017. Calculations were performed to obtain the following information: average damage amounts per tornado, annual probability, and estimated future annual losses.

The following are definitions of the terms used in the tables in this section:

- Total Damages = Cumulative sum of all reported damages associated with all tornadoes occurring in the 67 year period from January 1, 1950, to December 31, 2017 (reported damages obtained from the Storm Events Database)
- Average Damage per Tornado = Total damages divided by the number of tornadoes
- Estimated Annual Tornadoes = Number of tornadoes divided by the number of reporting years (67)
- Estimated Future Annual Losses = Average Damage per Tornado x Estimated Annual Tornadoes

Damage calculations include all reported property and crop damage as well as injuries and deaths sustained as a result of the tornadic event. Injury and death values were calculated as follows:

1. Injury was assigned a value based on the December 2011 FEMA Benefit-Cost Analysis Re-engineering (BCAR) Development of Standard Economic Values report, which incorporates research completed on behalf of the Department of Homeland Security in 2008. The values can be thought of as the "willingness-to-pay" (WTP) to avoid an injury.

The report recommends using 1997 values and adjusting for inflation using the US Bureau of Labor Statistics (BLS) Consumer Price Index (CPI) Inflation Calculator. These are the adjusted 2017 values:

Minor - $14,000
Moderate - $109,000
Serious - $406,000
Severe - $1,325,000
Critical - $5,391,000

2. Since the NWS does not differentiate between injury categories in their data, a combined injury value was calculated. 3.6 percent of tornadoes in the state are EF-4 to EF-5 (violent). About 23.5 percent are EF-2 to EF-3 (strong), and 72.8 percent are EF-0 to EF-1 (weak). That means that the types of injuries suffered will overwhelmingly be those types most likely to occur in weak tornadoes.

   According to FEMA's BCAR Tornado Safe Room Methodology Report (2009), on average, 5% of those injured will be hospitalized (injury categories Serious through Critical) in an EF-1 tornado and 10% in an EF-2. Therefore, the Serious through Critical injury WTP values were averaged and weighted as 10% of the total. The Minor and Moderate injury (non-hospitalization categories) WTP values were averaged and weighted as 90% of the total. The total was then rounded to the nearest thousand.

   {[($14,000 + $109,000)/2] x .9} +
   {[($406,000 + $1,325,000 + $5,391,000)/3] x .1} = $292,750

3. The CPI 2015 adjusted value of a statistical life is $7.07 million.

These calculations were done for each county to arrive at the future annual probability of a tornado and estimated annual losses from tornado events. Table 2.3.d lists the counties in alphabetical order and highlights the top five counties in each category. The top county is in black, the next four in grey.

County	Total # of Tornados	Total Damages	Avg. Damage per Event	Estimated Annual Tornados	Est. Future Annual Losses	Region
Adams	14	$4,327,105	$309,079	0.21	$64,584	3
Allen	17	$24,334,255	$1,431,427	0.25	$363,198	1
Ashland	16	$11,349,327	$709,333	0.24	$169,393	2
Ashtabula	15	$20,952,867	$1,396,858	0.22	$312,729	3
Athens	2	$1,683,093	$841,546	0.03	$25,121	3
Auglaize	13	$7,172,782	$551,752	0.19	$107,056	1
Belmont	2	$114,500	$57,250	0.03	$1,709	3
Brown	17	$47,933,351	$2,819,609	0.25	$715,423	3
Butler	16	$157,021,006	$9,813,813	0.24	$2,343,597	2

Carroll	8	$1,491,625	$186,453	0.12	$22,263	3
Champaign	5	$2,866,932	$573,386	0.07	$42,790	1
Clark	21	$16,425,120	$782,149	0.31	$245,151	1
Clermont	20	$33,461,205	$1,673,060	0.30	$499,421	3
Clinton	25	$32,697,805	$1,307,912	0.37	$488,027	2
Columbiana	15	$74,652,331	$4,976,822	0.22	$1,114,214	3
Coshocton	5	$64,768,200	$12,953,640	0.07	$966,690	3
Crawford	12	$7,173,778	$597,815	0.18	$107,071	1
Cuyahoga	15	**$353,263,446**	$23,550,896	0.22	**$5,272,589**	2
Darke	20	$79,928,571	$3,996,429	0.30	$1,192,964	1
Defiance	10	$6,156,855	$615,686	0.15	$91,893	1
Delaware	9	$23,330,489	$2,592,277	0.13	$348,216	2
Erie	12	$6,776,978	$564,748	0.18	$101,149	1
Fairfield	20	$6,588,032	$329,402	0.30	$98,329	2
Fayette	15	$13,892,275	$926,152	0.22	$207,347	2
Franklin	**32**	$101,400,430	$3,168,763	**0.48**	$1,513,439	2
Fulton	12	$14,241,637	$1,186,803	0.18	$212,562	1
Gallia	7	$20,530,908	$2,932,987	0.10	$306,431	3
Geauga	8	$5,514,050	$689,256	0.12	$82,299	2
Greene	20	**$1,376,241,590**	**$68,812,079**	0.30	**$20,540,919**	2
Guernsey	9	$14,225,350	$1,580,594	0.13	$212,319	3
Hamilton	16	$293,041,197	$18,315,075	0.24	$4,373,749	2
Hancock	10	$46,967,448	$4,696,745	0.15	$701,007	1
Hardin	6	$1,294,050	$215,675	0.09	$19,314	1
Harrison	3	$2,077,930	$692,643	0.04	$31,014	3
Henry	17	$7,232,458	$425,439	0.25	$107,947	1
Highland	16	$8,020,573	$501,286	0.24	$119,710	3
Hocking	3	$116,165	$38,722	0.04	$1,734	3
Holmes	9	$12,127,975	$1,347,553	0.13	$181,015	3
Huron	23	$33,799,378	$1,469,538	0.34	$504,468	1
Jackson	3	$8,507,500	$2,835,833	0.04	$126,978	3
Jefferson	4	$2,486,820	$621,705	0.06	$37,117	3
Knox	11	$4,732,072	$430,188	0.16	$70,628	2
Lake	2	$1,951,567	$975,783	0.03	$29,128	2
Lawrence	6	$8,526,589	$1,421,098	0.09	$127,263	3
Licking	23	$76,313,779	$3,317,990	0.34	$1,139,012	2
Logan	6	$1,965,000	$327,500	0.09	$29,328	1
Lorain	**27**	$225,473,132	$8,350,857	**0.40**	$3,365,271	2
Lucas	9	$215,581,412	**$23,953,490**	0.13	$3,217,633	1
Madison	9	$14,624,520	$1,624,947	0.13	$218,276	2
Mahoning	16	$18,135,126	$1,133,445	0.24	$270,674	3
Marion	15	$4,659,811	$310,654	0.22	$69,549	1
Medina	23	$13,618,884	$592,125	0.34	$203,267	2

Meigs	6	$3,472,484	$578,747	0.09	$51,828	3
Mercer	19	$31,396,989	$1,652,473	0.28	$468,612	1
Miami	21	$11,655,246	$555,012	0.31	$173,959	1
Monroe	2	$1,788,750	$894,375	0.03	$26,698	3
Montgomery	13	$20,618,124	$1,586,010	0.19	$307,733	2
Morgan	1	$68,400	$68,400	0.01	$1,021	3
Morrow	15	$104,942,762	$6,996,184	0.22	$1,566,310	2
Muskingum	16	$21,649,573	$1,353,098	0.24	$323,128	3
Noble	3	$729,544	$243,181	0.04	$10,889	3
Ottawa	11	$63,939,460	$5,812,678	0.16	$954,320	1
Paulding	12	$5,193,593	$432,799	0.18	$77,516	1
Perry	10	$15,800,575	$1,580,057	0.15	$235,829	3
Pickaway	20	$18,824,010	$941,201	0.30	$280,955	2
Pike	12	$2,665,815	$222,151	0.18	$39,788	3
Portage	14	**$591,200,591**	**$42,228,614**	0.21	**$8,823,889**	2
Preble	12	$67,178,530	$5,598,211	0.18	$1,002,665	1
Putnam	21	$31,619,797	$1,505,705	0.31	$471,937	1
Richland	**27**	$23,032,052	$853,039	**0.40**	$343,762	2
Ross	11	$11,596,973	$1,054,270	0.16	$173,089	3
Sandusky	7	$108,672,854	$15,524,693	0.10	$1,621,983	1
Scioto	15	$26,951,836	$1,796,789	0.22	$402,266	3
Seneca	20	$44,069,859	$2,203,493	0.30	$657,759	1
Shelby	6	$23,286,876	$3,881,146	0.09	$347,565	1
Stark	12	$88,937,842	$7,411,487	0.18	$1,327,430	2
Summit	11	$92,890,210	$8,444,565	0.16	$1,386,421	2
Trumbull	17	**$1,198,682,122**	**$70,510,713**	0.25	**$17,890,778**	3
Tuscarawas	13	$14,948,159	$1,149,858	0.19	$223,107	3
Union	9	$2,235,309	$248,368	0.13	$33,363	2
Van Wert	**33**	$51,911,893	$1,573,088	**0.49**	$774,804	1
Vinton	1	$25,500	$25,500	0.01	$381	3
Warren	24	$93,912,531	$3,913,022	0.36	$1,401,680	2
Washington	7	$4,958,252	$708,322	0.10	$74,004	3
Wayne	22	$75,075,209	$3,412,510	0.33	$1,120,526	2
Williams	9	$68,787,593	$7,643,066	0.13	$1,026,680	1
Wood	28	$192,134,845	$6,861,959	**0.42**	$2,867,684	1
Wyandot	9	**$872,714,153**	**$96,968,239**	0.13	**$13,025,584**	1
State	**1158**	**$7,519,337,586**	**$6,044,992**	**0.20**	**$112,228,919**	

Table 2.3.d –Source: NWS, NOAA and OEMA. All dollar amount have been adjusted to 2018 dollars

There are 14 counties in the Ohio (out of 88) which have experienced over $100 million in tornado damages, as reported by the NWS. Table 2.3 lists those top 14 counties.

County	Total # of Tornados	Total Damages
Greene	20	$1,366,757,514
Trumbull	17	$1,196,447,155
Wyandot	9	$872,683,567
Portage	14	$591,191,852
Cuyahoga	15	$349,961,028
Hamilton	16	$289,135,143
Lorain	27	$222,883,361
Lucas	9	$212,975,476
Wood	28	$190,633,284
Butler	16	$156,780,032
Sandusky	7	$108,581,096
Morrow	15	$104,118,686
Franklin	32	$101,352,366

Table 2.3.e – Source: NWS, NOAA and OEMA. All dollar amount have been adjusted to 2018 dollars

There is a large difference between the areas of the state that may experience the greatest number of tornados versus where the costliest tornados occur. Table 2.3.f lists the counties in Ohio which have on average experienced the costliest tornado events. Nine counties have experienced average reported damages that exceed 10 million dollars per event.

County	Total # of Tornados	Avg. Damage per Event
Wyandot	9	$96,964,841
Trumbull	17	$70,379,244
Greene	20	$68,337,876
Portage	14	$42,227,989
Lucas	9	$23,663,942
Cuyahoga	15	$23,330,735
Hamilton	16	$18,070,946
Sandusky	7	$15,511,585
Coshocton	5	$12,953,640

Table 2.3.f –Source: NWS, NOAA and OEMA. All dollar amount have been adjusted to 2018 dollars

When we look at the regional perspective, Region 2 had sustained more losses, other than crop damage, than another other region. Region 2 also leads in every other category related damages and possible future losses. Region 3 has the least amount in every category including related damages and possible future losses per Table 2.3.g.

County	Property Damage	Crop Damage	Total Damages	Avg. Damage per Event	Estimated Annual Tornados	Est. Future Annual Losses
Region 1	$2,038,000,183	$168,220	$2,049,138,150	$6,617,648	0.214	$1,416,851
Region 2	$3,799,492,312	$290,620	$3,822,722,240	$8,205,254	0.251	$2,059,251
Region 3	$1,641,377,786	$61,710	$1,647,477,196	$3,703,301	0.132	$487,223

Table 2.3.g –Source: NWS, NOAA and OEMA. All dollar amount have been adjusted to 2018 dollars

NWS data was used to project the annual probability of death and injury at the county level. Table 2.3.h lists the counties in alphabetical order for estimated future death and injury losses from tornado events with dollar amounts determined using the methodology explained earlier in this section.

County	Deaths	Estimated Annual Deaths	Estimated Annual Lost Due to Death	Injuries	Estimated Annual Injuries	Estimated Annual Lost Due to Injuries
Adams	2	0.030	$211,045	2	0.030	$8,739
Allen	11	0.164	$1,160,746	101	1.507	$441,310
Ashland	0	0.000	$0	16	0.239	$69,910
Ashtabula	0	0.000	$0	29	0.433	$126,713
Athens	0	0.000	$0	7	0.104	$30,586
Auglaize	0	0.000	$0	4	0.060	$17,478
Belmont	0	0.000	$0	0	0.000	$0
Brown	1	0.015	$105,522	6	0.090	$26,216
Butler	1	0.015	$105,522	31	0.463	$135,451
Carroll	1	0.015	$105,522	5	0.075	$21,847
Champaign	0	0.000	$0	4	0.060	$17,478
Clark	0	0.000	$0	11	0.164	$48,063
Clermont	4	0.060	$422,090	51	0.761	$222,840
Clinton	2	0.030	$211,045	19	0.284	$83,019
Columbiana	0	0.000	$0	27	0.403	$117,974
Coshocton	0	0.000	$0	0	0.000	$0
Crawford	0	0.000	$0	6	0.090	$26,216
Cuyahoga	**12**	**0.179**	**$1,266,269**	**466**	**6.955**	**$2,036,142**
Darke	0	0.000	$0	26	0.388	$113,604
Defiance	0	0.000	$0	0	0.000	$0
Delaware	4	0.060	$422,090	38	0.567	$166,037
Erie	2	0.030	$211,045	26	0.388	$113,604
Fairfield	0	0.000	$0	16	0.239	$69,910
Fayette	1	0.015	$105,522	5	0.075	$21,847
Franklin	0	0.000	$0	11	0.164	$48,063
Fulton	1	0.015	$105,522	8	0.119	$34,955
Gallia	0	0.000	$0	20	0.299	$87,388

Geauga	0	0.000	$0	0	0.000	$0
Greene	**37**	**0.552**	**$3,904,328**	**1277**	**19.060**	**$5,579,728**
Guernsey	0	0.000	$0	11	0.164	$48,063
Hamilton	**13**	**0.194**	**$1,371,791**	**580**	**8.657**	**$2,534,254**
Hancock	2	0.030	$211,045	16	0.239	$69,910
Hardin	0	0.000	$0	0	0.000	$0
Harrison	1	0.015	$105,522	15	0.224	$65,541
Henry	5	0.075	$527,612	2	0.030	$8,739
Highland	0	0.000	$0	6	0.090	$26,216
Hocking	0	0.000	$0	0	0.000	$0
Holmes	0	0.000	$0	11	0.164	$48,063
Huron	6	0.090	$633,134	114	1.701	$498,112
Jackson	0	0.000	$0	0	0.000	$0
Jefferson	0	0.000	$0	1	0.015	$4,369
Knox	0	0.000	$0	17	0.254	$74,280
Lake	0	0.000	$0	40	0.597	$174,776
Lawrence	0	0.000	$0	1	0.015	$4,369
Licking	1	0.015	$105,522	26	0.388	$113,604
Logan	0	0.000	$0	0	0.000	$0
Lorain	**18**	**0.269**	**$1,899,403**	158	2.358	$690,366
Lucas	**16**	**0.239**	**$1,688,358**	**210**	**3.134**	**$917,575**
Madison	0	0.000	$0	1	0.015	$4,369
Mahoning	3	0.045	$316,567	15	0.224	$65,541
Marion	0	0.000	$0	3	0.045	$13,108
Medina	0	0.000	$0	15	0.224	$65,541
Meigs	0	0.000	$0	9	0.134	$39,325
Mercer	2	0.030	$211,045	29	0.433	$126,713
Miami	0	0.000	$0	2	0.030	$8,739
Monroe	0	0.000	$0	0	0.000	$0
Montgomery	0	0.000	$0	33	0.493	$144,190
Morgan	0	0.000	$0	0	0.000	$0
Morrow	4	0.060	$422,090	92	1.373	$401,985
Muskingum	1	0.015	$105,522	24	0.358	$104,866
Noble	1	0.015	$105,522	1	0.015	$4,369
Ottawa	0	0.000	$0	17	0.254	$74,280
Paulding	0	0.000	$0	7	0.104	$30,586
Perry	0	0.000	$0	11	0.164	$48,063
Pickaway	0	0.000	$0	37	0.552	$161,668
Pike	0	0.000	$0	11	0.164	$48,063
Portage	0	0.000	$0	2	0.030	$8,739
Preble	0	0.000	$0	0	0.000	$0
Putnam	2	0.030	$211,045	0	0.000	$0
Richland	0	0.000	$0	16	0.239	$69,910

Ross	0	0.000	$0	8	0.119	$34,955
Sandusky	0	0.000	$0	21	0.313	$91,757
Scioto	7	0.104	$738,657	77	1.149	$336,444
Seneca	6	0.090	$633,134	32	0.478	$139,821
Shelby	3	0.045	$316,567	74	1.104	$323,336
Stark	2	0.030	$211,045	12	0.179	$52,433
Summit	0	0.000	$0	0	0.000	$0
Trumbull	10	0.149	$1,055,224	**270**	**4.030**	**$1,179,739**
Tuscarawas	0	0.000	$0	10	0.149	$43,694
Union	0	0.000	$0	11	0.164	$48,063
Van Wert	2	0.030	$211,045	27	0.403	$117,974
Vinton	0	0.000	$0	0	0.000	$0
Warren	0	0.000	$0	26	0.388	$113,604
Washington	0	0.000	$0	5	0.075	$21,847
Wayne	0	0.000	$0	10	0.149	$43,694
Williams	0	0.000	$0	19	0.284	$83,019
Wood	11	0.164	$1,160,746	78	1.164	$340,813
Wyandot	0	0.000	$0	7	0.104	$30,586
State	**195**	**0.033**	**$233,828**	**4432**	**0.752**	**$220,059**

Table 2.3.h– Source: NWS, NOAA and OEMA. All dollar amount have been adjusted to 2018 dollars

When we look at the regions, Region 1 has sustained more losses than another other region related to deaths and injuries. This is driven primarily by Greene, Lucas and Cuyahoga Counties.

County	Total # of Tornados	Deaths	Estimated Annual Deaths	Estimated Annual Lost Due to Death	Injuries	Estimated Annual Injuries	Estimated Annual Lost Due to Injuries
Region 1	416	69	0.036	$251,071	844	0.434	$127,165
Region 2	454	95	0.053	$371,282	2955	1.633	$478,207
Region 3	288	31	0.014	$102,225	633	0.295	$86,432

Table 2.3.i – Source: NWS, NOAA and OEMA. All dollar amount have been adjusted to 2018 dollars

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

Tornadoes, being non-spatial hazards, make it difficult to predict their impact on state owned and leased critical facilities. The entire state is within the 250 mph wind speed zone per map 2.a.; therefore, the potential for tornado to impact state-owned or leased structures exists. When comparing the Counties with the greatest value of state owned and leased critical facilities noted in Appendix C and the vulnerability analysis and loss estimation performed above using historical data, there is only one county (Cuyahoga) who is in the top ten for both value of critical facilities and estimate future losses to property and crops.

County	Critical Facility Value	Total # of Tornados	Total Damages	Avg. Damage per Event	Est. Future Annual Losses
Adams	$ 6,635,481	14	$4,327,105	$309,079	$64,584
Allen	$ 90,950,176	17	$24,334,255	$1,431,427	$363,198
Ashland	$ 64,079,271	16	$11,349,327	$709,333	$169,393
Ashtabula	$ 18,832,622	15	$20,952,867	$1,396,858	$312,729
Athens	$ 33,380,530	2	$1,683,093	$841,546	$25,121
Auglaize	$ 11,545,804	13	$7,172,782	$551,752	$107,056
Belmont	$ 54,856,808	2	$114,500	$57,250	$1,709
Brown	$ 36,403,605	17	$47,933,351	$2,819,609	$715,423
Butler	$ 17,563,033	16	$157,021,006	$9,813,813	$2,343,597
Carroll	$ 3,661,999	8	$1,491,625	$186,453	$22,263
Champaign	$ 5,161,316	5	$2,866,932	$573,386	$42,790
Clark	$ 8,868,061	21	$16,425,120	$782,149	$245,151
Clermont	$ 17,885,810	20	$33,461,205	$1,673,060	$499,421
Clinton	$ 11,528,821	25	$32,697,805	$1,307,912	$488,027
Columbiana	$ 13,236,861	15	$74,652,331	$4,976,822	$1,114,214
Coshocton	$ 12,943,450	5	$64,768,200	$12,953,640	$966,690
Crawford	$ 10,357,812	12	$7,173,778	$597,815	$107,071
Cuyahoga	**$ 248,840,544**	15	**$353,263,446**	$23,550,896	**$5,272,589**
Darke	$ 8,619,026	20	$79,928,571	$3,996,429	$1,192,964
Defiance	$ 7,562,674	10	$6,156,855	$615,686	$91,893
Delaware	$ 46,217,477	9	$23,330,489	$2,592,277	$348,216
Erie	$ 162,265,731	12	$6,776,978	$564,748	$101,149
Fairfield	$ 86,519,830	20	$6,588,032	$329,402	$98,329
Fayette	$ 5,118,182	15	$13,892,275	$926,152	$207,347
Franklin	**$ 2,160,396,499**	**32**	$101,400,430	$3,168,763	$1,513,439
Fulton	$ 4,397,188	12	$14,241,637	$1,186,803	$212,562
Gallia	$ 35,860,837	7	$20,530,908	$2,932,987	$306,431
Geauga	$ 8,594,197	8	$5,514,050	$689,256	$82,299
Greene	$ 9,914,088	20	**$1,376,241,590**	**$68,812,079**	**$20,540,919**
Guernsey	$ 39,704,477	9	$14,225,350	$1,580,594	$212,319
Hamilton	$ 173,140,806	16	$293,041,197	$18,315,075	$4,373,749
Hancock	$ 16,195,898	10	$46,967,448	$4,696,745	$701,007
Hardin	$ 4,141,282	6	$1,294,050	$215,675	$19,314
Harrison	$ 9,054,441	3	$2,077,930	$692,643	$31,014
Henry	$ 3,113,844	17	$7,232,458	$425,439	$107,947
Highland	$ 9,678,402	16	$8,020,573	$501,286	$119,710
Hocking	$ 19,239,206	3	$116,165	$38,722	$1,734
Holmes	$ 10,336,112	9	$12,127,975	$1,347,553	$181,015
Huron	$ 10,543,997	23	$33,799,378	$1,469,538	$504,468
Jackson	$ 15,130,501	3	$8,507,500	$2,835,833	$126,978

Jefferson	$	7,592,901	4	$2,486,820	$621,705	$37,117
Knox	$	40,507,246	11	$4,732,072	$430,188	$70,628
Lake	$	5,525,021	2	$1,951,567	$975,783	$29,128
Lawrence	$	7,469,158	6	$8,526,589	$1,421,098	$127,263
Licking	$	158,043,312	23	$76,313,779	$3,317,990	$1,139,012
Logan	$	6,290,042	6	$1,965,000	$327,500	$29,328
Lorain	$	110,598,850	**27**	$225,473,132	$8,350,857	$3,365,271
Lucas	**$**	**276,597,391**	9	$215,581,412	**$23,953,490**	$3,217,633
Madison	**$**	**321,691,881**	9	$14,624,520	$1,624,947	$218,276
Mahoning	$	73,288,381	16	$18,135,126	$1,133,445	$270,674
Marion	$	128,613,896	15	$4,659,811	$310,654	$69,549
Medina	$	18,601,644	23	$13,618,884	$592,125	$203,267
Meigs	$	8,547,106	6	$3,472,484	$578,747	$51,828
Mercer	$	7,655,738	19	$31,396,989	$1,652,473	$468,612
Miami	$	14,677,401	21	$11,655,246	$555,012	$173,959
Monroe	$	6,530,556	2	$1,788,750	$894,375	$26,698
Montgomery	$	78,066,704	13	$20,618,124	$1,586,010	$307,733
Morgan	$	3,950,084	1	$68,400	$68,400	$1,021
Morrow	$	6,874,959	15	$104,942,762	$6,996,184	$1,566,310
Muskingum	$	10,647,135	16	$21,649,573	$1,353,098	$323,128
Noble	$	50,867,811	3	$729,544	$243,181	$10,889
Ottawa	$	65,293,745	11	$63,939,460	$5,812,678	$954,320
Paulding	$	1,387,796	12	$5,193,593	$432,799	$77,516
Perry	$	3,884,728	10	$15,800,575	$1,580,057	$235,829
Pickaway	$	195,643,558	20	$18,824,010	$941,201	$280,955
Pike	$	3,878,547	12	$2,665,815	$222,151	$39,788
Portage	$	7,594,529	14	**$591,200,591**	**$42,228,614**	**$8,823,889**
Preble	$	4,859,547	12	$67,178,530	$5,598,211	$1,002,665
Putnam	$	5,590,738	21	$31,619,797	$1,505,705	$471,937
Richland	$	109,750,465	**27**	$23,032,052	$853,039	$343,762
Ross	**$**	**265,584,512**	11	$11,596,973	$1,054,270	$173,089
Sandusky	$	5,519,069	7	$108,672,854	$15,524,693	$1,621,983
Scioto	$	171,351,723	15	$26,951,836	$1,796,789	$402,266
Seneca	$	33,546,722	20	$44,069,859	$2,203,493	$657,759
Shelby	$	26,824,309	6	$23,286,876	$3,881,146	$347,565
Stark	$	102,066,812	12	$88,937,842	$7,411,487	$1,327,430
Summit	$	201,182,298	11	$92,890,210	$8,444,565	$1,386,421
Trumbull	$	54,712,352	17	**$1,198,682,122**	**$70,510,713**	**$17,890,778**
Tuscarawas	$	56,132,900	13	$14,948,159	$1,149,858	$223,107
Union	$	88,869,557	9	$2,235,309	$248,368	$33,363
Van Wert	$	7,459,562	**33**	$51,911,893	$1,573,088	$774,804
Vinton	$	5,854,782	1	$25,500	$25,500	$381
Warren	$	150,201,626	24	$93,912,531	$3,913,022	$1,401,680

Washington	$ 28,580,706	7	$4,958,252	$708,322	$74,004
Wayne	$ 7,056,104	22	$75,075,209	$3,412,510	$1,120,526
Williams	$ 5,459,757	9	$68,787,593	$7,643,066	$1,026,680
Wood	$ 67,981,624	**28**	$192,134,845	$6,861,959	$2,867,684
Wyandot	$ 10,280,904	9	**$872,714,153**	**$96,968,239**	**$13,025,584**

Table 2.3.j – Source: NWS, NOAA and OEMA. All dollar amounts have been adjusted to 2018 dollars

From a regional perspective, the impacts to Region 2 are significantly greater for two very clear reasons; one the amount of exposed critical facilities is significantly greater in Region 2 compared to the other regions. Second, Region 2 is impacted at a greater rate across all of the tornado related categories when compared to the other regions.

County	Critical Facility Value	Total # of Tornados	Total Damages	Avg. Damage per Event	Est. Future Annual Losses
Region 1	$ 1,011,761,050	416	$2,049,138,150	$6,617,648	$1,416,851
Region 2	$ 4,434,187,314	454	$3,822,722,240	$8,205,254	$2,059,251
Region 3	$ 1,095,714,524	288	$1,647,477,196	$3,703,301	$487,223

Table 2.3.k – Source: NWS, NOAA and OEMA. All dollar amount have been adjusted to 2018 dollars

2.4 WINTER STORM

Canadian and Arctic cold fronts that push cold temperatures, ice, and snow into the State generally cause winter storms, blizzards, and ice storms. Severe winter weather in Ohio consists of freezing temperatures and heavy precipitation, usually in the form of snow, freezing rain, or sleet. Severe winter weather affects all parts of the State.

Blizzard conditions occur when the following conditions last three hours or longer:

- 35 mph or greater wind speeds,
- Considerable snowfall and blowing snow bringing visibility below ¼ mile, and,
- Temperatures of 20º F or lower.

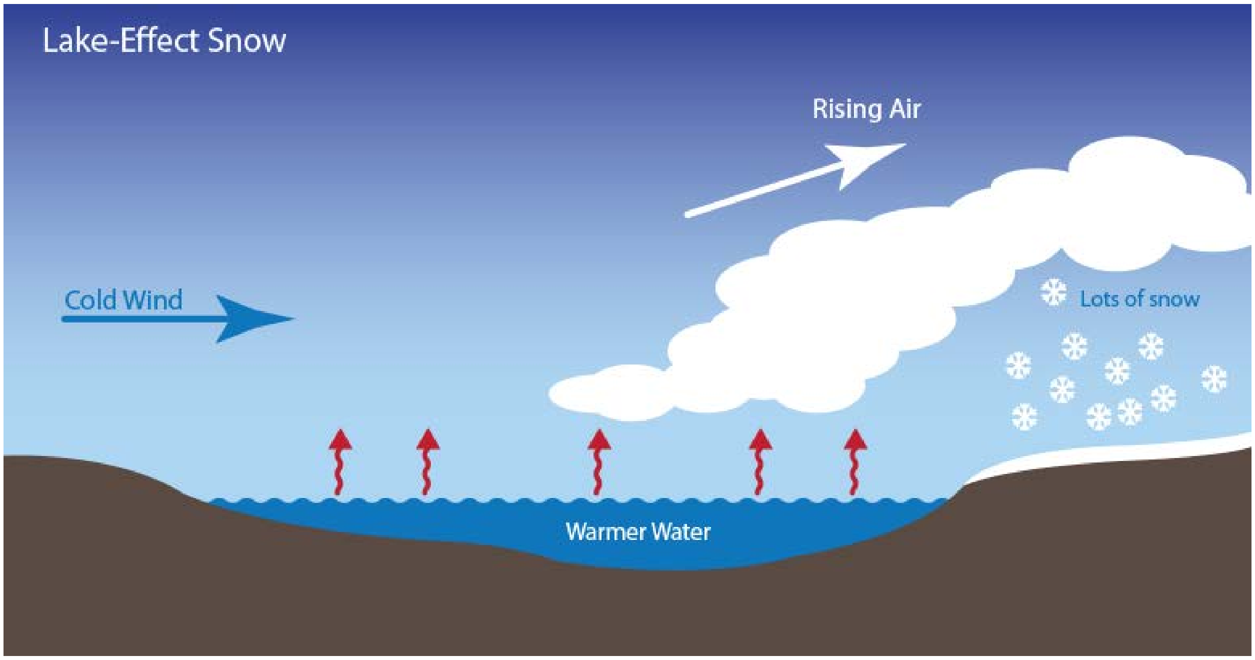
Severe blizzards have wind speeds exceeding 45 mph, visibility near zero, and temperatures of 10º F or lower.

While Ohio residents and governments are accustomed to handling winter storm events, occasional extreme events can make conditions dangerous and disruptive. Heavy snow volume makes snow removal difficult. Trees, cars, roads, and other surfaces develop a coating of ice, making even small accumulations of ice extremely hazardous to motorists and pedestrians. The most prevalent impacts of heavy accumulations of ice are slippery roads and walkways that lead to vehicle and pedestrian accidents; collapsed roofs from fallen trees and limbs from heavy ice and snow loads; and felled trees, telephone poles and lines, electrical wires, and communication towers. As a result of severe ice storms, telecommunications and power can be disrupted for days.

The northeastern portion of Ohio near the Great Lakes experiences what is known as “lake-effect snow” (see Figure 2.4.a). As cold air passes over the relatively warm waters of the large lakes, the weather system absorbs moisture and heat, and releases this in the form of snow. Lake effect snowfall intensity is affected by:

- The contrast between the lake and air temperatures,
- The distance air has traveled over water, known as the fetch, and
- The regional weather conditions-- a snow storm’s maximum penetration inland will generally be greatest during late autumn/early winter and shortest during the late winter.

Figure 2.4a
Generation of Lake Effect Snow



Source: https://scijinks.gov/lake-snow/

Lake-effect snowstorms have been known to cause continuous snowfall for as long as 48 hours over a sharply defined region. One single, intense local storm cell can yield as much as 48 inches of light-density snow in 24 hours or less. Consequently, snowfalls can vary greatly, with areas of deep snowfall adjacent to areas with relatively little snow.

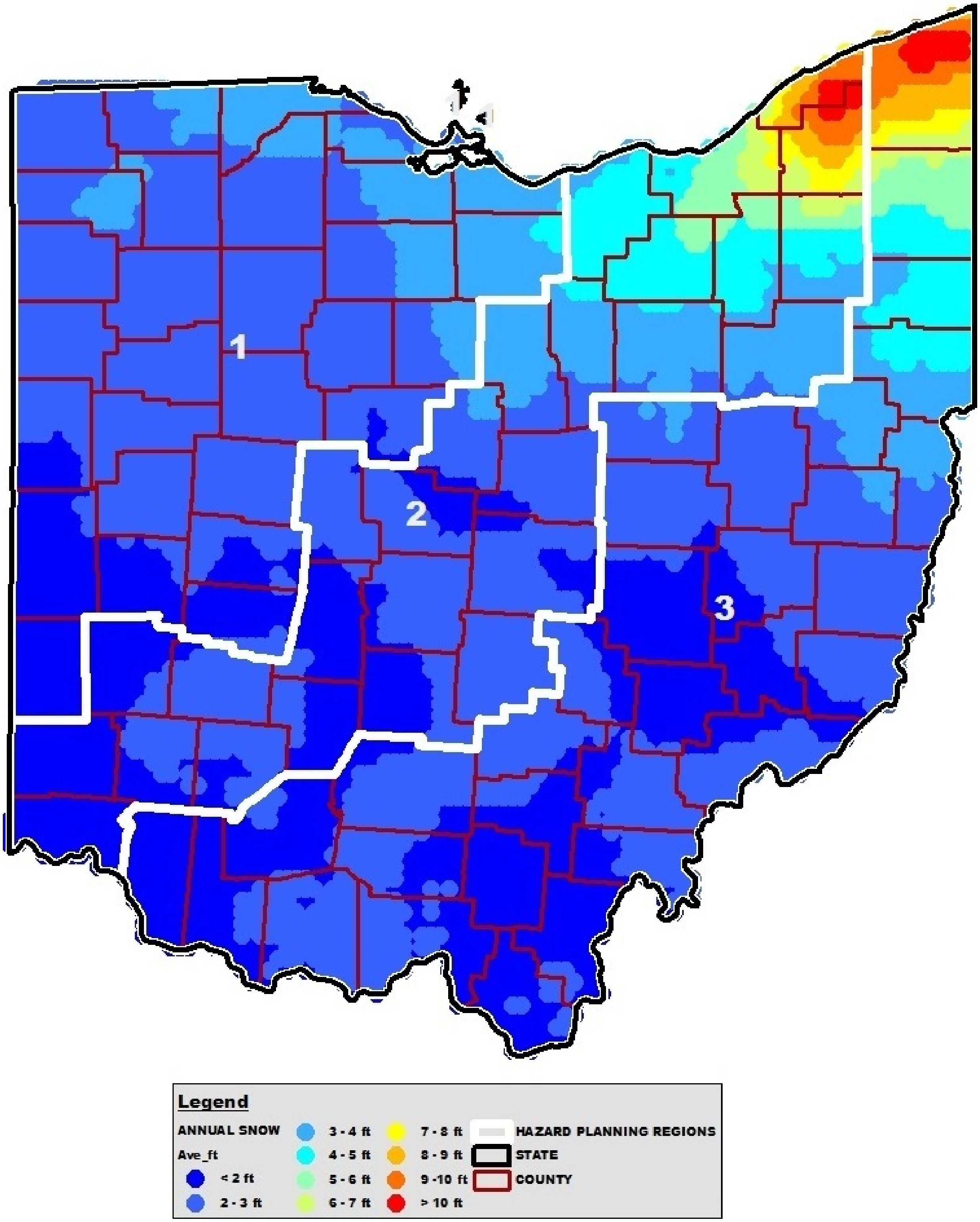
Snow and strong easterly wind conditions ahead of a warm front usually cause ice storms. The snow, however, changes temporarily to sleet and then to rain that freezes when it hits the ground, covering exposed surfaces with a layer of ice. Local accumulations of ice may be heavy if the storm halts over a region for extended periods of time. Ice storms lasting more than 12 hours usually produce ice accumulations several inches thick and affect an area that may range from a few square miles to areas covering several states. The typical ice storm swath is 30 miles wide and 300 miles long.

RISK ASSESSMENT

LOCATION

Winter storms are non-spatial hazards; therefore, it is difficult to determine the actual location of the damage that may result from a winter storm event. In an effort to address this limitation the mean annual snow depth from 2013 to 2017 was mapped (see Map 2.4.a).

State of Ohio
Map 2.4a: Annual Mean Snow Depth
2013-2017



Source: https://www.nohrsc.noaa.gov/snowfall/

In the last five years, the state of Ohio has experienced more snow in the northeastern part of the state. Counties that are closer to Lake Erie see greater levels of snowfall than the rest of the state. Lake, Geauga, and Ashtabula counties can see greater than ten feet of snowfall in a given year. This trend tapers off as the level of snowfall generally decreases as you move closer to the south and southwestern counties. Region 1 generally receives milder levels of snowfall compared to the other regions.

PAST OCCURANCES

Ohio experienced more than 280 severe winter storms between 1925 and 2014. Several storms were notable and since 1964, two involved federal declarations. In the 10-year window from the beginning of 2008 to the end of 2017, there were 69 days with winter storm events.

In January 1978, the Great Blizzard of 1978 closed homes and businesses for one week and caused the deaths of 51 people. Wind gusts reached 70 mph and caused blowing and drifting snow. The worst winter storm in Ohio history struck before dawn on Thursday, January 26th, 1978. The Blizzard of ’78 continued through Thursday and into Friday. Transportation, business, industry, and schools were closed statewide for two days with the normal pace of society not returning to the state for five days. Atmospheric pressure fell to 28.28 inches at Cleveland, the lowest ever recorded in Ohio, as the center of the blizzard crossed Ohio. This rapidly intensifying storm pulled bitterly cold air across Ohio on winds of 50 to 70 mph. These conditions, combined with heavy snow and blowing of deep snow already on the ground, caused extreme blizzard conditions all across Ohio. Enormous snowdrifts covered cars and houses, blocked highways and railways, and closed all airports for two days. More than 5,000 members of the Ohio National Guard were called to duty and were pressed into long hours of work with heavy equipment clearing roads, assisting electric utility crews, rescuing stranded persons, and transporting doctors and nurses to hospitals. Forty-five National Guard helicopters flew 2,700 missions across Ohio rescuing thousands of stranded persons, many in dire medical emergencies. Thousands of volunteers with snowmobiles and four-wheel drive vehicles responded to pleas from police statewide to deliver medicine and transport doctors and nurses to hospitals. The death toll of 51 made this one of the deadliest winter storms in Ohio history. As a result of this event, Ohio counties received a total of $3,546,669 in public assistance funds.

February 2003 (DR-1453): Prior to this event, a several series of low-pressure systems tracked through the Ohio River valley, producing up to four inches of snow across west central Ohio all through the month of January. The main event happened when a warm front ahead of low-pressure passing through the Tennessee Valley brought abundant moisture to the Ohio Valley on east-southeast winds. Cold air was already in place on the surface and conditions were right for snow accumulation of 6 to 8 inches to occur over much of the region north of the Ohio River. Counties closest to the Ohio River saw some ice accumulations to a quarter or a half inch, but the majority of the weather associated with this system was heavy snow along the I-70 corridor. Fayette, Franklin, Greene, Guernsey, Monroe, and Muskingum counties received record snowfall from this event. Adams, Gallia, Lawrence, Meigs, and Scioto Counties had severe ice accumulation in addition to snow that downed trees and power lines. Loss of power to water treatment and sewage systems resulted in the loss of water pressure to customers. For those who had some water, boil alerts were issued. In Gallia County, most of the water customers lost service and needed generators to restore service. Booster station in the affected areas did not have full power until a week after the storm hit the region. At one time more than an estimated 12,000 customers were without water. As a result of this event, thirty Ohio counties received a total of $15,761,979.42 in public assistance funds.

December 2004 – January 2005 (DR-1580): A low-pressure system moved into the northeast across the Ohio Valley. Cold west to northwest winds behind the low caused lake effect snow showers to develop in Northeast Ohio. This activity began during the predawn hours of the 16th and continued through midday on the 17th. The heaviest fell during the late afternoon and evening hours of the 16th when visibilities at times were near zero. Accumulations ranged from 6 to 8 inches in Geauga, southern Ashtabula, and eastern Cuyahoga Counties. This storm system affected four additional counties to the previous storm and caused an approximate $106,901,000 in property damage. As a result of this event, Ohio counties received a total of $7,948,685.48 in public assistance funds.

January - February 2005 (EM-3198): An Alberta Clipper passed to the north of Lake Erie during the evening hours of November 23rd. An arctic cold front trailing this low swept east across Ohio by the early morning hours of the 24th. Cold northwest winds behind this front caused lake effect snow showers to develop just before daybreak on the 24th. These bands quickly intensified and by mid-morning, visibilities in some areas were less than one-quarter mile. Northwest winds gusting in excess of 30 mph accompanied the snow and caused considerable blowing and drifting. The snow showers tapered to flurries during the early evening hours. Snowfall totals of 6 to 9 inches were reported in both Geauga and inland Ashtabula Counties by sunset on the 24th. Then, after midnight on the 25th, an upper-level disturbance rotated through the region. This caused a new round of lake effect snow showers to develop. This activity diminished during the afternoon of the 25th after another 6 to 9 inches of snow had fallen. Two-day totals for this event exceed a foot of snow in many locations.

A peak of 15.6 inches was measured in Hambden Township (Geauga County) with 14 inches at Hartsgrove (Ashtabula County). This storm system affected four additional counties to the previous storm and caused an approximate $5,475,000 in property damage. As a result of this event, Ohio counties received a total of $1,447,217.85 in public assistance funds.

March 2008 (EM-3286): On the morning of March 7th, snow spread into the region during the morning and afternoon hours, then tapered off during the evening and overnight into the 8th. Snow intensified across the area as low-pressure moved north into the Carolinas by the morning of the 8th. Snow persisted across much of the area but did mix with sleet and freezing rain at times across far eastern Ohio. By the evening hours of the 8th, snow began tapering off from west to east. Any areas of mixed precipitation across far eastern Ohio changed back to snow before ending. The low-pressure continued intensifying as it moved into New England by the morning hours of the 9th. Some light snow and flurries persisted overnight, mainly from around Cleveland and points east, but by midday on the 9th the snow tapered off across the entire area. Throughout this event, locations across northwest Ohio picked up between 5 and 10 inches. Those locations experienced a rather steep gradient for snowfall totals. In eastern Ohio, snowfall amounts were slightly lower as sleet and freezing rain mixed in at times causing reduced snowfall amounts. Locations across northeast and north-central Ohio saw the greatest snowfall amounts with 21.5 inches in Broadview Heights in Cuyahoga County, and 21.0 inches in Galion located in Crawford County. As a result of this event, Ohio counties received a total of $1,709,668.49 in public assistance funds.

PROBABILITY OF FUTURE EVENTS

Map 2.4.a depicts National Climatic Data Center figures of Ohio's annual mean snow depth for the years 2013 to 2017. South and Southwestern portions of Ohio have mean snow depths of one to two feet and central Ohio has between two and three feet. However, the northeastern corner of the state has mean snow depths of four feet or more. Lake, Geauga, and Ashtabula counties can see greater than ten feet of snowfall in a given year.

In the ten-year timeframe from January 1, 2008 to December 31, 2017, there were 69 days with winter storm events. In terms of probability, the state has a 100% chance of seeing snowfall in any given year, and 6.9 days with winter storm events per year. However, the level and severity of snowfall vary greatly by location. The vast majority of Ohio has the same chance of exceeding one to three feet of snow. The higher snowfall totals and probability for the northeastern portion of Ohio can be attributed to the lake effect snows caused by the area's proximity to the Great Lakes. Global climate change may have an impact on the probability of future events; however, it is unclear as to the extent of this impact.

LHMP DATA

Cuyahoga County: The Countywide All Natural Hazards Mitigation Plan of 2017 states that severe winter storm hazards can cause a range of damage to structures that will depend on the magnitude and duration of storm events. Losses may be as small as lost productivity and wages when workers are unable to travel or as large as sustained roof damage or building collapse. According to the National Climatic Data Center website, between January 1996 and February 2015, Cuyahoga County has been impacted by 69 severe winter weather events that have accounted for $17,770,000 in damages.

Lake County: The Lake County Hazard Mitigation Plan of 2017 indicates there have been 99 severe winter storms from 1950 to 2016 causing $27,787,000 in damages. These types of storms are known to cause utility, infrastructure, structural damages. They can also cause severe transportation problems and make travel extremely dangerous. After extensive examination and spreadsheet calculations, loss estimates show a total of $1,808,927.63 in possible structure damaged.

Ashtabula County: The HIRA of the Ashtabula County Countywide All Natural Hazards Mitigation Plan of August 2012 examines subcategories of winter storms: blizzards, ice storms, lake effect snow on the southeastern Lake Erie Snow Belt, and extreme cold. From 1993 to 2011, there were 105 severe winter events causing a total of over $200 million in property and crop damage. The frequency is the expectation of eight storms in any given year.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHODOLOGY

A hybrid approach was taken using historical data and the taxable value of real property for each county within the state. First, a historical analysis was done first for each county. The total reported property damage of each event was adjusted to 2017 dollars and summed up to for each county. This was then divided by 10 for the number of years assessed. The result of this is the estimated annual damage for each county. This number was then divided by the total taxable value of real property within the county to determine the percentage of estimated damage for each of the 88 county in any given year. The problem with this approach was that in last ten years, only 34 of 88 counties reported damage and that the other 54 counties would then have an estimated annual damage of 0 dollars which is unrealistic whether the county has reported damage or not.

To offset the lack of data for these counties, the sum of the ten-year damages across the state ($144,653,100) was divided by 10 to determine the annual loss. This figure as well as the state-wide real value of property was respectively divided by the 88 (counties in the state) to determine the average damage per county and the average taxable value per county in the state. The first was then divided by the latter resulting in the percentage of estimated damage the average county, 0.00608%, in Ohio in any given year. This percentage was for the 54 counties determined to have a zero-percent of estimated damage and the eight with less than 0.00608%.

RESULTS

In Region 1, it is estimated that Lucas County will have the highest county-wide damage per year at $418,249.94. However, the county with the highest per-capita cost is tied between Crawford County and Wyandot at $6.67 dollars per person. At $278,348.50, Crawford has almost double the estimated annual damage than Wyandot County, however also has double the number of people in the county.

Table 2.4.a

Estimate of Potential Losses to Winter Storms by Region						
Region 1						
County	**Region**	**Population**	**County-wide Taxable Value of Real Property**	**Percentage Relative to County-wide Real Property**	**Countywide Annual Damage**	**Annual Damage per Capita**
Allen	1	103198	$ 1,826,294,900	0.00608%	$ 110,962.01	$ 1.08
Auglaize	1	45778	$ 1,045,961,280	0.00608%	$ 63,550.50	$ 1.39
Champaign	1	38840	$ 837,712,700	0.00608%	$ 50,897.74	$ 1.31
Clark	1	134557	$ 2,238,882,200	0.00608%	$ 136,029.98	$ 1.01
Crawford	1	41746	$ 682,344,300	0.04079%	$ 278,348.50	$ 6.67
Darke	1	51536	$ 1,204,199,630	0.00608%	$ 73,164.75	$ 1.42
Defiance	1	38156	$ 810,287,070	0.00608%	$ 49,231.41	$ 1.29
Erie	1	74817	$ 1,948,076,220	0.01147%	$ 223,352.50	$ 2.99
Fulton	1	42289	$ 962,533,270	0.00608%	$ 58,481.59	$ 1.38
Hancock	1	75754	$ 1,795,323,240	0.01374%	$ 246,661.00	$ 3.26
Hardin	1	31364	$ 498,135,770	0.00608%	$ 30,265.73	$ 0.96
Henry	1	27185	$ 733,870,540	0.00608%	$ 44,588.50	$ 1.64
Huron	1	58494	$ 1,082,908,850	0.02258%	$ 244,572.00	$ 4.18
Logan	1	45325	$ 1,184,524,350	0.00608%	$ 71,969.32	$ 1.59
Lucas	1	430887	$ 6,883,867,330	0.00608%	$ 418,249.94	$ 0.97
Marion	1	64967	$ 1,082,107,640	0.02203%	$ 238,396.00	$ 3.67
Mercer	1	40873	$ 1,085,979,200	0.00608%	$ 65,981.91	$ 1.61
Miami	1	105122	$ 2,201,940,990	0.00608%	$ 133,785.51	$ 1.27
Ottawa	1	40657	$ 1,704,672,130	0.01455%	$ 248,061.50	$ 6.10
Paulding	1	18845	$ 448,002,890	0.00608%	$ 27,219.75	$ 1.44
Preble	1	41120	$ 881,141,010	0.00608%	$ 53,536.36	$ 1.30
Putnam	1	33878	$ 895,134,450	0.00608%	$ 54,386.57	$ 1.61
Sandusky	1	59195	$ 1,190,519,630	0.02125%	$ 252,981.50	$ 4.27
Seneca	1	55243	$ 1,096,270,950	0.01387%	$ 152,083.00	$ 2.75
Shelby	1	48759	$ 1,126,081,630	0.00608%	$ 68,418.46	$ 1.40
Van Wert	1	28217	$ 692,123,620	0.00608%	$ 42,052.04	$ 1.49
Williams	1	36784	$ 753,802,910	0.00608%	$ 45,799.55	$ 1.25
Wood	1	130492	$ 2,940,024,810	0.00942%	$ 276,890.00	$ 2.12
Wyandot	1	22029	$ 528,510,740	0.02781%	$ 146,976.00	$ 6.67
Total					$ 3,906,893.60	

In Region 2, it is estimated that Cuyahoga County will have the highest county-wide damage per year at $1,612,463.18. Close behind are Lake and Franklin Counties at $1,590,875.00 and $1,585,949.85 respectively. The county with the highest per-capita cost is Geauga County at $8.53 dollars per person.

Region 2						
County	Region	Population	County-wide Taxable Value of Real Property	Percentage Relative to County-wide Real Property	Countywide Annual Damage	Annual Damage per Capita
Ashland	2	53628	$ 962,136,090.00	0.03724%	$ 358,262.50	$ 6.68
Butler	2	380604	$ 7,053,834,350.00	0.00608%	$ 428,576.79	$ 1.13
Clinton	2	42009	$ 903,332,250.00	0.00608%	$ 54,884.65	$ 1.31
Cuyahoga	2	1248514	$ 26,539,113,700.00	0.00608%	$ 1,612,463.18	$ 1.29
Delaware	2	200464	$ 6,748,868,310.00	0.00608%	$ 410,047.67	$ 2.05
Fairfield	2	154733	$ 3,379,701,100.00	0.00608%	$ 205,343.84	$ 1.33
Fayette	2	28752	$ 701,511,200.00	0.00608%	$ 42,622.41	$ 1.48
Franklin	2	1291981	$ 26,102,737,640.00	0.00608%	$ 1,585,949.85	$ 1.23
Geauga	2	93918	$ 2,986,153,270.00	0.02683%	$ 801,325.00	$ 8.53
Greene	2	166752	$ 3,823,992,400.00	0.00608%	$ 232,338.09	$ 1.39
Hamilton	2	813822	$ 17,484,107,920.00	0.00608%	$ 1,062,299.24	$ 1.31
Knox	2	61261	$ 1,257,755,060.00	0.01421%	$ 178,744.00	$ 2.92
Lake	2	230117	$ 5,479,741,000.00	0.02903%	$ 1,590,875.00	$ 6.91
Licking	2	173448	$ 3,737,212,631.00	0.00608%	$ 227,065.52	$ 1.31
Lorain	2	307924	$ 6,291,968,810.00	0.00937%	$ 589,724.50	$ 1.92
Madison	2	44036	$ 1,072,677,480.00	0.00608%	$ 65,173.73	$ 1.48
Medina	2	178371	$ 4,827,956,520.00	0.01211%	$ 584,555.00	$ 3.28
Montgomery	2	531542	$ 8,701,115,370.00	0.00608%	$ 528,662.27	$ 0.99
Morrow	2	34994	$ 758,945,430.00	0.02502%	$ 189,913.50	$ 5.43
Pickaway	2	57830	$ 1,206,929,010.00	0.00608%	$ 73,330.58	$ 1.27
Portage	2	162277	$ 3,284,252,070.00	0.01184%	$ 388,943.00	$ 2.40
Richland	2	120589	$ 1,892,485,930.00	0.03524%	$ 666,999.00	$ 5.53
Stark	2	372542	$ 6,849,294,110.00	0.00826%	$ 565,755.00	$ 1.52
Summit	2	541228	$ 11,172,733,850.00	0.00922%	$ 1,029,598.00	$ 1.90
Union	2	56741	$ 1,579,301,910.00	0.00608%	$ 95,955.21	$ 1.69
Warren	2	228882	$ 6,011,510,440.00	0.00608%	$ 365,247.29	$ 1.60
Wayne	2	116038	$ 2,282,848,540.00	0.01412%	$ 322,296.00	$ 2.78
Total					$ 14,256,950.81	

In Region 3, it is estimated that Ashtabula County will have the highest county-wide damage per year by far at $1,572,526.50. The second highest is Trumbull County at $573,621.50. Ashtabula County also had the highest per-capita cost at $16.08 dollars per person and Holmes County had the second highest at $4.56 per person.

Region 3						
County	**Region**	**Population**	**County-wide Taxable Value of Real Property**	**Percentage Relative to County-wide Real Property**	**Countywide Annual Damage**	**Annual Damage per Capita**
Adams	3	27726	$ 413,701,850.00	0.00608%	$ 25,135.69	$ 0.91
Ashtabula	3	97807	$ 1,708,599,100.00	0.09204%	$ 1,572,526.50	$ 16.08
Athens	3	66597	$ 913,312,640.00	0.00608%	$ 55,491.04	$ 0.83
Belmont	3	68029	$ 1,375,513,000.00	0.00608%	$ 83,573.40	$ 1.23
Brown	3	43576	$ 761,341,030.00	0.00608%	$ 46,257.55	$ 1.06
Carroll	3	27385	$ 795,006,730.00	0.00608%	$ 48,303.01	$ 1.76
Clermont	3	204214	$ 3,954,639,620.00	0.00608%	$ 240,275.95	$ 1.18
Columbiana	3	103077	$ 1,637,054,170.00	0.00608%	$ 99,464.12	$ 0.96
Coshocton	3	36544	$ 652,306,860.00	0.00608%	$ 39,632.85	$ 1.08
Gallia	3	29973	$ 520,288,280.00	0.00608%	$ 31,611.67	$ 1.05
Guernsey	3	39093	$ 770,693,150.00	0.00608%	$ 46,825.77	$ 1.20
Harrison	3	15216	$ 498,135,770.00	0.00608%	$ 30,265.73	$ 1.99
Highland	3	42971	$ 751,637,960.00	0.00608%	$ 45,668.01	$ 1.06
Hocking	3	28474	$ 548,516,950.00	0.00608%	$ 33,326.79	$ 1.17
Holmes	3	43957	$ 958,818,840.00	0.02088%	$ 200,225.50	$ 4.56
Jackson	3	32449	$ 472,159,990.00	0.00608%	$ 28,687.49	$ 0.88
Jefferson	3	66359	$ 964,893,330.00	0.00608%	$ 58,624.98	$ 0.88
Lawrence	3	60249	$ 913,035,320.00	0.00608%	$ 55,474.19	$ 0.92
Mahoning	3	229796	$ 3,849,081,530.00	0.01228%	$ 472,554.50	$ 2.06
Meigs	3	23080	$ 315,965,200.00	0.00608%	$ 19,197.41	$ 0.83
Monroe	3	13946	$ 396,545,480.00	0.00608%	$ 24,093.31	$ 1.73
Morgan	3	14709	$ 250,036,190.00	0.00608%	$ 15,191.70	$ 1.03
Muskingum	3	86149	$ 1,490,291,520.00	0.00608%	$ 90,547.12	$ 1.05
Noble	3	14406	$ 339,100,440.00	0.00608%	$ 20,603.06	$ 1.43
Perry	3	36024	$ 542,980,750.00	0.00608%	$ 32,990.42	$ 0.92
Pike	3	28270	$ 357,023,590.00	0.00608%	$ 21,692.04	$ 0.77
Ross	3	77313	$ 1,212,098,990.00	0.00608%	$ 73,644.70	$ 0.95
Scioto	3	75929	$ 950,713,830.00	0.00608%	$ 57,763.46	$ 0.76
Trumbull	3	200380	$ 3,076,110,470.00	0.01865%	$ 573,621.50	$ 2.86
Tuscarawas	3	92297	$ 1,737,945,240.00	0.00608%	$ 105,594.06	$ 1.14
Vinton	3	13092	$ 170,345,810.00	0.00608%	$ 10,349.87	$ 0.79
Washington	3	60418	$ 1,165,122,780.00	0.00608%	$ 70,790.52	$ 1.17
Total					$ 4,330,003.88	

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

METHODOLOGY

A similar method as Method B above was used to determine the estimated damage to state-owned and state-leased critical facilities in Ohio. The total value of all critical facilities in each county was multiplied by the percentage of estimated damage of their respective counties. Table 2.4.b depicts the estimated annual damage to State-owned and State-leased critical facilities by county.

RESULTS

Table 2.4b

Estimate of Potential Losses to Winter Storms by Region				
Region 1				
County	Percentage Relative to County-wide Real Property	Number of State-owned and State-leased Critical Facilities	Value of State-owned and State-leased Critical Facilities	Estimated Annual Damage to State-owned and State-leased Critical Facilities
Allen	0.00608%	120	$ 90,950,176.00	$ 5,525.95
Auglaize	0.00608%	21	$ 11,545,804.00	$ 701.50
Champaign	0.00608%	24	$ 5,161,316.00	$ 313.59
Clark	0.00608%	17	$ 8,868,061.00	$ 538.81
Crawford	0.04079%	13	$ 10,357,812.00	$ 4,225.26
Darke	0.00608%	27	$ 8,619,026.00	$ 523.67
Defiance	0.00608%	11	$ 7,562,674.00	$ 459.49
Erie	0.01147%	54	$ 162,265,731.00	$ 18,604.23
Fulton	0.00608%	16	$ 4,397,188.00	$ 267.16
Hancock	0.01374%	23	$ 16,195,898.00	$ 2,225.17
Hardin	0.00608%	12	$ 4,141,282.00	$ 251.62
Henry	0.00608%	14	$ 3,113,844.00	$ 189.19
Huron	0.02258%	22	$ 10,543,997.00	$ 2,381.33
Logan	0.00608%	1	$ 735,568.00	$ 44.69
Lucas	0.00608%	47	$ 276,597,391.00	$ 16,805.50
Marion	0.02203%	100	$ 128,613,896.00	$ 28,334.55
Mercer	0.00608%	26	$ 7,655,738.00	$ 465.15
Miami	0.00608%	23	$ 10,005,576.00	$ 607.92
Ottawa	0.01455%	75	$ 65,291,745.00	$ 9,501.16
Paulding	0.00608%	3	$ 1,387,796.00	$ 84.32
Preble	0.00608%	24	$ 4,859,547.00	$ 295.26
Putnam	0.00608%	18	$ 5,590,738.00	$ 339.68
Sandusky	0.02125%	15	$ 5,519,069.00	$ 1,172.78
Seneca	0.01387%	49	$ 33,546,722.00	$ 4,653.86
Shelby	0.00608%	35	$ 26,824,309.00	$ 1,629.79
Van Wert	0.00608%	13	$ 7,459,562.00	$ 453.23
Williams	0.00608%	13	$ 5,459,757.00	$ 331.72
Wood	0.00942%	36	$ 67,981,624.00	$ 6,402.47
Wyandot	0.02781%	19	$ 10,280,904.00	$ 2,859.06
TOTAL		871	$ 1,001,532,751.00	$ 110,188.13

In Region 1, Lucas County had the highest value of State-owned and State-leased critical facilities. However because they reported zero dollars in property damages due to winter storms from 2008 to

2017, they only had $16,805, the third highest estimated damage, to critical facilities in Region 1 based on the baseline average percentage of 0.00608%. Marion County had less than half the value of critical facilities compared to Lucas County, however had the highest estimated damage at $28,334 dollars.

Region 2				
County	Percentage of Real Property	Number of State-owned and State-leased Critical Facilities	Value of State-owned and State-leased Critical Facilities	Estimated Annual Damage to State-owned and State-leased Critical Facilities
Ashland	0.03724%	143	$ 64,539,880.00	$ 24,032.17
Butler	0.00608%	21	$ 17,563,033.00	$ 1,067.09
Clinton	0.00608%	22	$ 11,528,821.00	$ 700.47
Cuyahoga	0.00608%	84	$ 248,840,544.00	$ 15,119.05
Delaware	0.00608%	37	$ 46,217,477.00	$ 2,808.08
Fairfield	0.00608%	78	$ 86,519,830.00	$ 5,256.77
Fayette	0.00608%	26	$ 5,118,182.00	$ 310.97
Franklin	0.00608%	249	$ 2,147,726,878.00	$ 130,491.57
Geauga	0.02683%	24	$ 8,594,197.00	$ 2,306.23
Greene	0.00608%	25	$ 10,629,296.00	$ 645.81
Hamilton	0.00608%	35	$ 173,140,806.00	$ 10,519.69
Knox	0.01421%	34	$ 40,507,246.00	$ 5,756.63
Lake	0.02903%	21	$ 5,525,021.00	$ 1,604.02
Licking	0.00608%	64	$ 168,043,312.00	$ 10,209.97
Lorain	0.00937%	90	$ 110,138,241.00	$ 10,322.88
Madison	0.00608%	109	$ 321,691,881.00	$ 19,545.35
Medina	0.01211%	22	$ 18,601,644.00	$ 2,252.23
Montgomery	0.00608%	71	$ 77,351,496.00	$ 4,699.72
Morrow	0.02502%	21	$ 6,874,959.00	$ 1,720.34
Pickaway	0.00608%	133	$ 195,643,558.00	$ 11,886.91
Portage	0.01184%	25	$ 7,594,529.00	$ 899.39
Richland	0.03524%	73	$ 109,750,465.00	$ 38,681.11
Stark	0.00826%	41	$ 102,066,812.00	$ 8,430.77
Summit	0.00922%	67	$ 201,182,298.00	$ 18,539.50
Union	0.00608%	53	$ 88,869,557.00	$ 5,399.54
Warren	0.00608%	109	$ 150,201,626.00	$ 9,125.95
Wayne	0.01412%	6	$ 7,056,104.00	$ 996.19
TOTAL		1,683	$ 4,431,517,693.00	$ 343,328.40

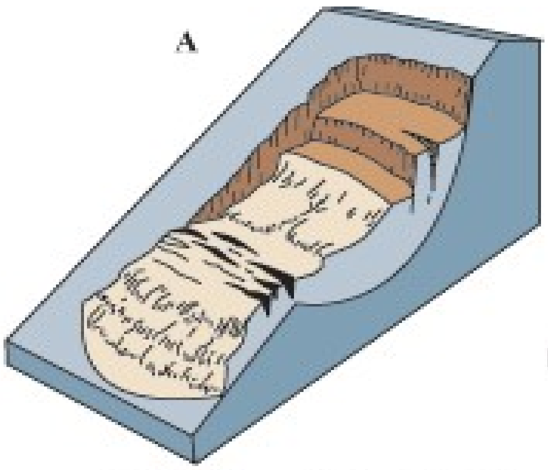
In Region 2, Franklin County had by far the highest estimated annual damage to State-owned and State-leased critical facilities at $130,491. This is largely due to it having the highest value of the assessed critical facilities in the region at 249. Richland County had the second highest estimated damage at $38,681 with 73 critical facilities and a higher percentage of damage relative to county-wide taxable real property.

Region 3				
County	**Percentage of Real Property**	**Number of State-owned and State-leased Critical Facilities**	**Value of State-owned and State-leased Critical Facilities**	**Estimated Annual Damage to State-owned and State-leased Critical Facilities**
Adams	0.00608%	24	$ 6,622,981.00	$ 402.40
Ashtabula	0.09204%	62	$ 20,008,110.00	$ 18,414.67
Athens	0.00608%	31	$ 45,496,640.00	$ 2,764.28
Belmont	0.00608%	62	$ 54,856,808.00	$ 3,332.99
Brown	0.00608%	18	$ 36,403,605.00	$ 2,211.81
Carroll	0.00608%	17	$ 3,661,999.00	$ 222.50
Clermont	0.00608%	38	$ 17,885,810.00	$ 1,086.71
Columbiana	0.00608%	38	$ 13,835,662.00	$ 840.63
Coshocton	0.00608%	19	$ 12,943,450.00	$ 786.42
Gallia	0.00608%	71	$ 35,860,837.00	$ 2,178.83
Guernsey	0.00608%	54	$ 39,704,477.00	$ 2,412.36
Harrison	0.00608%	30	$ 9,054,441.00	$ 550.13
Highland	0.00608%	8	$ 9,690,902.00	$ 588.80
Hocking	0.00608%	19	$ 7,123,096.00	$ 432.78
Holmes	0.02088%	25	$ 10,336,112.00	$ 2,158.44
Jackson	0.00608%	18	$ 15,130,501.00	$ 919.30
Jefferson	0.00608%	37	$ 7,592,901.00	$ 461.33
Lawrence	0.00608%	27	$ 11,760,373.00	$ 714.54
Mahoning	0.01228%	66	$ 72,389,280.00	$ 8,887.28
Meigs	0.00608%	18	$ 8,512,106.00	$ 517.18
Monroe	0.00608%	22	$ 11,202,381.00	$ 680.63
Morgan	0.00608%	10	$ 3,700,608.00	$ 224.84
Muskingum	0.00608%	25	$ 10,647,135.00	$ 646.90
Noble	0.00608%	31	$ 50,299,353.00	$ 3,056.09
Perry	0.00608%	16	$ 3,884,728.00	$ 236.03
Pike	0.00608%	10	$ 3,878,547.00	$ 235.65
Ross	0.00608%	142	$ 265,584,512.00	$ 16,136.38
Scioto	0.00608%	55	$ 171,351,723.00	$ 10,410.99
Trumbull	0.01865%	60	$ 55,012,652.00	$ 10,258.55
Tuscarawas	0.00608%	53	$ 56,132,900.00	$ 3,410.52
Vinton	0.00608%	20	$ 5,854,782.00	$ 355.72
Washington	0.00608%	55	$ 29,149,164.00	$ 1,771.04
TOTAL		1,181	$ 1,105,568,576.00	$ 97,306.73

Region 3 the lowest estimated annual damage compared to the other two regions. Ashtabula, the county with the highest estimated damage per capita due to winter storms in the state had the highest estimated annual damage to critical facilities in the region at $18,414. Ross County had the second highest estimated damage at $16,136.38

2.5 LANDSLIDE

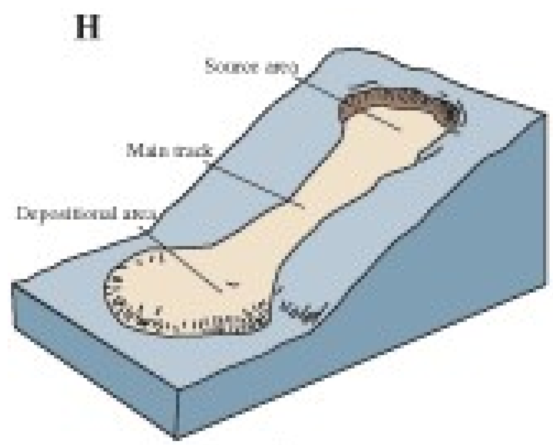
Per the Ohio Department of Natural Resources – Division of Geological Survey GeoFacts publication, a landslide is the downward and outward movement of soil and rock material on slopes. There are three main types of landslides that occur in Ohio (http://geosurvey.ohiodnr.gov/portals/geosurvey/PDFs/GeoFacts/geof08.pdf):



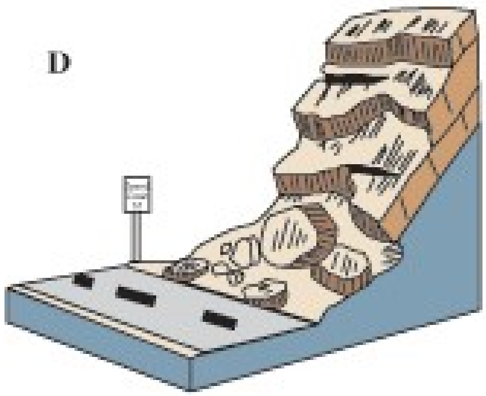
Rotational landslide

Rotational Slump: the movement of a mass of weak rock or sediment as a block unit along a curved slip plane. In Ohio, these types of slides commonly involve hundreds of thousands of cubic yards of material and extend for hundreds of feet. The crown or head, located in the upper section of the ground surface, consists of one or more rupture zones (scarps) that form a stair-step pattern of displaced blocks. The surfaces of these blocks are commonly rotated backward (reverse slope) and form depressions where water may accumulate, creating small ponds or swampy areas. Trees on these blocks may be inclined upslope, toward the top of the hill. The lower, downslope end (toe) of a rotational slump is a fan-shaped, bulging mass of material characterized by radial ridges and cracks. Trees on this portion of the landslide may be inclined at strange angles, giving rise to the descriptive terms "drunken" or "staggering" forest. Rotational slumps may develop comparatively slowly and commonly require several months or even years to reach stability; however, on occasion, they may move rapidly, achieving stability in only a few hours.

Earthflow: involves rock, sediment, or weathered surface materials moving downslope in a mass. The most common form of earth movement in Ohio, earthflow involves a smaller area than a rotational slump and forms a hummocky topography of ridges and swales. Trees may be inclined at odd angles throughout the length of an earthflow. Earthflows are most common in weathered surface materials, do not necessarily indicate weak rock, and are also common in unconsolidated glacial sediments. The rate of movement of an earthflow is generally quite slow.



Earthflow



Rockfall: an extremely rapid, potentially dangerous downslope movement of earth materials. Large blocks of massive bedrock suddenly become detached from a cliff or steep hillside and free fall in a rolling, bounding, or sliding manner downslope. Most rockfalls in Ohio involve massive beds of sandstone or limestone. Surface water seeps into joints or cracks in the rock, increasing its weight and causing expansion of joints in freezing temperatures, thus prying blocks of rock away from the main cliff. Weak and easily eroded clay or shale beneath the massive bed is an important contributing factor to rockfall. All illustrations were provided by the USGS.

One or more of the following conditions contribute to the occurrence of landslide events:

- ***Steep slope:*** All landslides move downslope under the influence of gravity. Therefore, steep slopes, cliffs, or bluffs are a required element leading to a landslide, especially in conjunction with one or more of the conditions listed below.
- ***Jointed rocks:*** Fractures in rocks allow surface moisture to penetrate and weaken it. When the moisture freezes, it pries the rock masses apart at the joint.
- ***Fine-grained, permeable rock or sediment:*** Fine rock particles are particularly conducive to landslide development because large amounts of moisture can enter them easily, increasing the material's weight, reducing the bonding strength of individual grains, and dissolving grain-cementing materials.
- ***Clay or shale units subject to lubrication***: Groundwater penetration of clay or shale can lead to a loss of binding strength between individual mineral grains and subsequent failure.
- ***Large amounts of water:*** Periods of heavy rainfall, excess snowmelt, or other events where water is accumulated saturate the zone above the normal water table and cause a landslide.

In addition to the conditions noted above, a landslide requires a triggering mechanism to initiate downslope movement. Several events or circumstances, many of them human-caused, can trigger landslides, including:

- ***Vibrations*** such as those from human-causes like blasting, the passing of a heavy truck, or from natural events like earthquakes, although no such occurrence has been documented in Ohio.
- ***Over steepened slopes*** caused by undercutting by stream or wave erosion, by human construction activities, or by the addition of fill material to the upper portion of a slope, disturb the equilibrium of a stable slope and cause the angle of stability to be exceeded.
- ***Increased weight on a slope*** caused by the addition of large amounts of fill, the construction of a building or other structure, or an unusual increase in precipitation, either from heavy rains or from artificial alteration of drainage patterns.
- ***Removal of vegetation and trees*** because of the loss of roots, which tend to hold the rock or sediment in place and soak up excess moisture.

RISK ASSESSMENT

LOCATION

Areas in southern and eastern Ohio have several conditions that can lead to the occurrence of landslide events. Thick deposits of broken and weathered bedrock fragments called colluvium, and lake silts, create slopes that are vulnerable to failure (among other geological factors). In addition, redbeds, soft shales that weather rapidly and slip, slide, and flow to form gentle contours that are quickly grassed over, have long presented landslide conditions in the Appalachian Plateau.

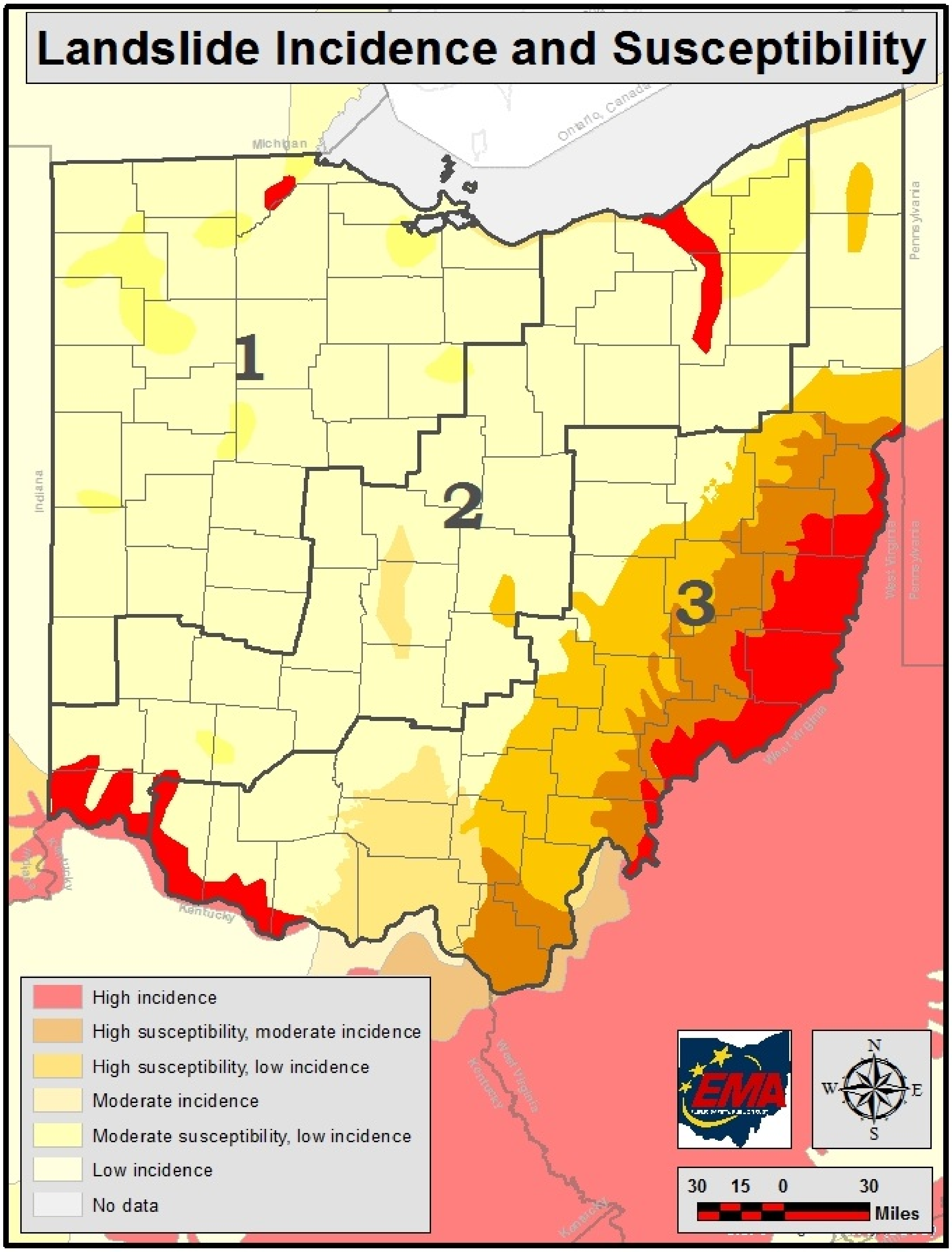
Per the USGS, (https://geochange.er.usgs.gov/sw/impacts/geology/landslides/) the Landslide incidence and susceptibility map (2.5.a) was digitized from the original stable-base manuscripts from USGS Professional Paper 1183. The map displays both the incidence of landslides and susceptibility of the land surface to landslides. Briefly, the map was constructed by evaluating geologic units shown on the geologic map of the United States (King and Beikman, 1974) and classifying them as having high, medium, or low landslide incidence based on number of known landslides, and as having the high, medium, or low susceptibility to landslide. High incidence was assigned to map units (indicated in red on the map) having more than 15 percent of their area involved in landslide; moderate incidence (in tan) to those having between 15 and 1.5 percent; and low incidence (in yellow) to those having less than 1.5 percent.

The largely subjective susceptibility indicators were defined as the probable degree of response of the rocks and soils at the surface to natural or artificial cutting or loading of slopes, or to anomalously high precipitation. The same percentages used to delimit landslide incidence were applied to the three categories of susceptibility. For example, a high susceptibility area would exhibit some movement over 15 percent or more of its surface area in response to widespread artificial cutting or high precipitation. The three susceptibility categories classified were: (1) high susceptibility with moderate incidence of landslide (dark brown); (2) high susceptibility combined with low landslide incidence (in gold); and (3) moderate susceptibility combined with low landslide incidence (in yellow/green).

Full weight could not be given to the important factors of slope angle and precipitation because no adequate slope or precipitation maps at the appropriate scale existed at the time the map was produced in 1982. A more detailed description about the construction of the map is given in the original U.S Geological Survey Professional Paper 1183

Region 1 primarily has a low landslide incidence. The most notable exception to this is Lucas and Wood Counties, which are reported to have a high landslide incidence. (Map 2.5.a). Along with Region 1, Region 2 also has a primarily low landslide incidence. Within Region 2, Butler, Hamilton, Warren, Cuyahoga, and Summit are all identified as having a high landslide incidence, which does not reflect the regional trend. Region 3 is identified as having the most area susceptible to landslide (i.e., the Appalachian Plateau). The largest part of the region has a high susceptibility with a low or moderate incidence. However, most of Belmont and Monroe counties have a high landslide incidence with parts of Columbiana, Jefferson, Harrison, Washington, Athens, Meigs, Adams, Brown, and Clermont Counties having a high incidence as well.

Map 2.5.a



LHMP DATA

Hamilton County – While Region 3 and parts of Region 2 have potentially high susceptibility and incidence to landslides. Hamilton County and the City of Cincinnati has some of the highest cost per capita in the United States for historical landslide damages. The 2013 Hamilton County Multi-Hazard Mitigation plan included a landslide assessment performed by the University of Cincinnati, which is summarized in Table 2.5.a.

Building Type	Number of Buildings	Estimated Losses/Exposure
Residential	1,346	$279,851,500
Non-Residential	610	$19,740,730
Critical Facilities	10	$2,150,000
Totals	1,966	$301,742,230

Table 2.5.a

According to the 2013 Hamilton County plan, landslides are considered to be their fourth area of concern for natural hazards, following flooding (number one), tornadoes, and severe storms. The county officials based their decision on the lack of building regulations in areas deemed high hazard for landslides. Also, the removal of vegetation in riparian corridors can increase the landslide potential, and this is not regulated systematically. Finally, the lack of public education and awareness limits communities' understanding of such geophysical and regulatory relationships. Hamilton County's goal to mitigate landslide events involves identification of methodologies used by other, similar communities, and they want to increase public awareness through outreach initiatives.

Stark County – The 2017 Stark County Multi-Jurisdictional All-Hazard Mitigation Plan states that landslides have occurred primarily in the western and southern portions of the county, near the villages of Brewster, East Canton, Navarre, Waynesburg, and Wilmot and the cities of Canal Fulton, Magnolia, Massillon, and North Canton. Safety problems for travelers caused by landslides are a growing concern. There are several highways that could become damaged as a result of landslides in Stark County. U.S. Routes 30 and 62, and State Routes 21, 43, 93, 172, 289, and 800 all are at risk.

PAST OCCURRENCES

Ohio has had a long history of damage from landslides; for example, geologists at the University of Cincinnati report that the Cincinnati metropolitan area has one of the highest per capita costs of landslide damage of any metropolitan area in the United States. Accounts of landslide concerns can date back to the 1970s. A 1980 U.S Geological survey report estimated Hamilton County likely had the highest annual per capita landslide damage costs in the country. Within Hamilton County, Cincinnati alone was spending about $500,000 annually on emergency landslide repairs. Despite the chronic problem, no long-term plan currently exists to permanently provide a solution. While landslides have been problematic in Cincinnati since the early to mid-1800s, documentation is limited. As the city began to expand and infrastructure was improved in the early 1900s, landslide hazards became better documented.

The University of Cincinnati report found that landslide damages in Hamilton County, primarily due to public road construction, averaged more than $5 million each year between 1973 and 1978. Well-publicized landslides that occurred in the 1970s included those along Columbia Parkway, Hillside Avenue, Delhi Pike, and Huffman Court. Mt. Adams (Cincinnati, Ohio) is the most prominent topographic feature in Cincinnati. It is also home to one of the most expensive landslide remediation projects in the history of the U.S. The cost of remediation was $44.5 million in 2005 dollars. A normal retaining wall for this slide could not be used because the failure surface was too deep.

Rockfalls have also caused dangerous conditions. Ohio DNR reports that on Christmas Eve in 1986, an individual traveling in an automobile was killed by falling rock along U.S. Route 52 in Lawrence County in southern Ohio. In 2017, ODOT reported several large boulders fell in Lawrence County blocking all four lanes of State Route 7 for several days. The westbound lanes of State Route 7 did not reopen for nearly a month. The photograph was provided by ODOT District 9.

Landslides can be triggered by heavy rainfall and flooding, leading to multiple disasters in the same location. The most recent example is from April of 2018 when the State received a disaster declaration (DR- 4360) due to the severe storms, flooding, mudslides, and landslides that struck the southern and southeastern counties of Ohio. Federal funding also was available to State and eligible local governments on a cost-sharing basis for the repair or replacement of public facilities damaged by the severe storms, flooding, mudslides, and landslides in the counties of Adams, Athens, Belmont, Brown, Columbiana, Gallia, Hamilton, Harrison, Jackson, Jefferson, Lawrence, Meigs, Monroe, Morgan, Muskingum, Noble, Perry, Pike, Scioto, Vinton, and Washington Counties. The photograph was provided by ODOT.

The impact of most if not all landslide and rockfall events in Ohio are directly tied to rainfall events, therefore more damage data related to such events in captured under flood related damages for the purposes of FEMA's public assistance program.

OHIO DEPARTMENT OF TRANSPORTATION LANDSLIDE AND ROCKFALL INVENTORIES

The Landslide (10/2013) and Rockfall (12/2016) manuals prepared the ODOT Office of Geotechnical Engineering (OGE), provide rational approach to manage the unsafe or failed slopes/embankments and rockfalls. The manuals include a systematic process for collecting the information needed for decision-making.

LANDSLIDE MANUAL

(http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Geotechnical_Documents/Manual%20of%20Landslide%20Inventory.pdf)
This manual was developed by ODOT OGE to inventory soil slopes, to identify potential hazardous slopes, to assess relative risk for those slopes, to determine degree of monitoring required, and to allow for actions to be taken to reduce, minimize, or eliminate the risk to the public's safety and to protect the highway system. The intent of this manual is to facilitate the creation of a statewide landslide inventory process through the development of a statewide inventory procedure and the establishment of office and field methods. These methods should be used during the initial population of the inventory, inventory of new sites following the initial population, and for maintenance and monitoring of the sites. The data collected from the SdAD inventory process will be stored within the Geologic Hazard Management System (GHMS) and other related components of the ODOT GeoMS.

Essentially, this manual provides the information about the following:

- procedure for landslide data collection;
- landside hazard assessment using ODOT rating matrix; and
- guidance on the use of a global positioning system (GPS) and an internet website for the ODOT landslide database

The Preliminary Rating will segregate the lower priority sites from the groups that will receive detailed data collection efforts. This Manual will outline a tiered data collection methodology which will allow landslides within Ohio to be rated for relative risk of slope instability to the public and Ohio's highway system. The map (2.5.b) was created by the Office of Geotechnical Engineering (OGE) and represents the number of landslide by county that are currently impacting the State's highway system. The map indicates the number of moderately and highly rated landslides, along with the total number of landslides for each county. The counties with the most impacted roadways are Monroe (1196), Morgan (1048) and Athens (831).

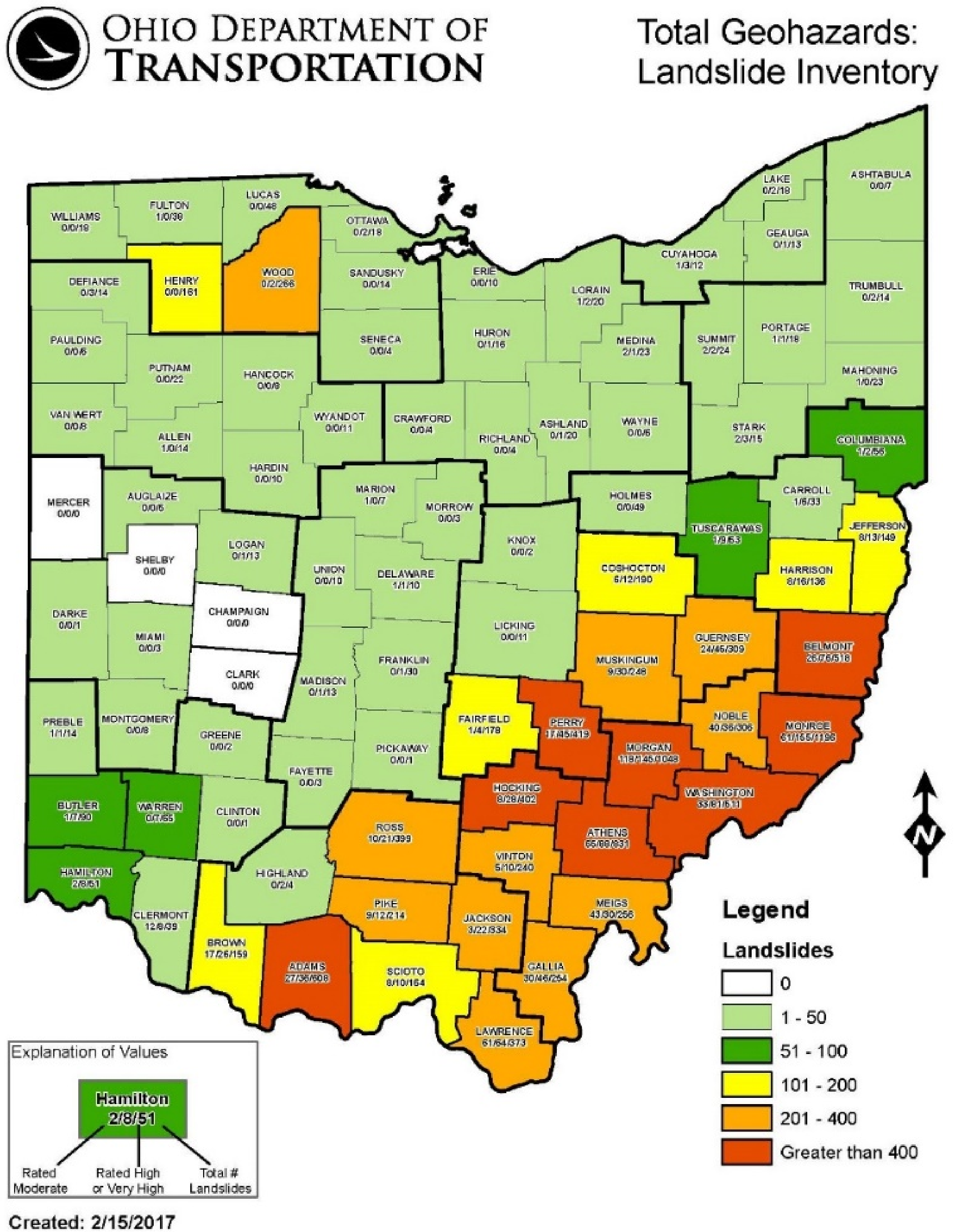

OHIO DEPARTMENT OF TRANSPORTATION
Total Geohazards: Landslide Inventory
WILLIAMS 0/0/19
FULTON 1/0/30
LUCAS 0/0/48
OTTAWA 0/2/18
DEFIANCE 0/3/14
HENRY 0/0/161
WOOD 0/2/266
SANDUSKY 0/0/14
ERIE 0/0/10
PAULDING 0/0/6
PUTNAM 0/0/22
HANCOCK 0/0/9
SENECA 0/0/4
HURON 0/1/16
LORAIN 1/2/20
CUYAHOGA 1/3/12
LAKE 0/2/19
GEAUGA 0/1/13
ASHTABULA 0/0/7
TRUMBULL 0/2/14
MEDINA 2/1/23
SUMMIT 2/2/24
PORTAGE 1/1/18
MAHONING 1/0/23
VAN WERT 0/0/8
ALLEN 1/0/14
WYANDOT 0/0/11
CRAWFORD 0/0/4
RICHLAND 0/0/4
ASHLAND 0/1/20
WAYNE 0/0/6
STARK 2/3/15
COLUMBIANA 1/2/56
MERCER 0/0/0
AUGLAIZE 0/0/5
HARDIN 0/0/10
MARION 1/0/7
MORROW 0/0/3
HOLMES 0/0/49
CARROLL 1/6/33
TUSCARAWAS 1/9/53
JEFFERSON 8/13/149
SHELBY 0/0/0
LOGAN 0/1/13
UNION 0/0/10
DELAWARE 1/1/10
KNOX 0/0/2
COSHOCTON 6/12/190
HARRISON 8/16/136
DARKE 0/0/1
MIAMI 0/0/3
CHAMPAIGN 0/0/0
CLARK 0/0/0
MADISON 0/1/13
FRANKLIN 0/1/30
LICKING 0/0/11
MUSKINGUM 9/30/248
GUERNSEY 24/45/309
BELMONT 26/76/518
PREBLE 1/1/14
MONTGOMERY 0/0/8
GREENE 0/0/2
FAYETTE 0/0/3
PICKAWAY 0/0/1
FAIRFIELD 1/4/178
PERRY 17/45/419
MORGAN 118/145/1048
NOBLE 40/36/306
MONROE 61/155/1196
BUTLER 1/7/90
WARREN 0/7/65
CLINTON 0/0/1
HOCKING 8/28/402
WASHINGTON 33/81/611
ROSS 10/21/399
ATHENS 65/88/831
HAMILTON 2/8/51
HIGHLAND 0/2/4
VINTON 5/10/240
CLERMONT 12/8/39
PIKE 9/12/214
JACKSON 3/22/334
MEIGS 43/30/256
BROWN 17/26/159
ADAMS 27/36/608
SCIOTO 8/10/164
GALLIA 30/46/254
LAWRENCE 61/64/373
N
Legend
Landslides
0
1 - 50
51 - 100
101 - 200
201 - 400
Greater than 400
Explanation of Values
Hamilton
2/8/51
Rated Moderate
Rated High or Very High
Total # Landslides
Created: 2/15/2017

Table 2.5.b

ROCKFALL MANUAL

http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Geotechnical_Documents/Manual%20for%20Rockfall%20Inventory.pdf

Rockfalls can constitute a major hazard along Ohio roadways, posing a risk to life, property, and traffic safety. As a result of rockfalls, maintenance problems are constantly occurring, resulting in a strain on the Ohio Department of Transportation (ODOT) funds and manpower. A rockfall inventory will be performed for the state highway system as noted in ODOT's policy on geohazards. This inventory will include all natural and manmade slopes with exposed bedrock.

The data collection procedures are grouped into four (4) primary sections with subsections:

- Site Inventory and Preliminary Rating
- Tier 1 Site Rating
- Tier 2 Site Rating
- Tier 3 and Tier 4 Site Rating

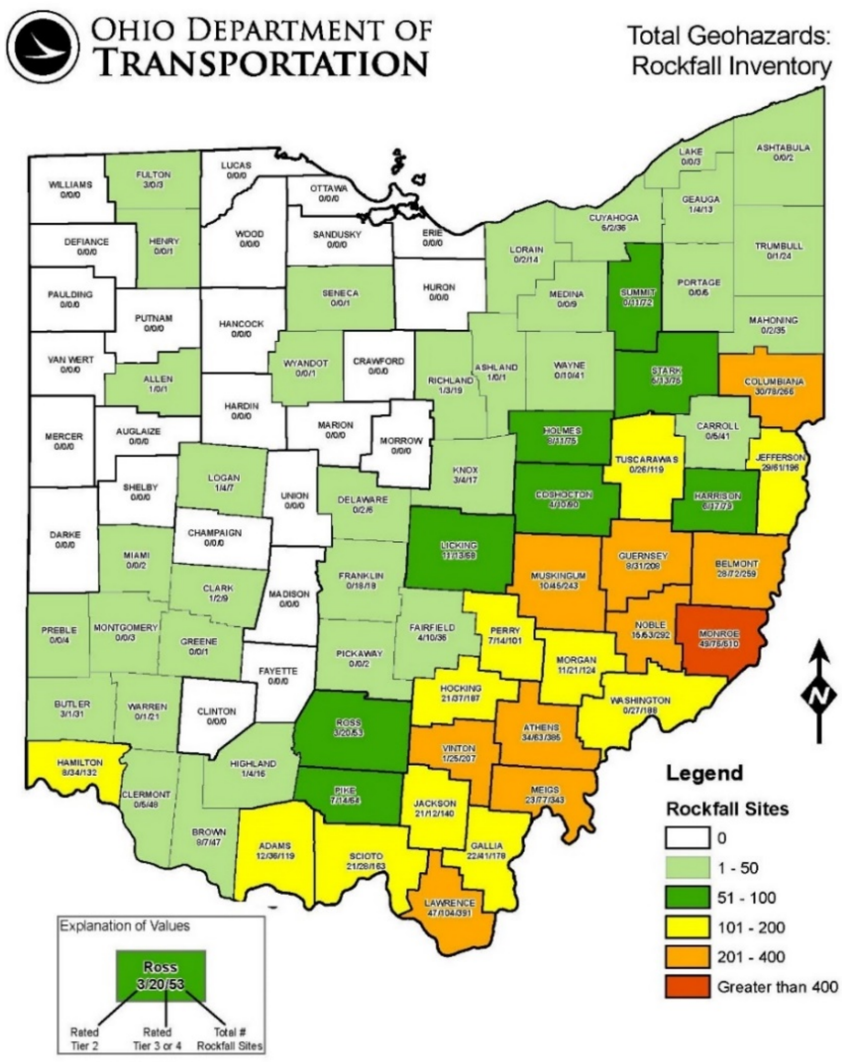


Table 2.5.c

This Manual outlines a tiered data collection methodology which allows rock slopes within Ohio to be rated for relative rockfall risk to the public and Ohio's highway system. The data collected from each site is incorporated into an Enterprise Database and integrated into a GIS system. The inventory consists of identifying and locating Inventory Sites within the rock slopes situated along Ohio's highway system. Generally, this inventory will be concerned with rock slopes located above the roadway, unless a rockfall event below the road could result in adverse impacts to the highway system.

PROBABILITY OF FUTURE EVENTS

Landslide probability is highly site-specific, and cannot be accurately characterized on a statewide basis, except in the most general sense. Statewide analyses for potential landslides have been performed by the US Geological Survey (USGS). The possible landslide incidence and susceptibility was discussed earlier in this chapter and illustrated on Map 2.5.a. When factoring for the previous USGS analyses (map 2.5.a) and the impacts documented in ODOT landslide (2.5.b) and Rockfall (2.5.c) manuals, Region 3 is identified as having the most area susceptible to landslide.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHODOLOGY

The only predictable impact that can be quantified for analysis is damage to Ohio's roadways. The Ohio Department of Transportation, Office of Geotechnical Engineering has a comprehensive inventory of the federal and state routes, which intersect with known and existing landslide and rock fall events. The location, length of each segment, potential for failure, along with a host of other data is maintained in a database (https://gis.dot.state.oh.us/tims/Map/Geotech). The counties with the greatest number of impacts are located within Region 3, particularly Athens, Lawrence, Morgan and Monroe Counties.

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

METHODOLOGY

Using the geocoded state owned and state leased critical facilities listing provided by the Ohio Department of Administrative Services (DAS), and the Landslide Incidence and Susceptibility map created and maintained by USGS, Ohio EMA GIS staff performed a buffer, which joined the two data sets and produced a new data set. This new data set allowed us to quantify the risk to the state owned and state leased critical facilities based upon their physical location within each county. For the purpose of this analysis, those critical facilities located within areas with a low incidence (less than 1.5 % chance) of landslide were not included.

RESULTS

The results were weighted based upon the number of critical facilities in each county that were located within areas of high incidence (having more than 15 % chance of landslide). There are counties who had a larger overall number of critical facilities located within areas that fell within the a category noted on the landslide incidence and susceptibility map, but were not considered to be at the same risk level as those counties with critical facilities located within high incidence areas.

Region 1 has a very low potential of loss, with only one county (Lucas) having any critical facilities within an area of high incidence and only eight counties total with possible losses. The vast majority of the region's possible losses and impacted critical facilities are located within Lucas County.

Region 1

County	Total Exposed Critical Facilities	Total Replacement Value	# of Critical Facilities in HIA	% of Critical Facilities in HIA
Lucas	46	$ 273,893,286.00	22	47.8%
Defiance	8	$ 7,200,331.00	0	0.0%
Putnam	1	$ 1,227,541.00	0	0.0%
Mercer	6	$ 885,687.00	0	0.0%
Erie	7	$ 685,079.00	0	0.0%
Darke	1	$ 626,117.00	0	0.0%
Hardin	3	$ 302,153.00	0	0.0%
Henry	5	$ 113,250.00	0	0.0%
TOTAL	77	$ 284,933,444.00	22	

Table 2.5.b

Compared to Region 1, Region 2 has a significantly greater potential for loss. Region 2 has a total of eight counties with possible losses. Of those eight counties, four of them Summit, Hamilton, Butler and Cuyahoga have critical facilities within an area of high incidence. Cuyahoga County the greatest number of critical facilities (38) within an area of high incidence in the state. Franklin County has the highest total critical facilities (111), which are in an area that is susceptible to landslide, but none of those areas exceed moderate incidence. Region 2 also has the greatest potential losses in dollars, although much of this is driven by Franklin County.

Region 2

County	Total Exposed Critical	Total Replacement Value	# of Critical Facilities in HIA	% of Critical Facilities in HIA
Cuyahoga	71	$ 223,491,915.00	38	53.5%
Summit	37	$ 178,272,585.00	37	100.0%
Hamilton	29	$ 172,251,987.00	29	100.0%
Butler	2	$ 367,875.00	2	100.0%
Franklin	111	$ 796,354,215.00	0	0.0%
Geauga	23	$ 8,576,693.00	0	0.0%
Portage	1	$ 684,224.00	0	0.0%
Fayette	1	$ 5,000.00	0	0.0%
TOTAL	352	$ 1,664,937,938.00	128	

Table 2.5.c

Region 3 has by far the highest number of counties with critical facilities, which could sustain potential losses from landslides (715). Region 3 had twenty-eight counties with the potential of loss and nine counties with critical facilities within an area of high incidence.

Region 3

County	Total Exposed Critical	Total Replacement Value	# of Critical Facilities in HIA	% of Critical Facilities in HIA
Washington	56	$ 29,149,164.00	37	66.1%
Belmont	62	$ 54,856,808.00	34	54.8%
Jefferson	37	$ 7,592,901.00	23	62.2%
Clermont	23	$ 3,710,528.00	23	100.0%
Monroe	19	$ 6,522,681.00	19	100.0%
Harrison	30	$ 9,054,441.00	16	53.3%
Brown	7	$ 29,882,234.00	7	100.0%
Meigs	19	$ 8,547,106.00	2	10.5%
Columbiana	37	$ 13,835,662.00	1	2.7%
Scioto	55	$ 171,351,723.00	0	0.0%
Noble	31	$ 50,299,353.00	0	0.0%
Athens	31	$ 45,496,640.00	0	0.0%
Guernsey	54	$ 39,704,477.00	0	0.0%
Gallia	71	$ 35,860,837.00	0	0.0%
Ross	19	$ 19,248,265.00	0	0.0%
Jackson	18	$ 15,130,501.00	0	0.0%
Lawrence	27	$ 11,760,373.00	0	0.0%
Muskingum	17	$ 9,232,685.00	0	0.0%
Vinton	20	$ 5,854,782.00	0	0.0%
Morgan	10	$ 3,950,084.00	0	0.0%
Pike	10	$ 3,878,547.00	0	0.0%
Carroll	17	$ 3,661,999.00	0	0.0%
Tuscarawas	17	$ 2,921,475.00	0	0.0%
Ashtabula	12	$ 1,889,649.00	0	0.0%
Hocking	2	$ 1,373,320.00	0	0.0%
Trumbull	8	$ 1,052,544.00	0	0.0%
Perry	5	$ 979,866.00	0	0.0%
Adams	1	$ 545,334.00	0	0.0%
TOTAL	715	$ 587,343,979.00	162	

Table 2.5.d

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 wastewater 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

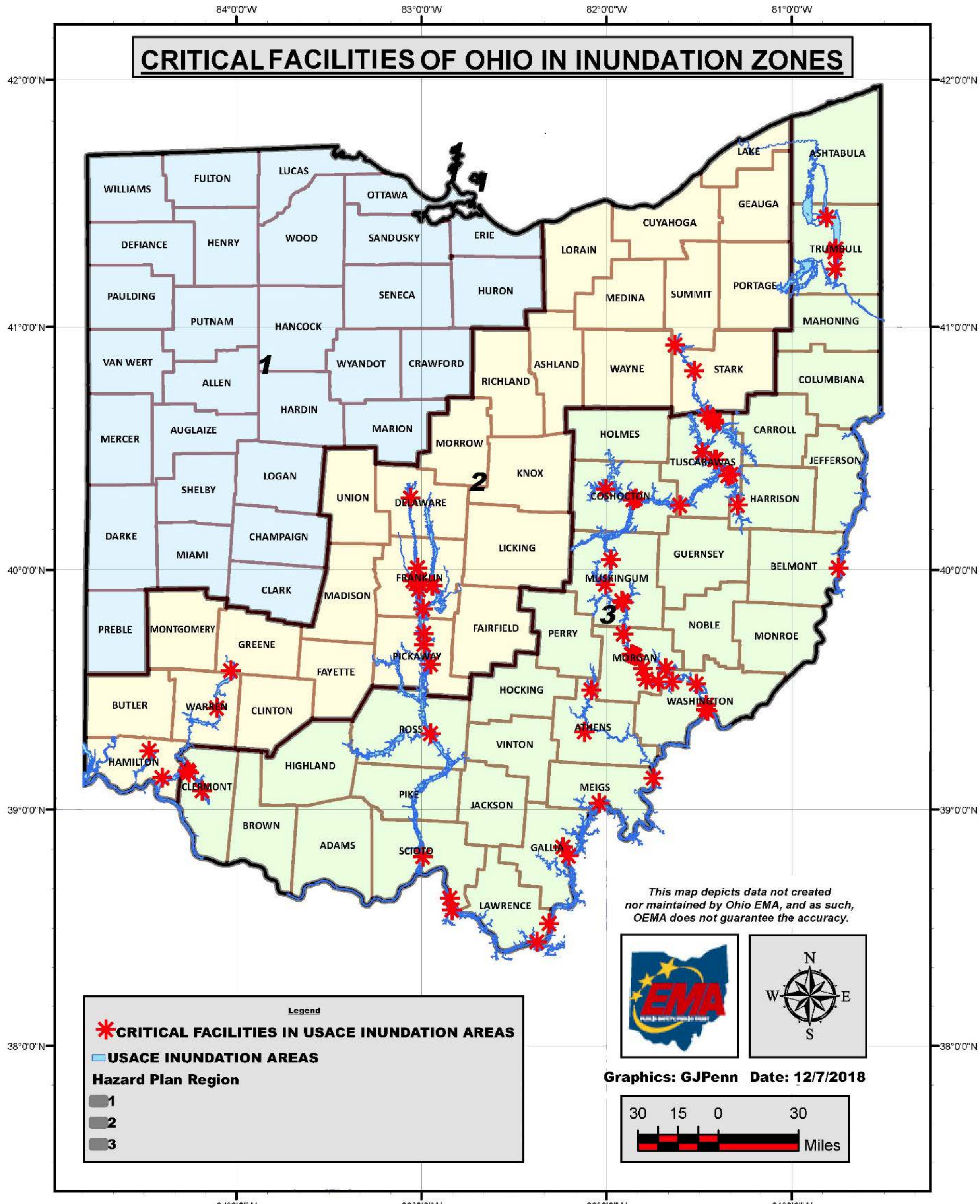
Table 2.6.g shows the numbers of state-owned and state-leased facilities potentially affected by an event equivalent to the spillway design flood with dam failure. Of the dams analyzed, Region 1 did not have any facilities within the spillway. In Region 2, there were an estimated 82 structures within 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
DEFIANCE
HENRY
WOOD
SANDUSKY
ERIE
LORAIN
CUYAHOGA
LAKE
GEAUGA
ASHTABULA
TRUMBULL
PAULDING
PUTNAM
HANCOCK
SENECA
HURON
MEDINA
SUMMIT
PORTAGE
MAHONING
VAN WERT
ALLEN
WYANDOT
CRAWFORD
RICHLAND
ASHLAND
WAYNE
STARK
COLUMBIANA
MERCER
AUGLAIZE
HARDIN
MARION
MORROW
HOLMES
CARROLL
JEFFERSON
LOGAN
UNION
DELAWARE
KNOX
COSHOCTON
TUSCARAWAS
HARRISON
SHELBY
DARKE
MIAMI
CHAMPAIGN
CLARK
MADISON
FRANKLIN
LICKING
MUSKINGUM
GUERNSEY
BELMONT
PREBLE
MONTGOMERY
GREENE
FAIRFIELD
PERRY
NOBLE
MONROE
FAYETTE
PICKAWAY
MORGAN
BUTLER
WARREN
CLINTON
HOCKING
WASHINGTON
ATHENS
ROSS
VINTON
HAMILTON
CLERMONT
HIGHLAND
PIKE
JACKSON
MEIGS
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
1
2
3
This map depicts data not created nor maintained by Ohio EMA, and as such, OEMA does not guarantee the accuracy.
N
W
E
S
Legend
CRITICAL FACILITIES IN USACE INUNDATION AREAS
USACE INUNDATION AREAS
Hazard Plan Region
1
2
3
Graphics: GJPenn Date: 12/7/2018
30 15 0 30
Miles

LEVEE VULNERABILITY METHODOLOGY

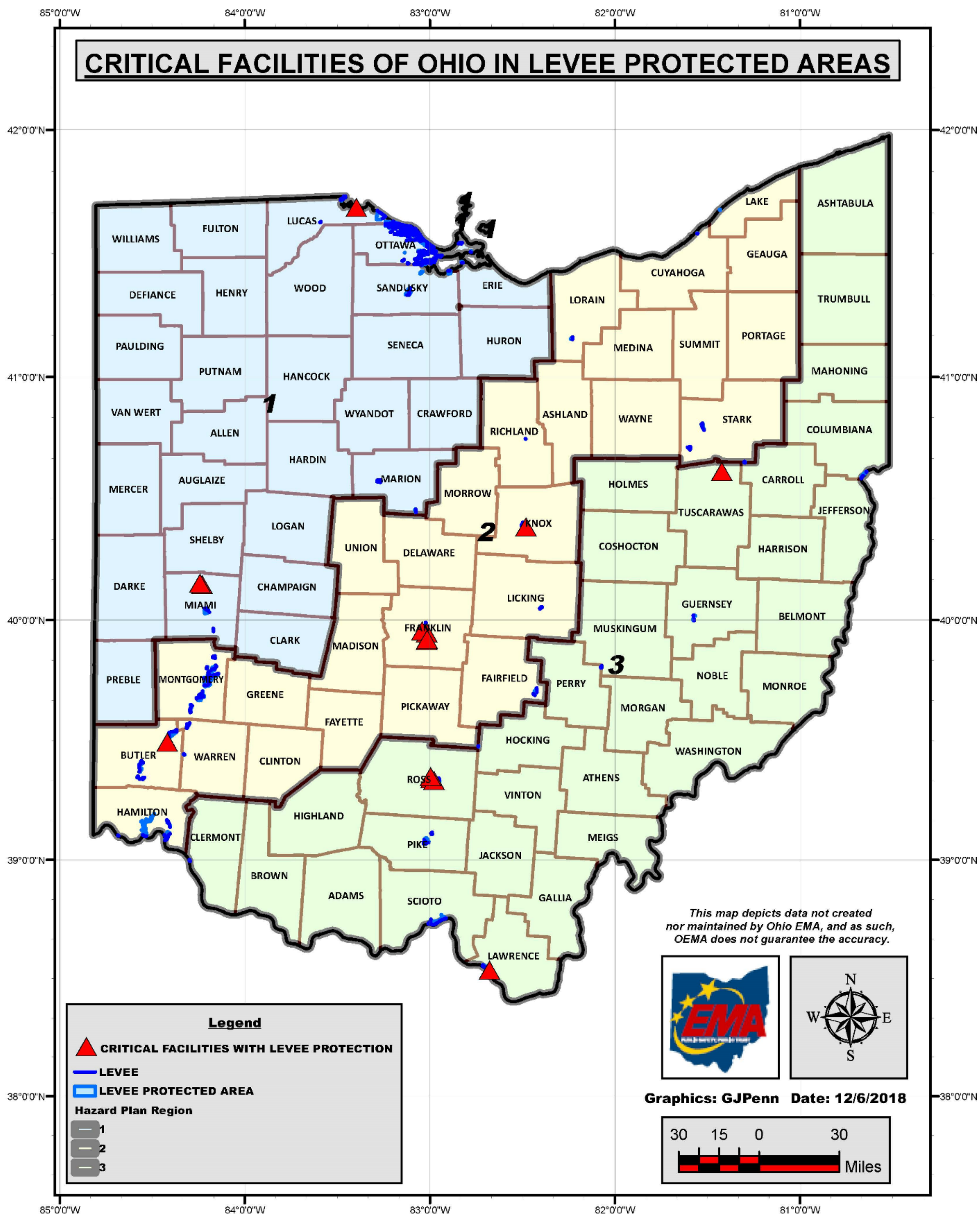
As referenced in Table 2.6.d, the National Levee Database lists 257 levee systems in Ohio. Each one of these levees protects a defined area as determined from FEMA FIRM maps. Each of these leveed areas were used to intersect with the list of State-owned and State-leased critical facilities in Ohio.

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
DEFIANCE
HENRY
WOOD
SANDUSKY
ERIE
PAULDING
SENECA
HURON
PUTNAM
HANCOCK
VAN WERT
ALLEN
WYANDOT
CRAWFORD
HARDIN
MARION
MERCER
AUGLAIZE
SHELBY
LOGAN
DARKE
MIAMI
CHAMPAIGN
CLARK
PREBLE
MONTGOMERY
GREENE
BUTLER
WARREN
CLINTON
HAMILTON
CLERMONT
BROWN
HIGHLAND
ADAMS
LAKE
ASHTABULA
GEAUGA
CUYAHOGA
LORAIN
TRUMBULL
MEDINA
SUMMIT
PORTAGE
MAHONING
ASHLAND
WAYNE
STARK
COLUMBIANA
RICHLAND
MORROW
KNOX
HOLMES
TUSCARAWAS
CARROLL
JEFFERSON
UNION
DELAWARE
COSHOCTON
HARRISON
LICKING
GUERNSEY
BELMONT
MADISON
FRANKLIN
MUSKINGUM
FAIRFIELD
PERRY
NOBLE
MONROE
PICKAWAY
MORGAN
FAYETTE
HOCKING
WASHINGTON
ROSS
ATHENS
VINTON
PIKE
JACKSON
MEIGS
SCIOTO
GALLIA
LAWRENCE
1
2
3
This map depicts data not created nor maintained by Ohio EMA, and as such, OEMA does not guarantee the accuracy.
Legend
CRITICAL FACILITIES WITH LEVEE PROTECTION
LEVEE
LEVEE PROTECTED AREA
Hazard Plan Region
1
2
3
Graphics: GJPenn Date: 12/6/2018
30 15 0 30
Miles
N
W
E
S

2.7 WILDFIRE

A wildfire is an uncontrolled fire that burns an area of combustible vegetation and typically occurs in rural areas. Each year in Ohio, an average of 1000 wildfires burn 4,000 to 6,000 acres of forest and grassland within ODNR Division of Forestry's Wildfire Protection Area (Map 2.7.a). The protection area includes all 200,000+ acres of Ohio's 21 State Forests, as well as all privately owned lands within the district boundaries. The forest fire protection district corresponds mostly to the state's unglaciated hill country (southern and eastern Ohio), and also encompasses a section of northwest Ohio (Maumee State Forest area). According to the Ohio Department of Natural Resources, Ohio's wildfire seasons occur primarily in the spring (March, April and May) before vegetation has "greened-up", and the fall (October and November) when leaf drop occurs. During these times and especially when weather conditions are warm, windy and with low humidity, cured vegetation is particularly susceptible to burning. Fuel (vegetation, woody debris), weather (wind, temperature, humidity) and topography (hills and valleys) when combined present an unpredictable danger to unwary civilians and firefighters in the path of a wildfire. Open burning is regulated by state laws and local burning ordinances, which may vary from one jurisdiction to another. Outside municipal limits, burning is prohibited from 6 am to 6 pm during the months of March, April, May, October and November. It is during these times of the year and day that wildfires are most likely to occur and are the most difficult to control.

While Ohio government agencies and local fire departments are accustomed to handling seasonal wildfires, occasional extreme events can make conditions dangerous and disruptive. Heavy fuel accumulations oftentimes make wildfire suppression extremely difficult due to more intense blazes. Occasionally, heavy fuel loadings and topography create problems in limiting access to fires, and lead to heavy equipment use for suppression. Prolonged drought may cause an exceptionally long or active wildfire season, as well as contribute to extreme wildfire behavior or burning conditions. Multiple concurrent fires can tax resources and quickly create a lack of manpower and other resources and retard the ability to suppress fires rapidly and safely.

The Wildland Urban Interface (WUI) conditions may create a serious issue of concern in Ohio. The WUI is defined as the situation where homes, residences, and structures are in close proximity to forested lands and grasslands prone to wildfire. This creates a situation where, in the event of a wildfire, personal and property safety are put in jeopardy. Additionally, WUI situations force fire departments to shift focus from fire suppression to structure protection, consequently increasing exposure time and risk. WUI situations are most effectively addressed prior to wildfire occurrence by individual homeowners. Mitigation strategies include reducing flammable vegetation and debris within 30 feet of the structure, choosing less flammable landscape species, using fire resistant building materials, and practicing safe open burning techniques. Currently in Ohio, there a numerous codes in place that regulate buildings and fire safety. The Ohio Fire Code 1301: 7-7 establishes regulations affecting or relating to structures, processes, premises and safeguards regarding:

1. The hazard of fire and explosion arising from the storage, handling or use of structures, materials or devices.
2. Conditions hazardous to life, property or public welfare in the occupancy of structures or premises.
3. Fire hazards in the structure or on the premises from occupancy or operation.

4. Matters related to the construction, extension, repair, alteration or removal of fire protection systems.
5. Conditions affecting the safety of fire fighters and emergency responders during emergency operations.

Because nearly all wildfire occurrences in Ohio are human caused, wildfire prevention through community outreach, education, and local fire department cooperation are critical to decreasing wildfire occurrence and minimizing damage. When local fire departments take the lead on community safety, chances for success are greater because of the leadership and trust that local responders have with community members. The ODNR Division of Forestry supports local fire departments by providing educational materials, brochures, and wildfire prevention handouts for events. The Division of Forestry also supports local Fire Departments by providing wildfire suppression training, grant opportunities, and other capacity-building programs.

Open burning (burning of yard waste or debris) is regulated by state laws and local burning ordinances, which may vary from one jurisdiction to another. ORC addresses kindled fires regulations, and states that outside municipal limits, open burning is prohibited from 6 am to 6 pm during the months of March, April, May, October and November. It is during these times of the year and days that wildfires are most likely to occur and are the most difficult to control. Additionally, the Ohio EPA enforces OAC 3745.19, which regulates materials that may or may not be incinerated through open burning. Prohibited substances include petroleum based materials, food waste, and animal carcasses. To ensure compliance with all regulations, residents should contact their local fire official with jurisdiction for the applicable laws.

RISK ASSESSMENT

LOCATION

Wildfires in Ohio occur most frequently in the southern, southeastern, and eastern parts of the state. This area is predominantly unglaciated, hilly country, and varies in land cover type, including abundant forests and grasslands. The ODNR Division of Forestry is responsible for wildland fire protection on all state and private lands within this area. Additionally, ODNR Division of Forestry has wildfire protection responsibility in a disjoined area in northwest Ohio surrounding Maumee State Forest. Local and volunteer fire departments across these parts of Ohio typically provide initial response wildfire suppression service within their respective jurisdictions. Following response to a wildfire event, local fire departments within the ODNR Division of Forestry wildfire protection area are encouraged to file a wildfire report to ODNR Division of Forestry. Wildfire reports contain information such as date, time, location, size, etc. Filing wildfire reports to ODNR Division of Forestry is not mandatory, but is highly encouraged.

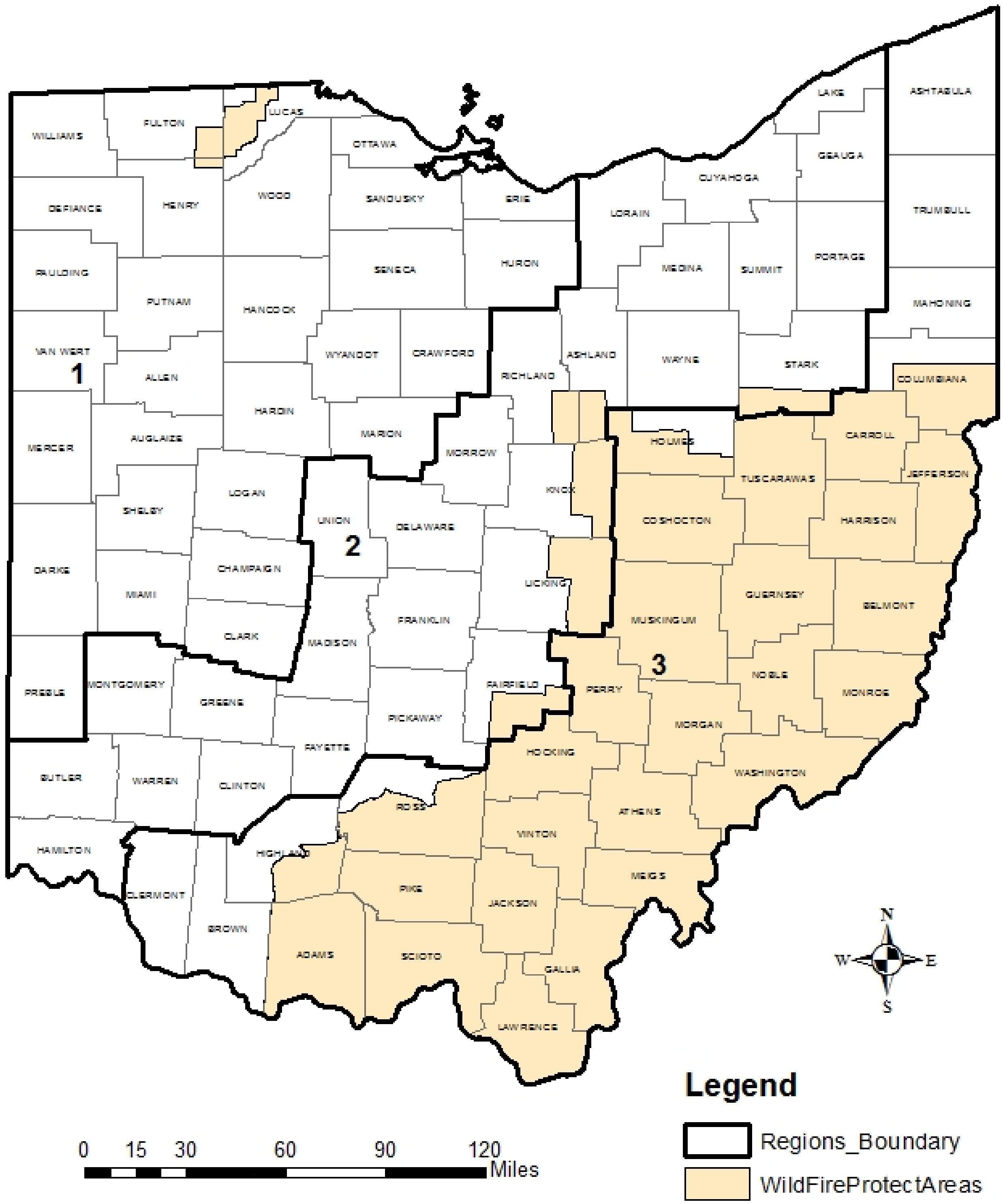
The ODNR Division of Forestry does not collect wildfire occurrence data from outside the ODNR Forestry protection area. Parts of Ohio that are outside of the protection area typically do not experience many wildfire events due to land use and land cover type (agricultural, developed urban/suburban); however certain parts of western Ohio have scattered Conservation Reserve Program (CRP) grasslands, which are a very volatile wildland fire fuel type. Since fire departments outside of the ODNR Forestry wildfire protection area do not file wildfire reports within the ODNR database, ODNR Division of Forestry does not have a dataset for wildfire occurrence in these areas. For the remaining parts of the state outside of the ODNR wildfire protection area, data obtained from the National Fire Incident Reporting System (NFIRS), established by the US Fire Administration, will be used for the purpose of research in this part of the plan. Per their website, NFIRS is a reporting standard that fire departments use to uniformly report on the full range of their activities. It is the largest national database of fire incident information and claims to comprise of about 75% of all reported fires that occur annually. For Ohio, the data is maintained and compiled by the Ohio Department of Commerce Division of State Fire Marshal and reports the compiled data to the US Fire Administration. For the historical and vulnerability analyses in this plan, counties that are entirely within the ODNR wildfire protection area will use ODNR data. Additionally, any historical data in this plan from 1/1/1997 to 11/20/2007 are fires reported from within the wildfire protection area. Counties that are partially covered or entirely outside of the area will be assessed using data from NFIRS (Map 2.7.a).

Region 1: ODNR Division of Forestry collects wildfire data from fire departments in parts of Lucas, Henry, and Fulton counties in Region 1, as these counties contain parts of Maumee State Forest. ODNR Division of Forestry does not collect wildfire report data in the remainder of Region 1 counties. Land cover type in Region 1 is predominantly agricultural land, and generally unforested; therefore, wildfire occurrence and risk are not as great as Region 3 where the topography provides abundant sources of natural combustible fuel.

Region 2: The majority of Region 2 lies outside of the ODNR Division of Forestry wildfire protection area – six counties straddle the wildfire protection area boundary. Ashland County contains Mohican State Forest, which is located completely within Region 2. Additional portions of Region 2 counties that report wildfires to ODNR Division of Forestry include southeastern Fairfield, western Licking, western Knox, and southern Stark. Region 2 contains Ohio's most developed metropolitan hubs, as well as areas of highest population density. Wildland fuel types (woodland, grasslands) are not as abundant. One notable location for potential large scale and damaging wildfire in Region 2 is the Mentor Marsh in Lake County, east of Cleveland. Mentor Marsh is a 691 acre nature preserve that has converted to nearly a monoculture of 8-12 foot high non-native Phragmites grass. This area is highly flammable, especially in spring with high winds coming off Lake Erie. Mentor Marsh has experienced 10 wildfire events since 1979, four of these being extremely noteworthy: May 1982 – 200 acres, May 1987 – 120 acres, May 1992 – 400 acres, April 2003 – 375 acres. All of these large-scale events were determined to be arson caused. Many homes, businesses, and high valued property are at risk from wildfire events in Mentor Marsh.

Region 3: Counties within Region 3 represent areas of highest wildfire risk and hazard in the State of Ohio. The vast majority of wildfires in Ohio occur in Region 3 due in part to abundant forested lands and grasslands. Population distribution and regional socio-cultural aspects contribute to higher wildfire occurrence, as well. Topography in Region 3 has more variety with numerous ridges and hollows, as opposed to flatter areas in western and central Ohio, which contributes to more complex wildfire behavior. ODNR Division of Forestry has identified 101 communities at risk (CAR) to wildfire in Ohio through GIS analysis, and all 101 CAR lie within Region 3 (Map 2.7.b). ODNR Division of Forestry collects wildfire data from fire departments in all counties of Region 3, with the exception of Brown and Clermont Counties which are completely outside their protection area.

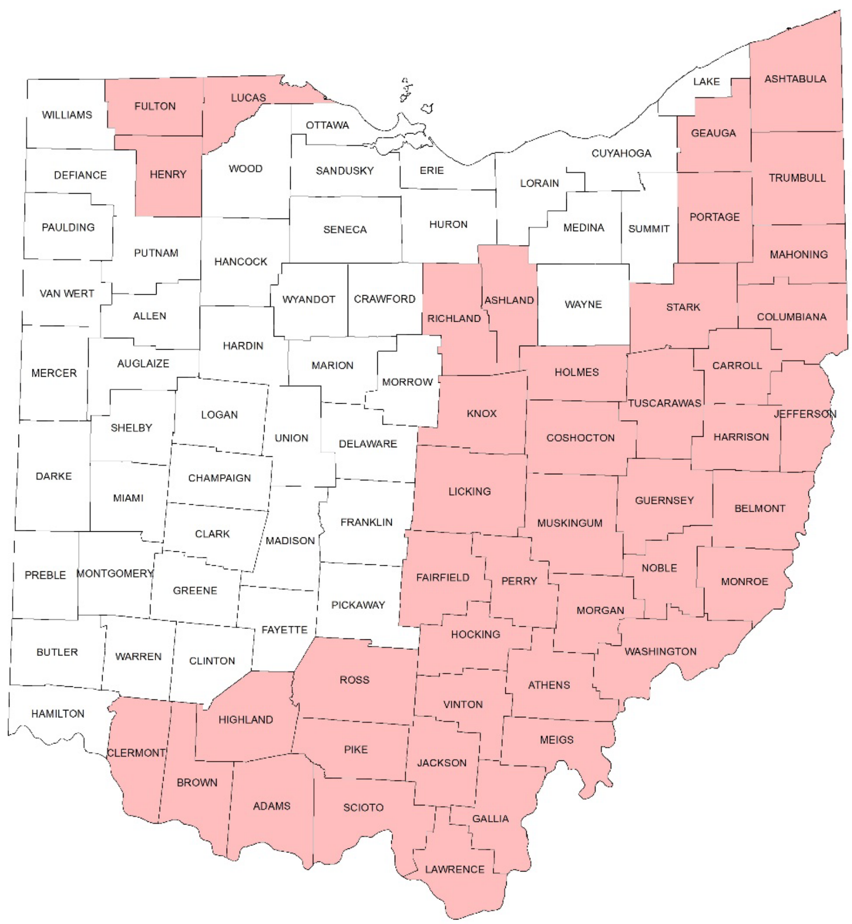
Map 2.7a
State of Ohio Wildfire Hazard Assessment
ODNR Division of Forestry Wildfire Protection Area Boundary



On February 6, 2019, The Ohio Department of Natural Resources Division of Forestry expanded the Wildfire Protection Area. According to Greg Guess, wildfire program coordinator and deputy chief for the ODNR Division of Forestry:

> "The expanded wildfire protection area contains approximately 580 fire departments, a significant increase from approximately 325 fire departments contained in the protection area prior to the expansion…The ODNR Division of Forestry is looking forward to partnering with more rural fire departments to increase wildfire protection efforts in their communities."

ODNR Division of Forestry's Expanded Forest Fire Protection Area

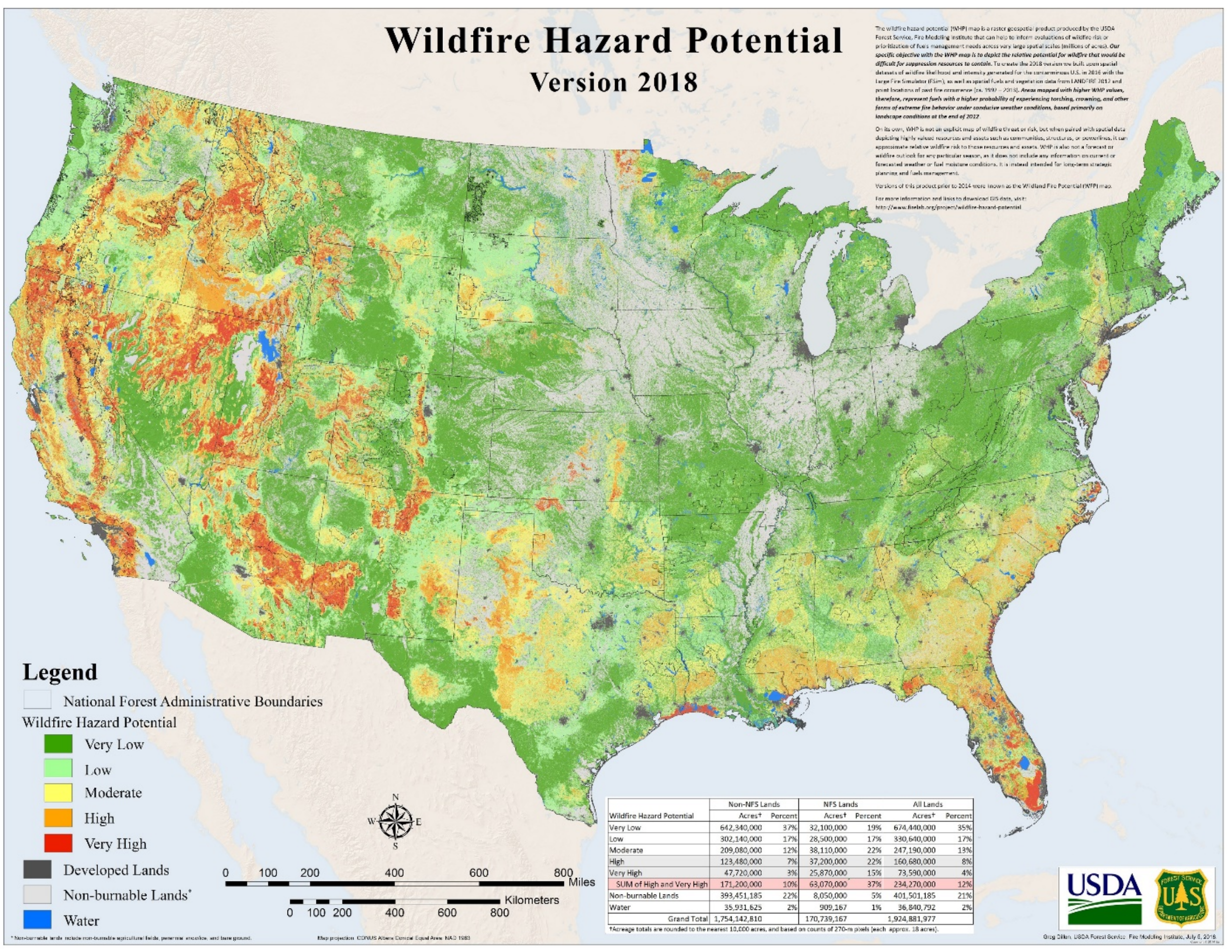


Due to the timing of the 2019 State of Ohio Hazard Mitigation Plan update and the expansion of the ODNR Wildfire Protection area, the newly expanded areas was not assessed based on incidents reported in the ODNR database. The expanded areas will continue to use the NFIRS database for historical assessment until the availability and timeframe of the expanded area's data becomes uniform with the rest of the state for future assessments.

WILDFIRE HAZARD POTENTIAL

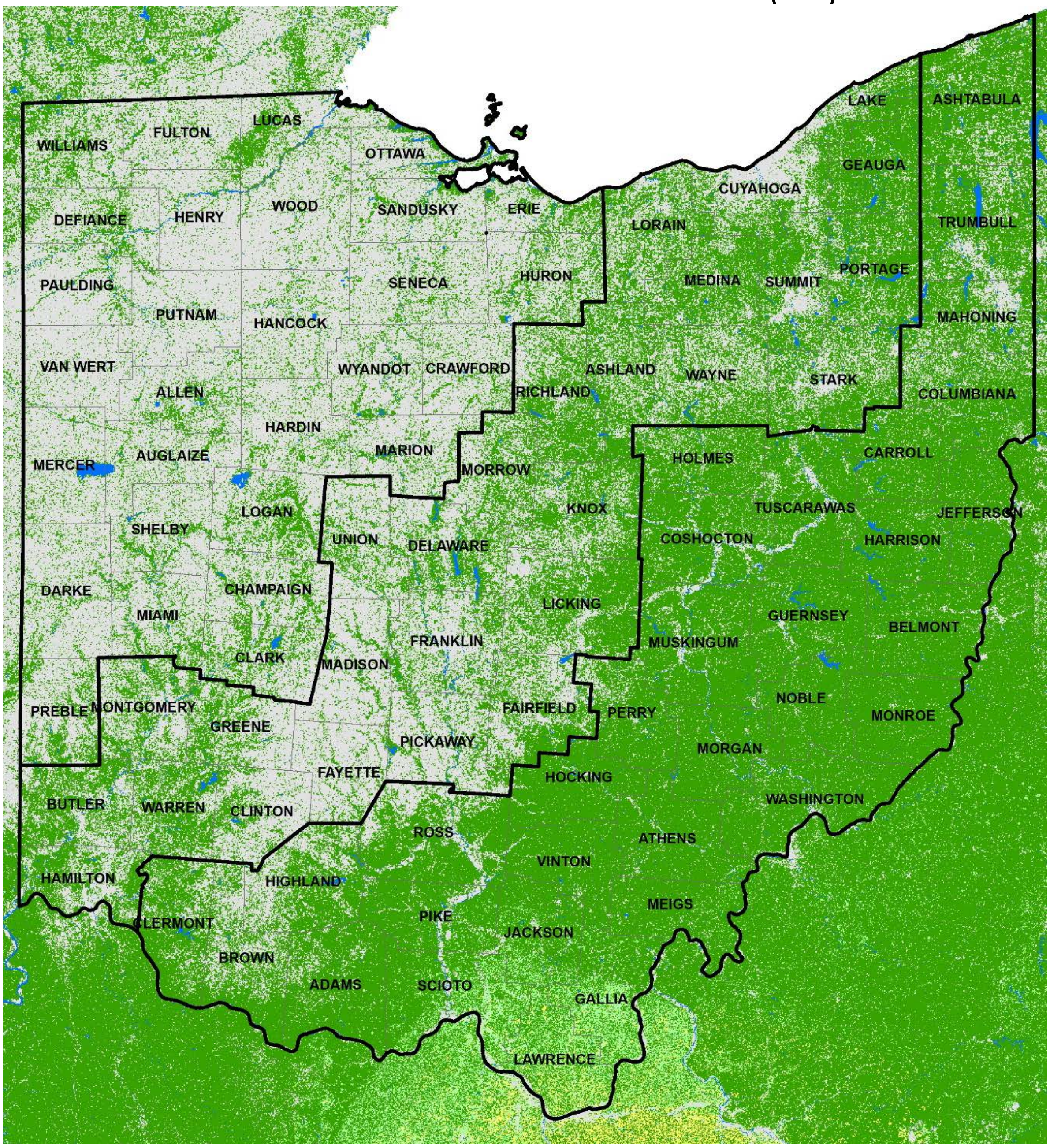
Per the US Forest Service, the wildfire hazard potential (WHP) map is a raster geospatial product produced by the USDA Forest Service, Fire Modeling Institute that can help to inform evaluations of wildfire risk or prioritization of fuels management needs across very large landscapes (millions of acres). It was produced for all of the conterminous United States at a 270-meter resolution. Areas mapped with higher WHP values represent fuels with a higher probability of experiencing torching, crowning, and other forms of extreme fire behavior under conducive weather conditions, based primarily on landscape conditions at the end of 2012. On its own, WHP is not an explicit map of wildfire threat or risk, but when paired with spatial data depicting highly valued resources and assets such as communities, structures, or powerlines, it can approximate relative wildfire risk to those resources and assets. WHP is also not a forecast or wildfire outlook for any particular season, as it does not include any information on current or forecasted weather or fuel moisture conditions. It is instead intended for long-term strategic planning and fuels management.

Map 2.7.b
USDA Forest Service Wildfire Hazard Potential



Source: https://www.firelab.org/project/wildfire-hazard-potential

Map 2.7.c
USDA Forest Service Wildfire Hazard Potential (Ohio)



Based on the WHP 2018 map, Ohio consists of areas of non-burnable to moderate wildfire potential. Most of the wildfire potential and risk exists in the south eastern portion of the state which is also where the ODNR Division of Forestry primarily designates as wildfire protection area. While the vast majority of the state does not have a high potential of wildfire, the potential exists statewide.

LHMP DATA

Scioto County

The Scioto County 2013 Hazard Mitigation Plan states that according to ODNR Division of Forestry Wildfires records, from January 1, 1993 to August 20, 2002, Scioto County experienced wildfires that destroyed 5,482 acres. The most frequent causes of these fires include: debris burning (63%), unknown (13%), and equipment fires (9%). No damages or injuries were reported. April 2010 saw the Largest State Wildfire in Ohio History at Shawnee Forest. Estimated response costs and damage exceeded $175,000.

Jackson County

According to the Jackson County 2017 Hazard Mitigation Plan, Fifty-one percent of Jackson County is forested and another 10% is scrub and brush land. Jackson and Liberty Townships are 74% to 79% forested. These fires generally burn less than five acres but may threaten individual homes and outbuildings. However, they do not pose a significant threat to densely populated areas. Jackson County experiences several wildfires per year, but most are relatively small.

Harrison County

The Harrison County 2015 Hazard Mitigation Plan states that the demographic effect can be high depending on the location of the fire. Many villages within Harrison County border large forested areas and are susceptible to wildland-urban interfaces fires. In addition, the large number of tourist attractions to include parks, national forests, and campgrounds, depending on the time of the year, can increase the demographic effect as temporary population densities increase well within the forest boundaries. The fiscal effects can be large due to the disruption of infrastructure (i.e., roads, rails, and bridges) or loss of commercial and industrial facilities. As the oil and gas industry grows within Harrison County (see section 2.2.11 for more detail), a loss to large processing facilities or transmission lines can result in the loss of billions of barrels of oil and/or millions of cubic feet of natural gas. Wildfire can also effect the timber and forest product industries.

PAST OCCURRENCES

Weather is the primary factor that determines the severity of fall and spring wildfire seasons in Ohio. Drought condition, combined with windy days create red flag, or extreme high fire danger. Consequently, the past fire occurrence record can be closely linked to historical weather data. Weather conditions leading up to and in 1930 resulted in the worst year to date for wildfires in Ohio, as 15,400 acres were recorded as burning over the course of the year.

Extreme drought in 1950 that continued for the next several years provided for very active wildfire seasons as well. March 27, 1950 is considered the worst day in Ohio fire control history – 65 fires burned a total of 5,900 acres. In 1952, continued summer drought spurred a record fall fire season in Ohio and neighboring states. ODNR Division of Parks and Division of Wildlife employees assisted in suppression efforts, and the Ohio National Guard also provided assistance. A total of 680 wildfires burned 22,445 acres in the fall of 1952.

Drought conditions in 1963 required placing on alert the ODNR Division of Forestry's pilots, 2000 fire wardens, 150 ODNR Division of Forestry employees, as well as several thousand volunteer firefighters and the Ohio National Guard. One or more fires were reported every day from September 17 through November 29, and October showed a record number of fires for that month.

1988 was another severe wildfire year, as drought conditions required that Civilian Conservation Corps crews be mobilized, as well as all other trained Division employees. More recently, 1999 proved to be a busy year for wildfire in Ohio, as an above average 7,836 acres were burned by nearly 1,500 wildfires.

Between 1/1/1997 and 11/20/2007, Ohio has experienced 8,235 wildfires that have burned 42,622 acres within the ODNR Division of Forestry Wildfire Protection Area. Wildfires that have occurred on federal lands in Ohio are not included in these data. It can be safely assumed that less than 100% of all wildfires on state and public land are reported; consequently, actual total occurrence and acres burned are suspected to be higher than data indicate. Data for areas outside of the protection area was not obtained in the 2014 State of Ohio Hazard Mitigation Plan.

For the 2019 State of Ohio Hazard Mitigation Plan, the assessed area was expanded from just the ODNR Division of Forestry Wildfire Protection Area to the entire state. In order to obtain historical data for each county, two different datasets were looked at: the ODNR Division of Forestry database, and NFIRS. Counties that are entirely within the ODNR wildfire protection area will use ODNR data. Counties that are partially covered or entirely outside of the area will be assessed using data from NFIRS. Between 1/1/1997 and 11/20/2007, there were 7,963 wildfire events statewide that burned approximately 60,620 acres. 6,609, or 83%, of the 7,963 reported events were classified as 9.99 acres and under. 493 events were from 10 to 99.99 acres, and 19 events were reported as 100 acres or more. Events that reported less than one acre burned were not assessed.

Region 1 had the second highest number of reported events and acres burned. 2,369 events were reported in this timeframe that burned 19,205 acres. Region 2 had the lowest numbers of the three regions at 1,814 events and 9,946 acres burned. Region 3 had the highest number of reported events at 3,780 as well as the highest number of acres burned at 31,469.

Table 2.7.a

Past Occurences of Wildfire Events (1/1/07 to 12/31/2017)										
Region 1										
County	Total Fire Events	Total Acres Burned	Average Acres/Event	Est. Events per Year	1 to 9.99 Acres		10 to 99.99 Acres		100+ Acres	
					# of Events	% of Total	# of Events	% of Total	# of Events	% of Total
Allen	84	477	5.68	8	74	88.10%	9	10.71%	1	1.19%
Auglaize	52	588	11.31	5	38	73.08%	13	25.00%	1	1.92%
Champaign	57	405	7.11	5	43	75.44%	14	24.56%	0	0.00%
Clark	72	524	7.28	7	57	79.17%	14	19.44%	1	1.39%
Crawford	34	219	6.44	3	25	73.53%	9	26.47%	0	0.00%
Darke	148	868	5.86	13	121	81.76%	26	17.57%	1	0.68%
Defiance	92	800	8.70	8	69	75.00%	22	23.91%	1	1.09%
Erie	49	375	7.65	4	37	75.51%	12	24.49%	0	0.00%
Fulton	111	763	6.87	10	90	81.08%	21	18.92%	0	0.00%
Hancock	74	439	5.93	7	59	79.73%	15	20.27%	0	0.00%
Hardin	115	789	6.86	10	93	80.87%	22	19.13%	0	0.00%
Henry	124	1136	9.16	11	88	70.97%	35	28.23%	1	0.81%
Huron	78	707	9.06	7	59	75.64%	18	23.08%	1	1.28%
Logan	117	683	5.84	11	103	88.03%	13	11.11%	1	0.85%
Lucas	73	426	5.84	7	62	84.93%	10	13.70%	1	1.37%
Marion	59	473	8.02	5	46	77.97%	13	22.03%	0	0.00%
Mercer	110	665	6.05	10	86	78.18%	24	21.82%	0	0.00%
Miami	69	407	5.90	6	56	81.16%	13	18.84%	0	0.00%
Ottawa	53	402	7.58	5	40	75.47%	13	24.53%	0	0.00%
Paulding	49	569	11.61	4	32	65.31%	16	32.65%	1	2.04%
Preble	69	839	12.16	6	54	78.26%	12	17.39%	3	4.35%
Putnam	120	1793	14.94	11	97	80.83%	22	18.33%	1	0.83%
Sandusky	63	624	9.90	6	41	65.08%	22	34.92%	0	0.00%
Seneca	68	629	9.25	6	52	76.47%	15	22.06%	1	1.47%
Shelby	94	770	8.19	9	75	79.79%	18	19.15%	1	1.06%
Van Wert	84	800	9.52	8	66	78.57%	16	19.05%	2	2.38%
Williams	100	620	6.20	9	81	81.00%	19	19.00%	0	0.00%
Wood	117	1152	9.85	11	87	74.36%	29	24.79%	1	0.85%
Wyandot	34	263	7.74	3	26	76.47%	8	23.53%	0	0.00%
TOTAL	2,369	19205	8.11	215	1857	78.39%	493	20.81%	19	0.80%

Table 2.7.a (Continued)

Past Occurences of Wildfire Events (1/1/07 to 12/31/2017)										
Region 2										
County	Total Fire Events	Total Acres Burned	Average Acres/Event	Est. Events per Year	1 to 9.99 Acres		10 to 99.99 Acres		100+ Acres	
					# of Events	% of Total	# of Events	% of Total	# of Events	% of Total
Ashland	50	346	6.92	5	44	88.00%	5	10.00%	1	2.00%
Butler	70	295	4.21	6	64	91.43%	6	8.57%	0	0.00%
Clinton	134	897	6.69	12	113	84.33%	20	14.93%	1	0.75%
Cuyahoga	27	102	3.78	2	25	92.59%	2	7.41%	0	0.00%
Delaware	55	227	4.13	5	50	90.91%	5	9.09%	0	0.00%
Fairfield	103	423	4.11	9	93	90.29%	10	9.71%	0	0.00%
Fayette	44	343	7.80	4	36	81.82%	8	18.18%	0	0.00%
Franklin	46	183	3.98	4	41	89.13%	5	10.87%	0	0.00%
Geauga	32	102	3.19	3	30	93.75%	2	6.25%	0	0.00%
Greene	60	221	3.68	5	55	91.67%	5	8.33%	0	0.00%
Hamilton	87	118	1.36	8	87	100.00%	0	0.00%	0	0.00%
Knox	78	370	4.74	7	68	87.18%	10	12.82%	0	0.00%
Lake	17	43	2.53	2	16	94.12%	1	5.88%	0	0.00%
Licking	139	961	6.91	13	117	84.17%	20	14.39%	2	1.44%
Lorain	37	217	5.86	3	36	97.30%	0	0.00%	1	2.70%
Madison	54	554	10.26	5	40	74.07%	13	24.07%	1	1.85%
Medina	39	381	9.77	4	35	89.74%	3	7.69%	1	2.56%
Montgomery	51	199	3.90	5	48	94.12%	3	5.88%	0	0.00%
Morrow	55	258	4.69	5	50	90.91%	5	9.09%	0	0.00%
Pickaway	57	881	15.46	5	38	66.67%	17	29.82%	2	3.51%
Portage	113	389	3.44	10	105	92.92%	8	7.08%	0	0.00%
Richland	97	211	2.18	9	79	81.44%	18	18.56%	0	0.00%
Stark	116	618	5.33	11	99	85.34%	17	14.66%	0	0.00%
Summit	30	218	7.27	3	24	80.00%	6	20.00%	0	0.00%
Union	81	565	6.98	7	62	76.54%	19	23.46%	0	0.00%
Warren	53	590	11.13	5	48	90.57%	3	5.66%	2	3.77%
Wayne	89	234	2.63	8	85	95.51%	4	4.49%	0	0.00%
TOTAL	1,814	9946	5.48	165	1588	87.54%	215	11.85%	11	0.61%

Because Region 3 primarily lies within the ODNR Division of Forestry Wildfire Protection area, the ODNR data was used to for historical and vulnerability analysis for most counties listed in Table 2.7.b. Counties noted with an asterisk (*) will use NFIRS data as they are either partly or completely outside of the protection area.

Table 2.7.b

Past Occurences of Wildfire Events (1/1/07 to 12/31/2017)										
Region 3										
County	Total Fire Events	Total Acres Burned	Average Acres/Event	Est. Events per Year	1 to 9.99 Acres		10 to 99.99 Acres		100+ Acres	
					# of Events	% of Total	# of Events	% of Total	# of Events	% of Total
Adams	125	890	7.12	11	100	80.00%	25	20.00%	0	0.00%
Ashtabula*	137	843	6.15	12	123	89.78%	12	8.76%	2	1.46%
Athens	84	426	5.07	8	78	92.86%	5	5.95%	1	1.19%
Belmont	66	514	7.79	6	55	83.33%	11	16.67%	0	0.00%
Brown*	82	572	6.98	7	62	75.61%	19	23.17%	1	1.22%
Carroll	111	1456	13.12	10	85	76.58%	23	20.72%	3	2.70%
Clermont*	81	373	4.60	7	71	87.65%	10	12.35%	0	0.00%
Columbiana*	80	258	3.23	7	76	95.00%	4	5.00%	0	0.00%
Coshocton	91	1004	11.03	8	70	76.92%	19	20.88%	2	2.20%
Gallia	190	1911	10.06	17	146	76.84%	40	21.05%	4	2.11%
Guernsey	102	638	6.25	9	92	90.20%	7	6.86%	3	2.94%
Harrison	50	459	9.18	5	38	76.00%	10	20.00%	2	4.00%
Highland*	182	1137	6.25	17	155	85.16%	26	14.29%	1	0.55%
Hocking	99	980	9.90	9	85	85.86%	12	12.12%	2	2.02%
Holmes*	53	178	3.36	5	48	90.57%	5	9.43%	0	0.00%
Jackson	161	949	5.89	15	147	91.30%	11	6.83%	3	1.86%
Jefferson	70	556	7.94	6	56	80.00%	13	18.57%	1	1.43%
Lawrence	456	4430	9.71	41	339	74.34%	112	24.56%	5	1.10%
Mahoning*	56	162	2.89	5	53	94.64%	3	5.36%	0	0.00%
Meigs	132	427	3.23	12	121	91.67%	11	8.33%	0	0.00%
Monroe	62	468	7.55	6	57	91.94%	4	6.45%	1	1.61%
Morgan	51	298	5.84	5	46	90.20%	5	9.80%	0	0.00%
Muskingum	145	787	5.43	13	127	87.59%	17	11.72%	1	0.69%
Noble	57	481	8.44	5	45	78.95%	11	19.30%	1	1.75%
Perry	113	710	6.28	10	103	91.15%	9	7.96%	1	0.88%
Pike	227	1309	5.77	21	193	85.02%	33	14.54%	1	0.44%
Ross*	108	855	7.92	10	86	79.63%	21	19.44%	1	0.93%
Scioto	225	6300	28.00	20	173	76.89%	44	19.56%	8	3.56%
Trumbull*	146	616	4.22	13	133	91.10%	13	8.90%	0	0.00%
Tuscarawas	87	392	4.51	8	72	82.76%	15	17.24%	0	0.00%
Vinton	94	674	7.17	9	80	85.11%	13	13.83%	1	1.06%
Washington	57	416	7.30	5	49	85.96%	7	12.28%	1	1.75%
TOTAL	3,780	31469	8.33	2861	3164	83.70%	570	15.08%	46	1.22%

PROABILITY OF FUTURE EVENTS

Based on historical events, there is a 100% probability that a wildfire will occur within any county in any given year. To further see this estimation by county, see the "Est. Events per Year" column in Table 2.7.a/b. For the historical probability of these events, see the "% of Total" columns. However, the severity of these events will depend on many factors. According to research and the historical record, wildfires have occurred every spring and fall in the hardwood forests and grasslands of southern, southeastern, and eastern Ohio for hundreds of years, and will continue to do so. The number of occurrences, size of wildfires, and severity of burn fluctuate annually in response to a variety of factors including:

- Weather – daily, monthly, seasonal, annual, and long-term trends in:
  - Precipitation
  - Relative Humidity
  - Temperature
  - Wind
- Fuels – condition of 1, 10, 100, 1000 hour fuels in terms of:
  - Moisture content
  - Arrangement
  - Accumulation level
  - Availability
  - See Map 2.7.b for The Wildfire Hazard Potential in Ohio, developed by the USDA Forest Service. It is a represention of fuels with a higher probability of experiencing extreme fire behavior under conducive weather conditions, based primarily on landscape.
- Ignitions – presence or absence of wildfire starts:
  - Human caused
    - Debris burning – compliance with ORC 1503.18, and safe debris burning techniques
    - Incendiary – arsonists at large
    - Wildfire prevention and awareness efforts
- Suppression Response – Capability and timeliness of initial attack:
  - Quickness of response to the incident
  - Local / Volunteer fire department capability
  - Availability of state and local resources
    - Number of concurrent wildfires

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHDOLOGY

In order to accurately and quantitatively determine statewide wildfire risk, ODNR Division of Forestry combined several available datasets, using GIS tools and extensions, to complete a wildfire hazard assessment. Datasets integrated in the wildfire assessment include historic wildfire occurrence and acres burned data (compiled from wildfire reports submitted to ODNR Division of Forestry from Ohio fire departments), USGS Landfire 13 Anderson Fire Behavior Fuel Models land cover dataset, and Wildland Urban Interface / Intermix (WUI) data derived from the University of Wisconsin SILVIS lab. These three datasets were chosen to represent a risk (wildfire occurrence and acres burned), hazard (land cover/fuel type), and value (population/homes through WUI). The township level was chosen to assign wildfire risk because rural fire departments in Ohio are typically organized at the township level. Evaluating wildfire hazard at the township level paints a better picture of the existing wildfire hazard at a level of organization that can affect change through operational function. It is also useful in scoring grant applications and assistance requests from the local fire departments that are responsible for particular high-risk jurisdictions.

Each of these respective datasets was converted to a raster format, and categorical values were reclassified accordingly. A weighted calculation was then performed using the ArcGIS raster calculator function, whereby a total wildfire hazard value was computed from the reclassified values as such:

(("acres_burned" + "fire_occurrence") / 2) + ("fuel_type" * 0.5) + ("wui_value" * 0.5)

The calculation resulted in a new raster. The calculated wildfire hazard value was broken into four categories and labeled low (0 to 1.185), moderate (1.186 to 2.37), high (2.38 to 3.16), and very high (3.17 and above). Areas that are blank are urban and incorporated areas that were not evaluated. Factors pertinent to overall wildfire hazard level not incorporated into the calculation include fire department capability, water availability, defensible space and accessibility of structures, and error associated with FDs who do not submit wildfire reports. The ODNR Division of Forestry wildfire hazard assessment was most recently updated in October 2012.

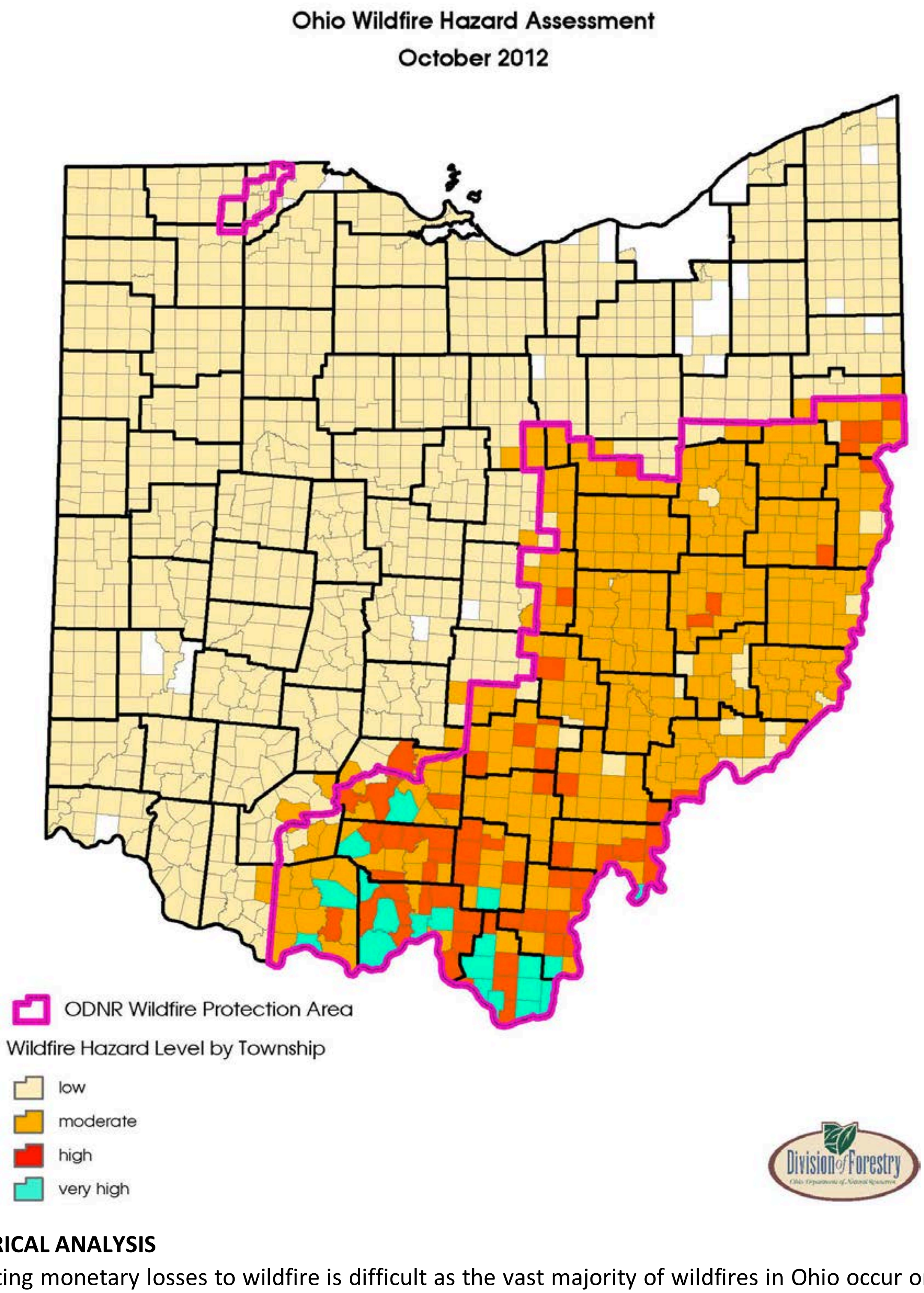
RESULTS

The product of this project, the Ohio wildfire hazard assessment map, accurately indicates wildfire hazard level for all townships in Ohio (see map 2.7.d). Communities at risk to wildfire in Ohio are those townships that were attributed with a calculated wildfire hazard value equal to High or Very High.

Region 1 and Region 2 are assessed as having generally low wildfire hazard, with several pockets of moderate risk of wildfire. Region 3 is assessed as having generally moderate risk of wildfire, with a sizeable section of southern Ohio having high or very high wildfire risk (Gallia, Lawrence, Scioto, Adams, Pike, and southern Ross Counties). Southeastern and eastern Ohio were assessed as having an additional 29 communities rated as having high wildfire hazard. Particular high-risk groups in southeastern and eastern Ohio occur in southern Athens and Meigs Counties, as well as in Belmont and southern Jefferson Counties.

High valued personal property, including homes, machinery, agricultural crops, and tree plantations in areas of high or very high wildfire hazard are more vulnerable to damage by wildfire. Fire engines belonging to local fire departments are occasionally damaged while suppressing wildfires. A great amount of personal property has been saved by fire departments through effective and safe wildfire suppression

Map 2.7.d



HISTORICAL ANALYSIS

Estimating monetary losses to wildfire is difficult as the vast majority of wildfires in Ohio occur on open land or fields and monetary losses are not often recorded. This lack of data may result in inconsistencies if an analysis was done based on reported monetary loss. However, from an exposure assumption, the greater the number of people and property in an area— and the greater variables for wildfire severity (weather, fuel, ignition, suppression response) of that area, the greater the potential of loss. Nevertheless, for the purpose of this plan, a broader (but more consistent) unit needs to be used to determine potential losses. The data that is more consistently available are the number of acres burned per event. For this estimate, the total number of acres burned from January 1st, 2007 to December 31st, 2017 for each county was divided by the respective number of events recorded. This results in the average number of acres burned per event. The results of this method can be seen in the "Acres/Event" column in Tables 2.7.a/b.

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

Using the wildfire hazard level classifications shown in Map 2.7.d, state-owned and state-leased facilities were analyzed in a GIS environment. Because of the limited attributes associated with the facility data, the assumptions used in this assessment had to be broad. Therefore, the figures projected are based on an exposure assessment. The entire property value is considered exposed based on the wildfire hazard level of the township it resides.

With the exception of Union Township in Ross County, the high and very high risk areas only fall within Region 3, which is the most undeveloped and heavily forested Region in the state. In terms of facilities in areas classified as "Very high" in ODNR's Wildfire Hazard Assessment, Scioto County had the most assets with 70 facilities valued at $20,764,332 followed by Lawrence County with 31 facilities valued at $10,611,231. In terms of facilities in areas classified as "High", Ross County had the most assets with 106 facilities valued at $236,423,088 followed by Scioto County with 40 facilities valued at $164,486,741. Overall statewide, there were 6,788 critical facilities assessed amongst the 4 classification levels. The results for the statewide overview are listed in Table 2.7.c. The county-specific results are listed in Table 2.7.d.

Table 2.7.c

State-owned and State-leased Critical Facility Wildfire Hazard Level Exposure								
State-wide								
Total # of Critical Facilities	ODNR Forestry Wildfire Hazard Level							
	Low		Moderate		High		Very High	
	# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF
6,788	4,360	$4,804,067,874	1,794	$743,306,445	465	$466,487,445	169	$37,391,207

Table 2.7.d

State-owned and State-leased Critical Facility Wildfire Hazard Level Exposure									
Region 1									
County	Total # of Critical Facilities	ODNR Forestry Wildfire Hazard Level							
		Low		Moderate		High		Very High	
		# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF
Allen	138	138	$123,081,953	0	$0	0	$0	0	$0
Auglaize	91	91	$20,888,999	0	$0	0	$0	0	$0
Champaign	58	58	$7,504,757	0	$0	0	$0	0	$0
Clark	81	81	$26,284,967	0	$0	0	$0	0	$0
Crawford	14	14	$10,388,299	0	$0	0	$0	0	$0
Darke	32	32	$8,687,352	0	$0	0	$0	0	$0
Defiance	20	20	$7,784,383	0	$0	0	$0	0	$0
Erie	93	93	$175,392,052	0	$0	0	$0	0	$0
Fulton	50	50	$4,930,612	0	$0	0	$0	0	$0
Hancock	53	53	$20,704,014	0	$0	0	$0	0	$0
Hardin	19	19	$4,343,406	0	$0	0	$0	0	$0
Henry	40	40	$5,810,222	0	$0	0	$0	0	$0
Huron	27	27	$10,829,844	0	$0	0	$0	0	$0
Logan	84	84	$12,154,380	0	$0	0	$0	0	$0
Lucas	116	116	$333,521,206	0	$0	0	$0	0	$0
Marion	116	116	$142,272,619	0	$0	0	$0	0	$0
Mercer	29	29	$8,037,491	0	$0	0	$0	0	$0
Miami	44	44	$13,864,357	0	$0	0	$0	0	$0
Ottawa	190	190	$99,375,613	0	$0	0	$0	0	$0
Paulding	4	4	$1,426,138	0	$0	0	$0	0	$0
Preble	113	113	$26,454,883	0	$0	0	$0	0	$0
Putnam	19	19	$5,634,425	0	$0	0	$0	0	$0
Sandusky	23	23	$6,999,502	0	$0	0	$0	0	$0
Seneca	59	59	$35,886,799	0	$0	0	$0	0	$0
Shelby	60	60	$29,660,305	0	$0	0	$0	0	$0
Van Wert	23	23	$8,258,684	0	$0	0	$0	0	$0
Williams	21	21	$8,502,979	0	$0	0	$0	0	$0
Wood	59	59	$70,021,518	0	$0	0	$0	0	$0
Wyandot	45	45	$13,019,332	0	$0	0	$0	0	$0
TOTAL	1,721	1,721	$1,241,721,091	0	$0	0	$0	0	$0

Table 2.7.d (Continued)

State-owned and State-leased Critical Facility Wildfire Hazard Level Exposure										
Region 2										
County	Total # of Critical Facilities	ODNR Forestry Wildfire Hazard Level								
		Low		Moderate		High		Very High		
		# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF	
Ashland	146	32	$19,300,471	114	$45,368,964	0	$0	0	$0	
Butler	37	37	$19,264,969	0	$0	0	$0	0	$0	
Clinton	71	71	$16,633,214	0	$0	0	$0	0	$0	
Cuyahoga	1	1	$10,279	0	$0	0	$0	0	$0	
Delaware	109	109	$68,818,336	0	$0	0	$0	0	$0	
Fairfield	92	27	$9,692,388	65	$77,983,487	0	$0	0	$0	
Fayette	45	45	$7,508,833	0	$0	0	$0	0	$0	
Franklin	317	317	$1,511,425,668	0	$0	0	$0	0	$0	
Geauga	75	75	$19,778,026	0	$0	0	$0	0	$0	
Greene	46	46	$24,773,257	0	$0	0	$0	0	$0	
Hamilton	25	25	$23,774,728	0	$0	0	$0	0	$0	
Knox	37	36	$39,860,400	1	$742,572	0	$0	0	$0	
Lake	23	23	$7,129,471	0	$0	0	$0	0	$0	
Licking	98	57	$138,739,051	40	$40,509,655	1	$27,500	0	$0	
Lorain	116	116	$111,907,809	0	$0	0	$0	0	$0	
Madison	137	137	$325,701,163	0	$0	0	$0	0	$0	
Medina	36	36	$19,934,012	0	$0	0	$0	0	$0	
Montgomery	40	40	$49,596,601	0	$0	0	$0	0	$0	
Morrow	37	37	$7,438,291	0	$0	0	$0	0	$0	
Pickaway	211	211	$233,138,844	0	$0	0	$0	0	$0	
Portage	102	102	$22,963,033	0	$0	0	$0	0	$0	
Richland	124	80	$110,097,403	44	$12,671,717	0	$0	0	$0	
Stark	51	50	$106,330,251	1	$685,702	0	$0	0	$0	
Summit	77	77	$128,011,211	0	$0	0	$0	0	$0	
Union	60	60	$89,278,962	0	$0	0	$0	0	$0	
Warren	182	182	$159,065,607	0	$0	0	$0	0	$0	
Wayne	17	17	$8,689,815	0	$0	0	$0	0	$0	
TOTAL	2,312	2,046	$3,278,862,093	265	$177,962,097	1	$27,500	0	$0	

Table 2.7.d (Continued)

State-owned and State-leased Critical Facility Wildfire Hazard Level Exposure									
Region 3									
County	Total # of Critical Facilities	ODNR Forestry Wildfire Hazard Level							
		Low		Moderate		High		Very High	
		# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF	# of CF	Value of CF
Adams	86	0	$0	50	$6,010,266	0	$0	36	$1,702,071
Ashtabula	198	198	$36,092,722	0	$0	0	$0	0	$0
Athens	76	5	$12,116,110	68	$38,460,045	3	$171,250	0	$0
Belmont	91	1	$22,108	90	$57,247,319	0	$0	0	$0
Brown	33	33	$39,124,798	0	$0	0	$0	0	$0
Carroll	20	0	$0	20	$4,821,847	0	$0	0	$0
Clermont	93	93	$27,079,516	0	$0	0	$0	0	$0
Columbiana	63	3	$1,150,998	45	$17,050,308	15	$1,497,943	0	$0
Coshocton	30	0	$0	30	$13,976,528	0	$0	0	$0
Gallia	85	0	$0	58	$28,282,329	27	$9,234,127	0	$0
Guernsey	181	0	$0	174	$86,597,167	7	$1,842,423	0	$0
Harrison	46	0	$0	46	$11,102,993	0	$0	0	$0
Highland	62	17	$3,271,961	43	$12,051,563	1	$6,600	1	$12,500
Hocking	168	1	$950,041	132	$14,854,928	35	$5,120,754	0	$0
Holmes	29	2	$837,134	14	$1,421,316	13	$8,221,793	0	$0
Jackson	46	0	$0	22	$13,801,180	10	$3,971,460	14	$1,664,476
Jefferson	59	10	$4,729,060	43	$5,675,815	6	$924,352	0	$0
Lawrence	32	0	$0	0	$0	1	$1,458,701	31	$10,611,231
Mahoning	77	77	$73,513,718	0	$0	0	$0	0	$0
Meigs	47	0	$0	10	$2,793,291	37	$7,297,553	0	$0
Monroe	31	5	$5,197,450	26	$6,290,191	0	$0	0	$0
Morgan	100	0	$0	96	$20,866,300	4	$22,875	0	$0
Muskingum	111	0	$0	111	$19,251,307	0	$0	0	$0
Noble	41	0	$0	41	$50,894,080	0	$0	0	$0
Perry	20	0	$0	20	$4,019,441	0	$0	0	$0
Pike	82	1	$61,687	13	$4,818,853	51	$5,844,928	17	$2,636,597
Ross	270	1	$78,375	163	$41,454,569	106	$236,423,088	0	$0
Scioto	127	0	$0	17	$8,147,074	40	$164,486,741	70	$20,764,332
Trumbull	116	116	$59,339,913	0	$0	0	$0	0	$0
Tuscarawas	106	0	$0	106	$65,210,242	0	$0	0	$0
Vinton	145	0	$0	46	$8,337,672	99	$19,255,113	0	$0
Washington	84	30	$19,919,099	45	$21,907,724	9	$680,244	0	$0
TOTAL	2,755	593	$283,484,690	1,529	$565,344,348	464	$466,459,945	169	$37,391,207

2.8 STORM SURGE / SEICHE / COASTAL FLOODING

When a storm system moves across a lake, typically the temperature drops and the wind changes direction. This disturbs the water in the lake and causes it to move in the same direction the storm is moving. The magnitude of storm surge events is dependent on a number of factors. Wind velocity and barometric pressure are the most obvious contributors to the size of an event. The orientation of the lake with respect to the direction the storm is moving is critical to the wind fetch distance over the lake, which in turn increases wave heights and storm surges. Lake Erie is oriented southwest to northeast, and the lake is shallowest near Toledo. Therefore, storms moving northeast to southwest have the potential to produce higher storm surges.

Seiche can be defined as a standing wave in an enclosed or partially enclosed body of water, which can result in coastal flooding. The most common cause of seiches in Ohio is a strong, constant wind blowing over the surface of the water forcing it to accumulate at the down-wind shore. When the wind diminishes, the water level will begin to return to its original equilibrium though a series of broad oscillations across the entire body. Often referred to as the bathtub effect, seiches cause the water levels to rise and fall along the shorelines repeatedly until equilibrium is restored. Other causes of seiches include earthquakes, changes in barometric pressure or any of a variety of atmospheric changes.

The United States Army Corps of Engineers office in Detroit, Michigan developed a profile of seiche as part of a larger work analyzing water levels for the Great Lakes. Figure 2.8.a displays the static impact storm surge has on a body of water with water levels rising on the downwind shore and falling along the upwind shore.

Figure 2.8.a

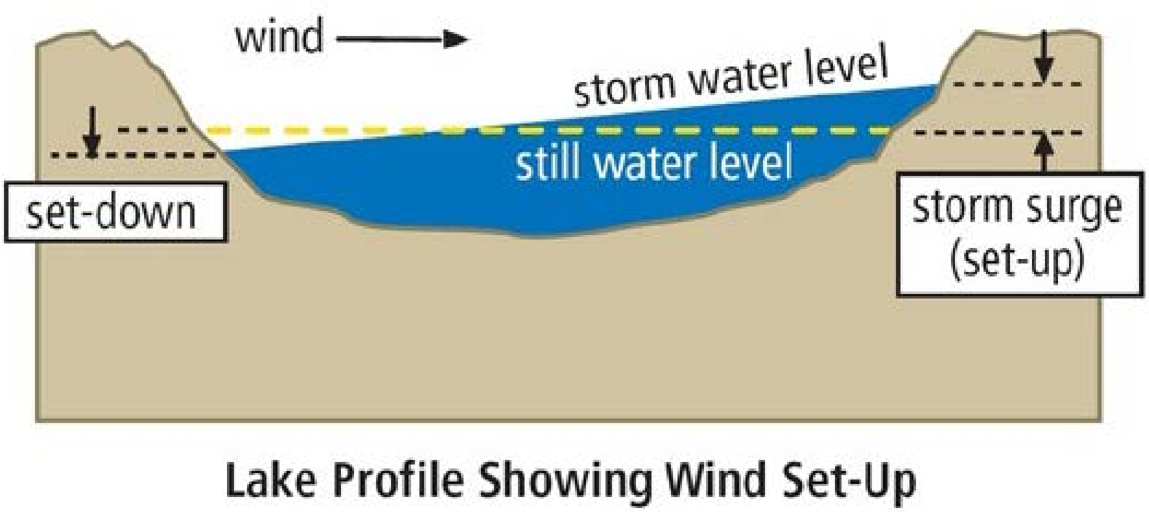


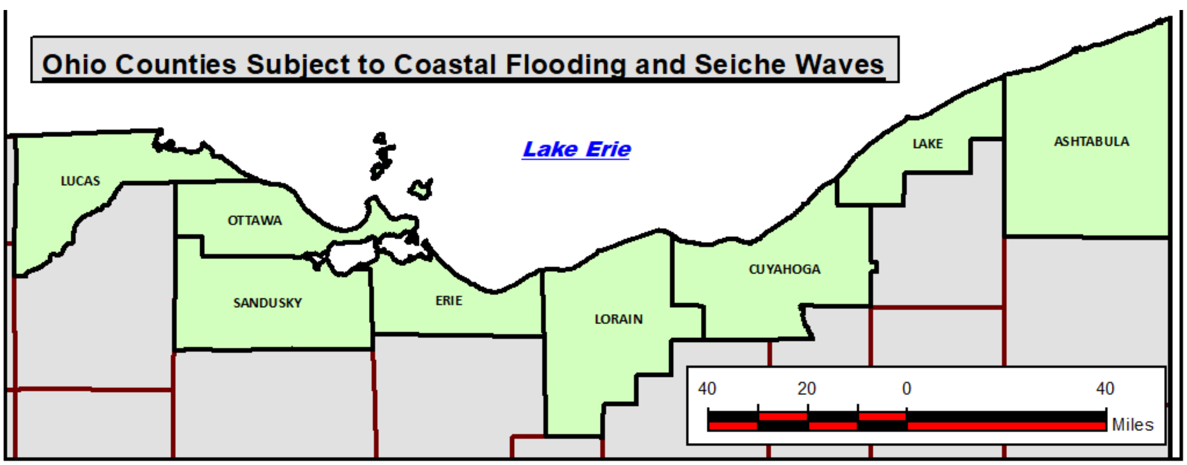
Figure 2.8.b provides a depiction of the combined effect of wind and wave actions. The base water level for the lake is marked as the SWL, or still water level. The position marked R is for run-up, the elevation a wave rises to as it spills on the shore or a structure. When winds are generated by severe storms the potential for wave action increases greatly.

Figure 2.8.b

RISK ASSESSMENT

LOCATION

Lake Erie is the most notable water body impacted by storm surge and seiches in Ohio. Although Lake Erie has 9,940 square miles of surface area implying a large body of water, it is relatively shallow with an average depth of 62 feet. Broken into what is generally referred to as the eastern, central and western basins, Lake Erie's susceptibility to storm surge and seiches varies greatly. The central basin, encompassing the area from Ohio's eastern border to Lorain, ranges from 45 to 65 feet deep with a shoreline that is mostly developed and armored. The western basin is much shallower with a depth averaging about 24 feet. The shorelines in the western basin are former coastal wetlands, many of which have been armored. One of the un-protected areas are the islands off of Ottawa County.



The seiche / coastal flooding hazard exposure is limited to counties adjacent to the south shore of Lake Erie. Region 1 counties impacted by seiche include: Lucas, Ottawa, Sandusky and Erie. Region 2 counties impacted by seiche include: Lorain, Cuyahoga, and Lake. Ashtabula is the only county impacted in Region 3.

PAST OCCURRENCES

The NCDC history of hazardous weather events currently lists only one seiche event, which occurred on November 10, 1998, impacting Erie, Lorain, Lucas and Ottawa counties. The event consisted of southwest storm force winds gusting to 69 miles per hour that pushed water away from the western end of Lake Erie towards the state of New York and Ontario Canada. As the water level fell to four feet below normal, boats and ferries were left stranded in the mud in marinas from the Maumee River east to the lagoons in Vermilion, while freighters were forced to drop anchor outside Sandusky Bay near Port Clinton. There were no estimates provided for property or other economic losses. Prolonged SW storm events create navigational hazards in the western basin due to the low water level. Put-In-Bay harbor has been near-emptied in this type of event, exposing rock and making the harbor non-navigable.

The earliest recorded seiche wave in Ohio history occurred on the morning of June 23, 1882 when an eight-foot wall of water suddenly crashed into the 9th Street Pier in Cleveland. This wave damaged or destroyed several boats and created a novel fishing experience as it propelled hundreds of fish farther inland from the docks. One fatality resulted from this event as a homeless person was sleeping near the shore and drowned. Other events occurred in May 1942, 1944 and 1948 with waves being recorded anywhere from six to 20 feet high. Seiche waves continued to oscillate from several hours to days.

The NCDC database also contains six days with events described as storm surge. The six descriptions cover a period of nearly record high water level. Lake water level is the most important factor in producing storm surges that cause wave damage and coastal flooding. The NE storms happen every year, but flooding and damage occur when there is high water.

March 13, 1997 Storm Surge - Gale force east winds to 35 knots caused the water level at the west end of Lake Erie to rise to 79 inches above low water datum, around 35 inches above the recent average lake level. Flooding and considerable beach erosion occurred along the lakeshores of Lucas, Ottawa, Sandusky and Erie Counties. In Toledo (Lucas County), roads and a parking lot were inundated, including Monroe and Second Streets, and at Point Place on Maumee Bay. Water also overtopped a road in Jerusalem Township. In Ottawa County, roads were flooded in Port Clinton and sandbagging was performed at some local businesses. Also, on Catawba Island, waves were recorded as overtopping at least one road. At Bayview (Sandusky County), County Road 259 was flooded. Losses approached $50,000 from this coastal event.

June 1, 1997 Storm Surge - Businesses and homes were flooded when strong northeasterly winds and near record high lake levels produced waves of six to eight feet, aggravating shoreline erosion and slowing discharge of stream outflow into Lake Erie. In Erie County, 75 – 100 families evacuated near the Vermilion and Huron Rivers, while those on Mudbrook Road moved to their second floors to escape the floodwaters. Also in Erie County, Riverside Avenue residents were evacuated as well as those in Franklin Flats, Rye Beach and White's Landing. Roads along the shoreline were flooded and covered with so much sand and debris that they had to be cleared with snowplows in Port Clinton and Marblehead. On Catawba Island, rising water flooded buildings and cars were submerged. Charter services cancelled trips and hundreds of travelers were stranded on South Bass Island when most ferry trips were also cancelled. In Erie County, the north end of Jackson Pier collapsed. As the water receded, a large number of fish were left behind in people's yards. Losses were estimated at $525,000 from the event, which encompassed Erie, Lorain, Lucas, Ottawa and Sandusky Counties.

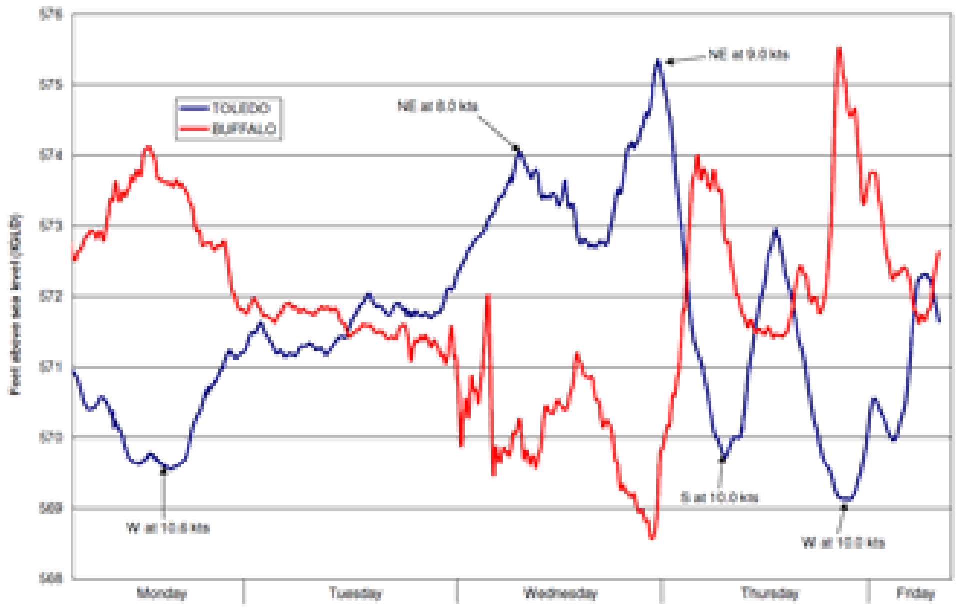
February 4, 1998 Storm Surge - Northeast winds up to 35 miles per hour caused flooding of the immediate lakeshore and beach erosion in Lucas, Erie, and Ottawa Counties. Losses were estimated at $75,000 from the event.

February 17, 1998 Storm Surge - Northeast winds up to 40 miles per hour increased the water level at the Toledo Coast Guard Station (Lucas County) to around seven feet above low water datum. Waves of seven to ten feet caused major flooding and beach erosion along the western shoreline of Lake Erie, particularly at Crystal Rock and Whites Landing (Erie County), where homes and yards were flooded. Losses were estimated at $700,000 from the event, which impacted Erie, Lucas and Ottawa Counties.

March 20, 1998 Storm Surge - North to northeast gales of 35 knots, with higher gusts, produced 11 to 14 foot waves on Lake Erie. Also, the water level at Toledo (Lucas County) was seven feet above low water datum. This combination resulted in major flooding and beach erosion. Many streets were flooded around Sandusky Bay (Ottawa, Sandusky, and Erie Counties) and Maumee Bay (Lucas County) and flooding had progressed further inland in some areas. In Sandusky and Huron (Erie County), several streets were flooded. At Beachwood Cove in Huron, the 30-foot high breakwall was destroyed and just a few feet of land separated the homes from the lake. Losses were estimated at $400,000 from the event, which impacted Sandusky, Lorain, Ottawa, Erie and Lucas counties.

April 9, 1998 Storm Surge - Northeast gales of 35 knots and water levels that peaked just below 100 inches above low water datum produced 10 to 14 foot waves, which caused major damage along the lakeshore. Many lakeshore roads were not only flooded, but also covered with rocks and other debris that, in some places, had to be removed by bulldozers. In Ottawa County, ten houses were destroyed and over 200 others were damaged, streets in downtown Port Clinton were flooded and the dike system and gravel roads in the Ottawa National Wildlife Refuge were badly damaged. Some evacuations took place at Whites Landing in Erie and Sandusky Counties and also at Wightmans Grove and Memory Marina in Sandusky County. A State of Emergency was declared and standing floodwater persisted for several days in some areas. Losses were estimated at $3,700,000 from the event, which impacted Erie, Ottawa, Lucas and Sandusky Counties.

October 17 to 21, 2011 Seiche Event - The graph below traces a recent Lake Erie seiche. From October 17 to 21, 2011, the wind shifted widely, from out of the west to out of the northeast, and to eventually out of the west again. The lines on the graph show the response of the water levels at Buffalo (red) and Toledo (blue) to these shifts. The greatest difference in water level was about 7 feet, and as the up-and-down swings of the lines show, the lake never settled to an equilibrium state over these several days.



Source: Ohio Dept. of Natural Resources, Division of Geological Survey

April 15, 2018 Storm Surge – High water, strong NE winds and rain combine to cause storm surge and flooding in Lucas, Ottawa, Erie and Sandusky Counties. Water levels within 6 inches of 1985's all-time record high, hours of 40-plus knot gale force winds from the east and 1 ½ inches of rain combined resulting in 13-15 foot waves. The municipalities of Marblehead, Port Clinton, Oak Harbor, Bayshore, Woodville, Toledo, Curtice, Point Place and Luna Pier (MI) were issued flood warnings. Damage was reported to structures in Port Clinton. Flooding inundated many farms, roads, businesses and homes on the west end of Lake Erie. State Route 2 was closed between S.R. 590 and Camp Perry, along with many other state routes along the north shore. The high water and waves caused $10-11 Million in damages to outer dikes protecting several of Lake Erie's marshes at Ottawa National Wildlife Refuge, Magee Wildlife Area, and Metzger's Marsh. There was also damage to docks and fishing piers in the area.

PROBABILITY OF FUTURE EVENTS

It is clear storm surge, coastal flooding, and seiche waves have a significant impact in Ohio. Based on the event profiles, it is possible for these events to occur between two and five times in a given year. Based on twelve events over 136 years, there is an 8.82% chance of a storm surge event significant enough to cause coastal flooding happening on any given year. The only seasonal limitation to events on Lake Erie would be during the height of winter when portions of the water surface can be covered by ice. It should be noted that ice coverage on Lake Erie varies from year to year, making it impossible to indicate any definitive time period when events cannot occur.

LHMP DATA

Cuyahoga County – Seiche. The Countywide All Natural Hazards Mitigation Plan states their northern coastline has a high frequency of seiche with a moderate vulnerability. The roads and highways along the coast can become flooded due to seiche waves. Most damage caused by seiche involves boat docks, low-lying areas along the lake shore, and river inlets to Lake Erie. The most severe seiche that hit the Cleveland area was an eight-foot seiche in the early 1990s.

Lucas County – Coastal Flooding. The Plan states that lake surges (also referred to as storm surges) are associated with extreme weather events and are responsible for coastal flooding and erosion (along

Lake Erie within Lucas County). The storms that generate large waves and lake surges can develop year-round, however within Lucas County, these events have typically occurred in the early spring and late fall months. Storm surges inundate coastal floodplains by dune over wash, the rise in water levels in inland bays and harbors, and backwater flooding through river mouths. Storm systems also generate large waves that run up and flood coastal beaches. The problem of lake surges and associated inland flooding is compounded by adjacent low-lying floodplains. The plan's history provides information that lake surges cause coastal flooding in the cities of Toledo, Oregon, the Village of Harbor View and the unincorporated Jerusalem Township. The total damages attributed to lake surges are $665,981.92, which equates to approximately $110,996.99 per event. There are limited data to calculate the probability of occurrence; however, records indicate multiple occurrences during the early spring and late fall months. It is fair to assume that future events would likely result in localized property damage to only specific areas within Lucas County, and that there is only a small potential for future events to result in injuries or deaths.

SHARPP. See section 4.3 for an analysis of SHARPP data in Ohio's coastal counties.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHODOLOGY

Loss estimates for Ohio's coastal flooding hazard were developed using FEMA's hazard analysis and loss estimation software HAZUS-MH MR3 coastal flooding application within the flood module. This application was updated in HAZUS-MH MR3 to reflect the unique issues associated with the Great Lakes. Still water lake elevations for each county were taken from the US Army Corps of Engineers report *Revised Report on Great Lakes Open-Coast Flood Levels* published April 1988.

HAZUS-MH MR3 analysis was run for each county bordering Lake Erie based on a 100-year return event. Each run was specifically adjusted to take into consideration the type of shoreline associated with each county. Sandusky County could not be analyzed due to the software failing to recognize any coastal exposure. Upon closer review, the exposure, which does exist within the county, was assessed as part of the two neighboring county evaluations.

RESULTS

Region 1 exposure to coastal flooding is limited to the coastal counties of Erie, Lucas, Ottawa and Sandusky. The total building exposure is estimated at $8,743,489,700. The numbers of impacted structures by percent of the structure damaged are estimated to be: 1 to 10 percent damaged at 455, 11 to 20 percent damaged at 2,184, 21 to 30 percent damaged at 1,476, 31 to 40 percent damaged at 1,059, 41 to 50 percent damaged at 309 and substantially damaged at 914. There are an estimated four essential facilities, which will experience at least moderate damage. According to Table 2.8.a, estimates for business interruption and building losses are $8,560,000 and $974,880,000, respectively.

Table 2.8.a

Estimate of Potential Losses to Coastal Flooding Region 1

County	Population	Building Exposure Value	1-10% Damage Count	11-20 % Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	Substantial Damage Count	Essential Facilities Count	Estimate Business Interrupt	Estimated Property Loss
Erie	79,321	$4,150,287,000	159	372	175	28	5	40	1	$2,070,000	$132,210,000
Lucas	454,029	$2,545,448,000	113	395	840	932	227	189	3	$3,260,000	$548,900,000
Ottawa	41,036	$2,047,754,700	183	1,417	461	99	77	685	0	$3,230,000	$293,770,000
TOTAL	**574,386**	**$8,743,489,700**	**455**	**2,184**	**1,476**	**1,059**	**309**	**914**	**4**	**$8,560,000**	**$974,880,000**

The majority of building loss is associated with Lucas County as a result of inland backup flooding of the Maumee River. HAZUS-MH MR3 profiles for the remaining counties do not indicate riverine backup flooding to a significant extent.

Region 2 exposure to coastal flooding is limited to the coastal counties of Cuyahoga, Lake and Lorain. The total building exposure is estimated at $2,396,004,000. The numbers of impacted structures by percent of the structure damaged are estimated to be: 1 to 10 percent damaged at 82, 11 to 20 percent damaged at 260, 21 to 30 percent damaged at 278, 31 to 40 percent damaged at 91, and 41 to 50 percent damaged at 20 and substantially damaged at 12. There are no essential facilities estimated as impacted. Estimates for business interruption and building loss are $500,000 and $82,690,000 respectively (see Table 2.8.b).

Table 2.8.b

Estimate of Potential Losses to Coastal Flooding Region 2

County	Population	Building Exposure Value	1-10% Damage Count	11-20 % Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	Substantial Damage Count	Essential Facilities Count	Estimated Business Interrupt	Estimated Property Loss
Cuyahoga	1,384,252	$1,033,868,000	2	19	16	0	2	0	0	$110,000	$10,410,000
Lake	227,324	$671,888,000	55	159	206	89	12	12	0	$240,000	$43,840,000
Lorain	285,798	$450,219,000	25	82	56	2	6	0	0	$150,000	$28,710,000
TOTAL	**1,897,374**	**$2,396,004,000**	**82**	**260**	**278**	**91**	**20**	**12**	**0**	**$500,000**	**$82,960,000**

Region 3 exposure to coastal flooding is limited to the coastal county of Ashtabula. The total building exposure is estimated at $240,290. The numbers of impacted structures by percent of the structure damaged are estimated to be: 1 to 10 percent damaged at 3, 11 to 20 percent damaged at 12, 21 to 30 percent damaged at 8, 31 to 40 percent damaged at 1, and 41 to 50 percent damaged at 0 and substantially damaged at 1. There are no essential facilities estimated as impacted. Estimates for business interruption and building loss are $80,000 and $5,280,000 respectively (see Table 2.8.c).

Table 2.8.c

Estimate of Potential Losses to Coastal Flooding Region 3

County	Population	Building Exposure Value	1-10% Damage Count	11-20 % Damage Count	21-30% Damage Count	31-40% Damage Count	41-50% Damage Count	Substantial Damage Count	Essential Facilities Count	Estimated Business Interrupt	Estimated Property Loss
Ashtabula	102,729	$240,029,000	3	12	8	1	0	1	0	$80,000	$5,280,000

GREAT LAKES COASTAL FLOOD STUDY

The FEMA has initiated a coastal analysis and mapping study to produce updated Digital Flood Insurance Rate Maps (DFIRMs) for coastal counties around the Great Lakes. This storm surge study is one of the most extensive coastal storm surge analyses to date, encompassing coastal floodplains in eight states. Ultimately, the study will update the coastal storm surge elevations for all of the U.S. shoreline of the Great Lakes. This new coastal flood hazard analyses will utilize updated 1-percent-annual chance stillwater elevations obtained from a comprehensive storm surge study conducted by the U.S. Army Corps of Engineers.

The effort to produce these maps for all the Great Lakes states began in 2012 and is expected to be completed in Ohio in 2020. The resulting DFIRMs will introduce VE Zones to Ohio and the Great Lakes Region. A VE Zone is used on a DFIRM to differentiate coastal high hazard areas from the rest of the 1%-annual-chance flood hazard area (100-year floodplain). The Zone VE designation indicates that during the 1%-chance-annual flood, wave hazards are expected to be particularly strong and have the potential to cause structural damage.

Zone VE is mapped for areas that meet one of more of the following criteria:

1. Wave runup depth exceeds 3 feet relative to the ground,
2. Wave overtopping rate exceeds 1cfs/ft.,
3. Wave heights exceed 3 feet in areas of overland wave propagation, or
4. The primary frontal dune.

Figure 2.8c illustrates wave runup and overtopping as well as overland wave propagation.

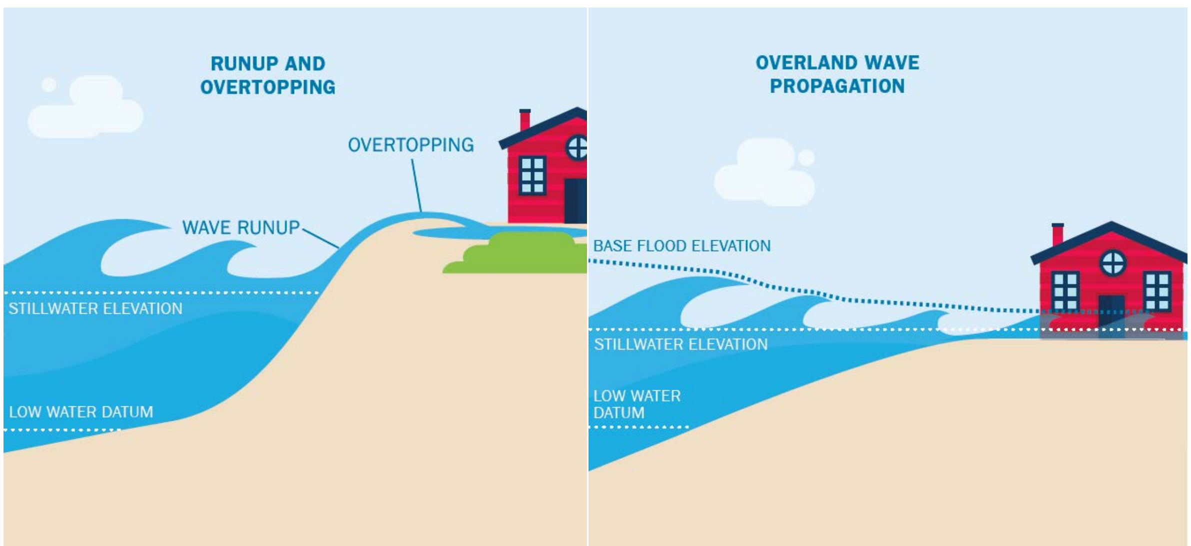


Figure 2.8d illustrates how the VE Zone designations on the FIRM relate to the wave risk.

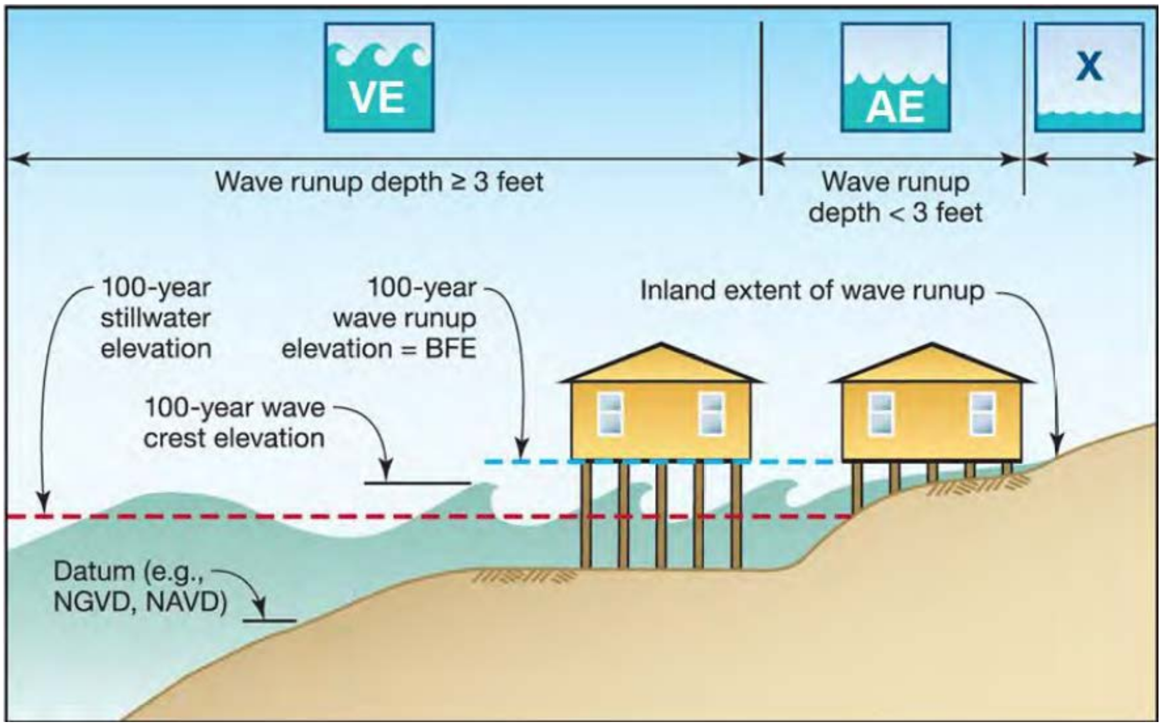


Table 2.8c summarizes building exposure based on analysis performed by the ODNR Office of Coastal Management using Preliminary DFIRM data and county auditor data. The results of this analysis will change as the Preliminary DFIRMs are reviewed and undergo the appeals period.

Table 2.8.c

County	Total Coastal Parcels	Parcels in V-Zone	Parcels with Buildings in V-Zone
Lucas	590	333	1
Ottawa	2,511	1,675	111
Erie	1,982	1,212	20
Lorain	962	1,019	28
Cuyahoga	899	875	24
Lake	1,111	1,070	20
Ashtabula	792	818	29
Total	**8847**	**7002**	**233**

* Sandusky County does not have identified V Zones

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

Using HAZUS-MH MR3 results and the FIRMs for the coastal counties, state- owned and state-leased facilities were evaluated for their involvement with seiche/coastal hazards. While all eight coastal counties were evaluated, only three of those contained facilities that could be at risk of flooding via seiche or coastal flooding, and all three are in Region 1. Table 2.8.d lists the results of this analysis.

One state-owned critical facility was located in the hazard area in Lucas County, which represents $153,000 at risk. While this facility is operated by the ODNR, it is a watercraft office that would be crucial to immediate response and rescue necessities. In terms of non-critical facilities, over 90 percent of those identified are located in Lucas County, and the majority of those involve state park facilities. Only one state-leased non-critical facility was noted to be at risk, and it is located in the City of Sandusky, Erie County, representing over $80,000 in annual rent at risk. It should be noted that no state-leased critical facilities were determined to be at risk to this hazard.

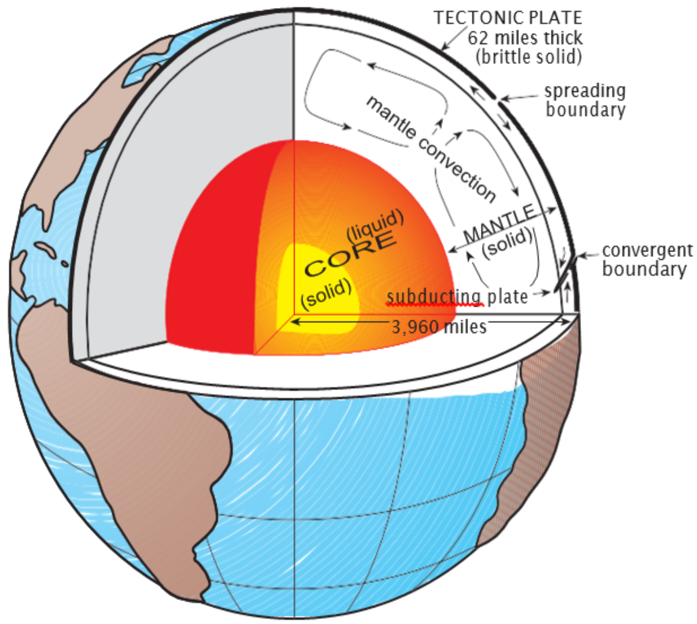
Table 2.8.d

Estimated Losses from Coastal Flooding for State-Owned and State-Leased Facilities						
County	State-Owned Critical Facility Count	State-Owned Critical Facility Value	State-Owned Non-Critical Facility Count	State-Owned Non-Critical Facility Value	State-Leased Non-Critical Facility Count	State-Leased Non-Critical Facility Rent
Erie	0	$0	5	$674,495	1	$82,131
Lucas	1	$153,000	33	$24,256,560	0	$0
Ottawa	0	$0	0	$0	0	$0
Sandusky	0	$0	6	$799,680	0	$0
TOTAL	**1**	**$153,000**	**44**	**$25,730,735**	**1**	**$82,131**

2.9 EARTHQUAKE

Earthquakes occur as a result of the constant motion of the earth. Current science describes the earth in three major regions: the core, mantle and crust. Figure 2.9a provides a three dimensional representation of the earth's regions. The core is hot and consists of two subsections. The very center of the planet's core is hottest and solid. Surrounding the solid center is a liquid (i.e. molten material/magma) layer. The mantle is cooler than the core and although solid, circulates with the consistency of malleable plastic. Through convection, the portion of the mantle closest to the core heats and subsequently rises in the same manner as the air in the earth's atmosphere. Conversely, the upper portion of the mantle transfers its heat to the crust, cools and descends back toward the core.

Figure 2.9a



Interior zones of Earth. Earth's crust consists of great plates that slowly move across the surface of Earth in response to convection cells in the mantle. Most earthquakes occur where plates meet, such as at spreading or convergent boundaries. Modified from Washington Division of Geology and Earth Resources, Information Circular No. 85, 1988.

Source: Educational Leaflet No. 9 Revised Edition 2015 Division of Geological Survey

The crust is also solid; however, unlike the mantle it is rigid and brittle. The crust consists of a number of individual plates, each in constant motion, resting on the mantle. The boundaries where plates meet are the locations where new crust develops (spreading boundary) and alternately existing crust material returns to the mantle (convergent boundary).

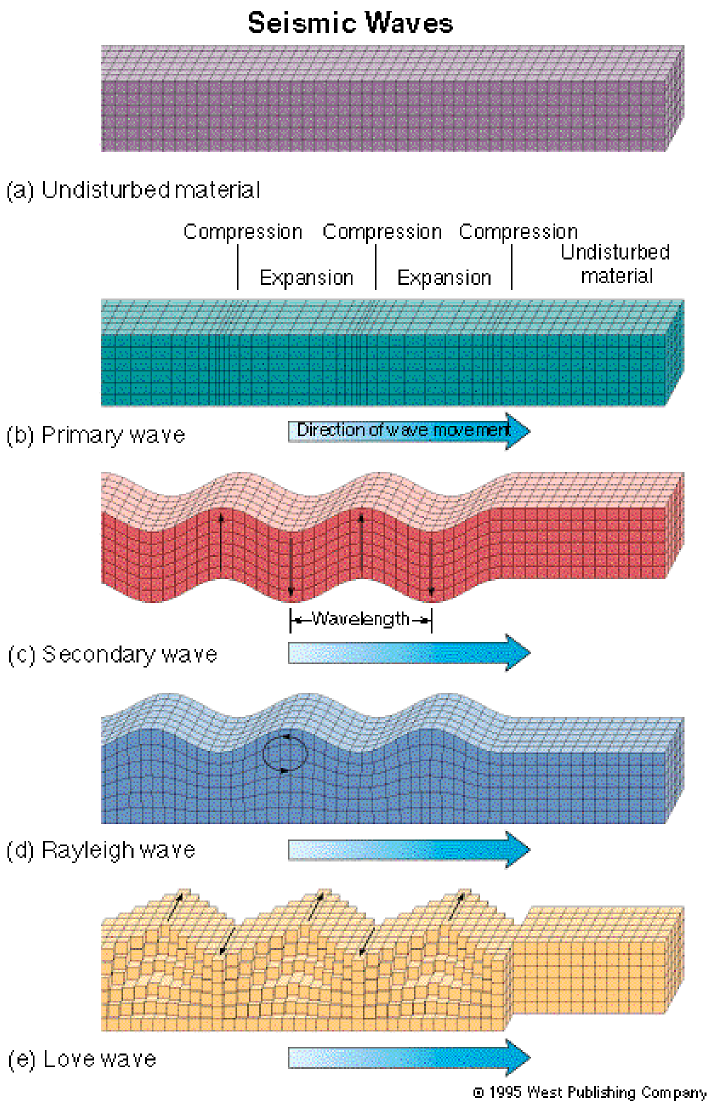
Understanding the composition of the earth is crucial because earthquakes are often associated with boundaries where the plates slide against, rise over or sink under each other. The movement at many of the plate boundaries is not smooth and consistent, but rather grinds and jerks. As entire plates move the boundaries become locked together and enormous amounts of tension build until a sudden release occurs, realigning the plate edges and creating the observed earthquake.

The locations where the crust is fractured and sliding are called faults. California has several famous faults (e.g. the San Andreas Fault), which can be clearly observed though aerial photography. In cases where the crust is pulling apart, the location is called a rift. The Reelfoot Rift and associated rift valley located in Missouri is one of the largest in North America. Ohio geologically contains both fault and rift zones.

Another significant source of earthquakes is associated with large bodies of magma, which are located near the earth's crust. The Hawaiian archipelago and Yellowstone National Park are examples where magma deposits are altering the crust and generating both volcanic activity and earthquakes.

Earthquake locations are recorded based on the latitude and longitude of the occurrence, called the epicenter, and the associated depth underneath the earth's surface. The energy released in earthquakes travels from the epicenter in seismic waves through the earth. The four major types of waves are often referred to as primary, secondary (body waves), Rayleigh and Love (surface waves) (Figure 2.9.b). Primary waves compress the earth's surface in front of it as they travel. Secondary waves cause the earth's surface to rise and fall perpendicular to its line of travel. Rayleigh waves travel in a circulating pattern similar to those in an ocean wave. Finally, Love waves cause the earth's surface to oscillate from side to side perpendicular to its line of travel. The primary and secondary waves travel faster than the Rayleigh and Love waves providing the initial evidence of an event.

Figure 2.9b



Source: West Publishing Company

Figure 2.9c

Modified Mercalli Intensity		Magnitude
I	Detected only by sensitive instruments.	1.5
II	Felt by few persons at rest, especially on upper floors; delicately suspended objects may swing.	2
III	Felt noticeably indoors, but not always recognized as earthquake; standing autos rock slightly, vibrations feel like passing truck.	2.5
IV	Felt indoors by many, outdoors by few, at night some awaken; dishes, windows, doors disturbed; standing autos rock noticeably.	3
V	Felt by most people; some breakage of dishes, windows, and plaster; disturbance of tall objects.	3.5, 4
VI	Felt by all, many frightened and run outdoors; falling plaster and chimneys, damage minor.	4.5
VII	Everybody runs outdoors; damage to buildings varies depending on quality of construction; noticed by drivers of autos.	5
VIII	Panel walls thrown out of frames; walls, monuments, and chimneys fall; sand and mud ejected; drivers of autos disturbed.	5.5
IX	Buildings shifted off foundations, cracked, or thrown out of plumb; ground cracked; underground pipes broken.	6, 6.5
X	Most masonry and frame structures destroyed; ground cracked; rails bent; landslides.	7
XI	Few structures remain standing; bridges destroyed; fissures in ground, pipes broken; landslides; rails bent.	7.5
XII	Damage total; waves seen on ground surface, lines of sight and level distorted; objects thrown up into air.	8

Scale showing general relationship between epicentral Modified Mercalli Intensities and magnitude. Intensities can be highly variable, depending on local geologic conditions. Modified from D. W. Steeples, 1978, Earthquakes: *Kansas Geological Survey pamphlet.*

Source: Educational Leaflet No. 9 Revised Edition 2015 Division of Geological Survey

Each wave affects structures differently. For example, secondary waves have much greater impact in tall structures. Additionally, each wave has unique characteristics. The secondary wave, for example, cannot travel through fluids, including the molten outer core.

Location of earthquake events has the added dimension of land / crust composition. Within the United States, areas like southern California are primarily young, hot rock that is broken by mountain ranges. Under these conditions seismic waves are somewhat limited in their ability to travel (attenuation) reducing the overall area of impact. Conversely, seismic zones in the central and eastern United States have flat-lying, cold, brittle rocks with much thicker deposits of soil and sediments. Loosely consolidated materials such as sand and soil cause seismic waves to amplify ground motion.

When seismic waves travel through unconsolidated materials it can have the effect of turning solid land into quicksand. When this phenomenon, called liquefaction, occurs, any object located in the affected area may slide over or sink into the soil. Entire buildings, roadways and bridges may be significantly damaged. One factor which greatly determines the extent of damage from an event is duration. Events can last anywhere from a few seconds to minutes. The longer the event is promulgating seismic waves the greater the opportunity for damage.

According to the US Geological Survey, The Modified Mercalli Intensity Scale (MMI) (Figure 2.9.c) was developed in 1931 and is currently used to evaluate the effects of earthquakes. It is composed of increasing levels of intensity that does not have a mathematical basis—only an arbitrary ranking based on observed effects.

RISK ASSESSMENT

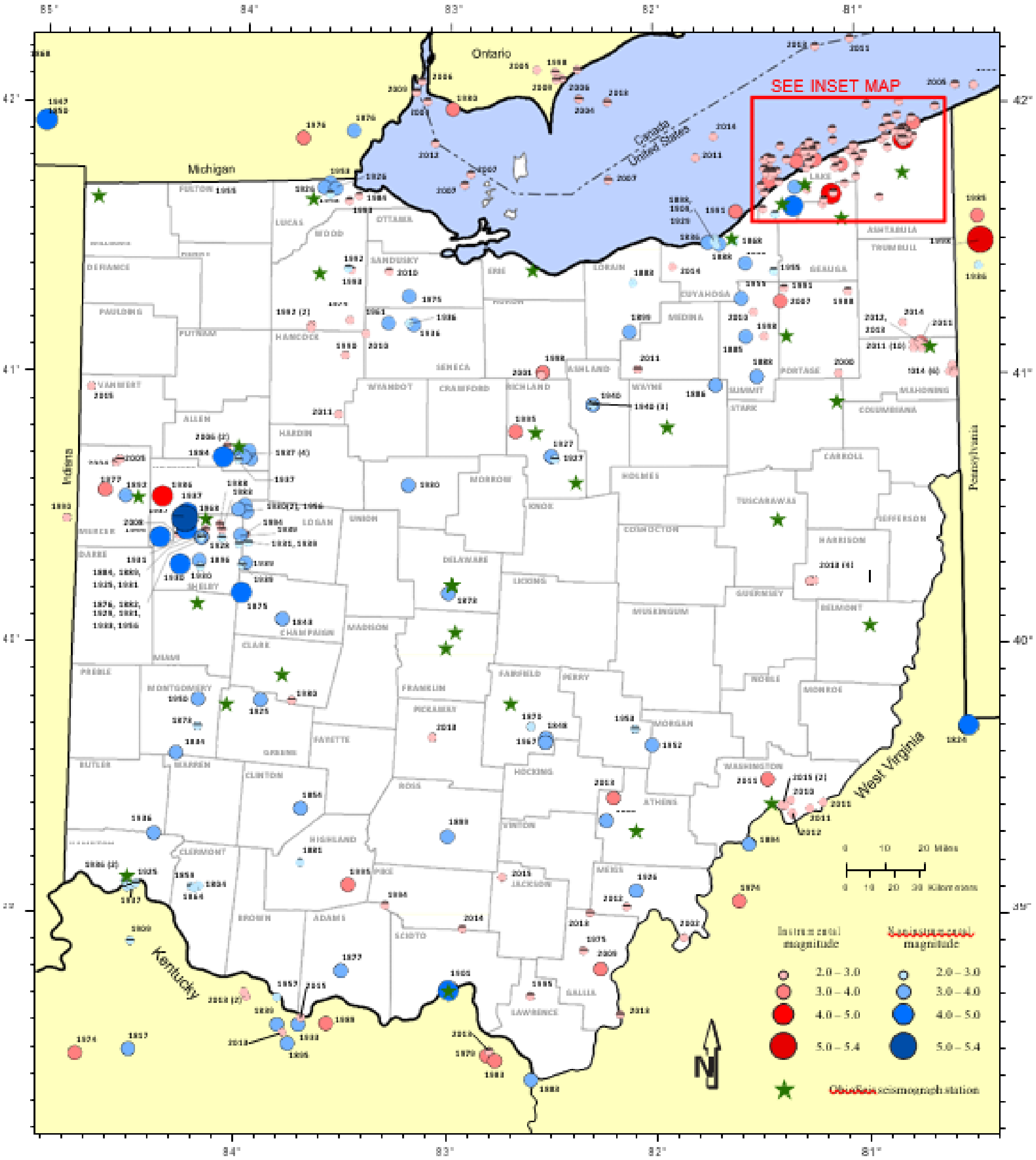
LOCATION

Earthquakes in Ohio are primarily located in the northeast and far west- central portions of the state and historically have not exceeded 5.4 magnitude (Map 2.9a). The map of historical epicenters lists all the events with magnitudes greater than 2.0. The size of the location marker increases with the magnitude of the event. Red circles represent instrumentally recorded events. Blue circles represent non-instrument recorded.

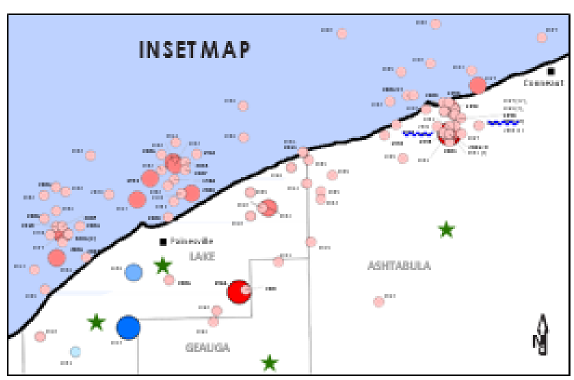
The epicenter map clearly identifies the northeast Ohio counties of Ashtabula, Geauga and Lake as one of the most earthquake-prone areas. Similarly, another earthquake-prone area is located in the west-central Counties of Auglaize, Champaign, Logan, Mercer, and Shelby. Although there are clear clusters of activity, a limited number of events have occurred and are spread over a large portion of the state.

According to information published by the ODNR Division of Geological Survey, the origins of Ohio earthquakes, as with earthquakes throughout the eastern United States, are poorly understood at this time. Those in Ohio appear to be associated with ancient zones of weakness in the Earth's crust that formed during continental collision and mountain-building events about one billion years ago. These zones are characterized by deeply buried and poorly known faults, some of which serve as the sites for periodic release of strain that is constantly building up in the North American continental plate due to continuous movement of the tectonic plates that make up the Earth's crust.

Map 2.9a

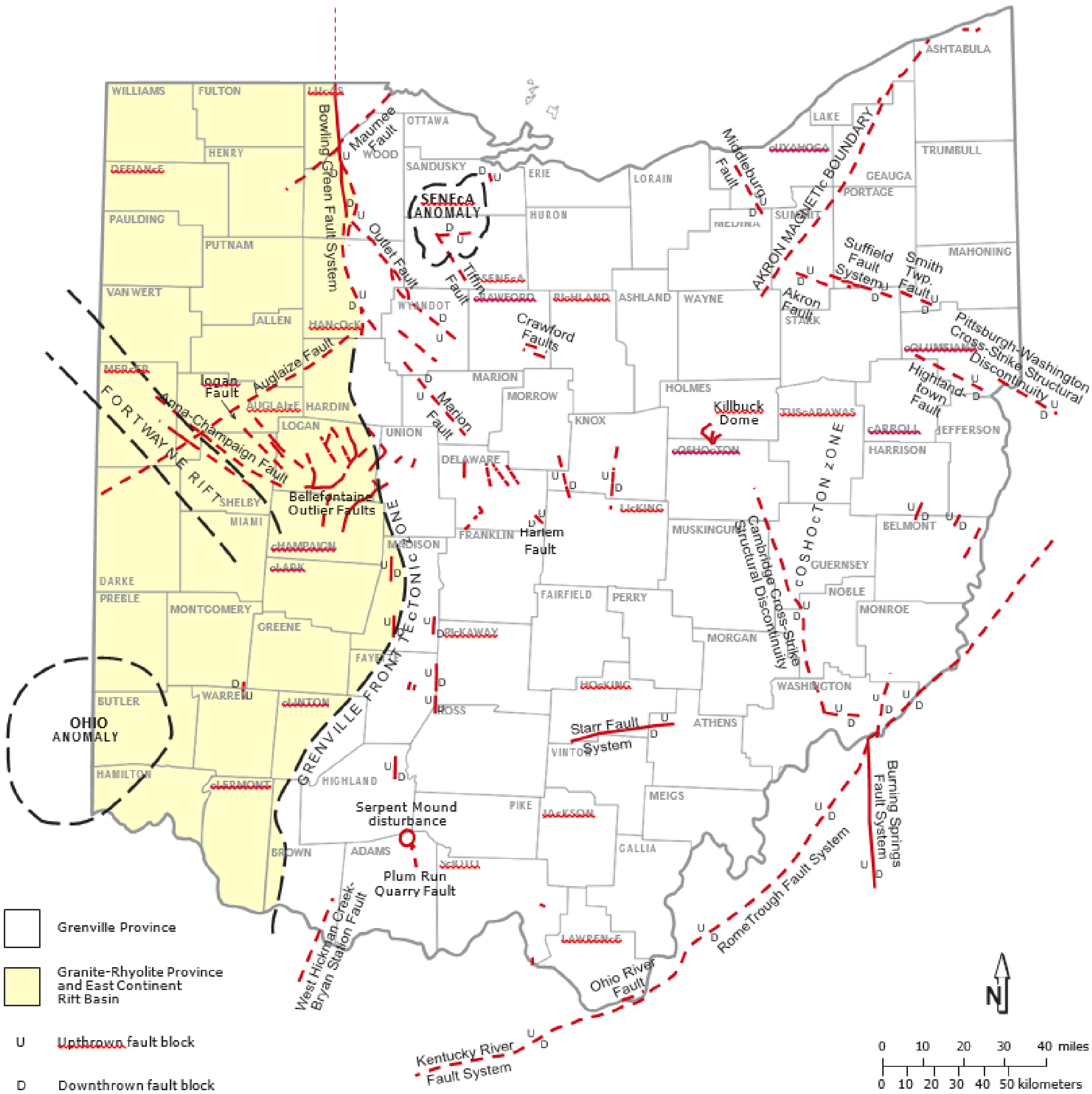


Locations of felt earthquakes or those with magnitudes of 2.0 or greater in Ohio and its border areas. Locations and magnitudes of historic earthquakes are represented by symbols corresponding to felt area or maximum epicentral MMI. Noninstrumental locations may be in error by a considerable distance, especially for early events.



Source: Educational Leaflet No. 9 Revised Edition 2015 Division of Geological Survey

Map 2.9b



Source: Educational Leaflet No. 9 Revised Edition 2015. ODNR - Division of Geological Survey

The Division of Geological Survey has developed a map of geologic features, referred to as basement structures, which lie far below the earth's surface (see Map 2.9.b). Several geologists have speculated the Akron Magnetic boundary is a fracture zone in crystalline rocks lying more than 6,000 feet below the surface. The Fort Wayne Rift along with the Anna-Champaign, Logan and Auglaize faults, though still poorly understood, can be evaluated using the existing understanding of how these structures behave.

LHMP DATA

Of the top 10 earthquakes in terms of magnitude that happened in Ohio, five occurred in Shelby County, two occurred in Ashtabula County, and Auglaize, Coshocton, Allen, and Lake each had one occurrence. Of the 384 earthquakes documented by the Ohio Department of Natural Resources, Lake, Ashtabula, and Shelby had the most occurrences of all counties in the state.

Shelby County, considered to be one of the most active seismic zones within the state, experienced more than 39 earthquakes averaging 2.80 magnitude, which includes the most damaging earthquake to strike the state at a 5.4 magnitude. The Shelby County Hazards Mitigation Plan of 2016 states that Shelby County has a moderate risk of incurring damage from earthquakes across all five vulnerability assessment categories of infrastructure, population, property, injuries/loss of life, and economic losses.

Ashtabula County experienced 53 events averaging 2.6 magnitude with their largest event having a magnitude at 4.5. The Ashtabula Hazard Mitigation Plan of 2012 states that many of the smaller magnitude earthquakes that have occurred since 1987 can be associated with a deep, now abandoned, Class I injection well located in the City of Ashtabula. The northeastern portion of Ohio is the second most seismically active area in the state.

Lake County experienced 64 events with an average of 2.53 magnitude and the second highest magnitude earthquake in the state at 5.0. The Lake County Multi-Jurisdictional Hazards Mitigation Plan updated in 2017 used HAZUS-MH to analyze a scenario of 5.0 magnitude located 10km underground and centered just off of Mentor Road, between Mentor High School and the Lakeland Freeway. It estimated that 18,273 residential, 8,679 non-residential, and 203 critical facilities are vulnerable to a loss of up to $7,275,468,199.

NATIONAL LEVEL EXERCISE, 2011 (NLE-11)

In September 2010, Ohio EMA's Mitigation Section was consulted to provide HAZUS runs for an earthquake tabletop exercise scenario. The scenario was designed for selected counties in southwest Ohio in preparation for NLE-11 (National Level Exercise 2011). The purpose is to test critical resource logistics and catastrophic planning in conjunction with FEMA Region V and participating States. HAZUS runs were produced for Hamilton, Butler, Clermont, Darke, Scioto and Warren Counties with a 5.7 moment magnitude scale epicenter in downtown Cincinnati to a depth of 10 kilometers.

The aggregate HAZUS runs resulted in 79,070 buildings with moderate damage and 4,418 buildings beyond repair. Four hundred eighty-seven (487) essential facilities would be less than 50% functional. One thousand four hundred sixty-eight (1,468) transportation systems and 201 utility systems would be damaged. Destruction is projected to produce 3.513 million tons of debris and 93 fire ignitions resulting 13,490 people displaced from their residences with $1,248,000,000 in damage. The social impact estimates 179 fatalities, 123 people with life-threatening injuries, 901 people would have to be hospitalized and 3,871 would have to be treated with first aid or at an aid station. Eight thousand eight hundred six (8,806) people would seek temporary shelter. The economic impact is projected to result in $10,828,490,000 in lost income and, $2,050,500,000 in capital stock loss. It is estimated to take 15 years for economic recovery from this event.

PAST OCCURENCES

Earthquakes are a continuously occurring hazard in Ohio. Data are available for events dating back almost 250 years. Most of Ohio's earthquake events are small, registering between 2 and 4 magnitudes. Significant events are discussed in Geological Survey document Educational Leaflet No. 9, which follows. The Ohio Department of Natural Resources have documented 384 earthquakes that have occurred since 1776.

September 19, 1884: An earthquake in the vicinity of Lima (Allen County) had an epicentral Modified Mercalli Intensity Scale (MMI) of VI. There were reports of fallen ceiling plaster as far away as Zanesville

(Muskingum County) and Parkersburg, West Virginia. On the basis of area feeling the earthquake (140,000 square miles), it is estimated to have had a magnitude of 4.8. Workmen on top of the Washington Monument in Washington, D.C., reported feeling this earthquake.

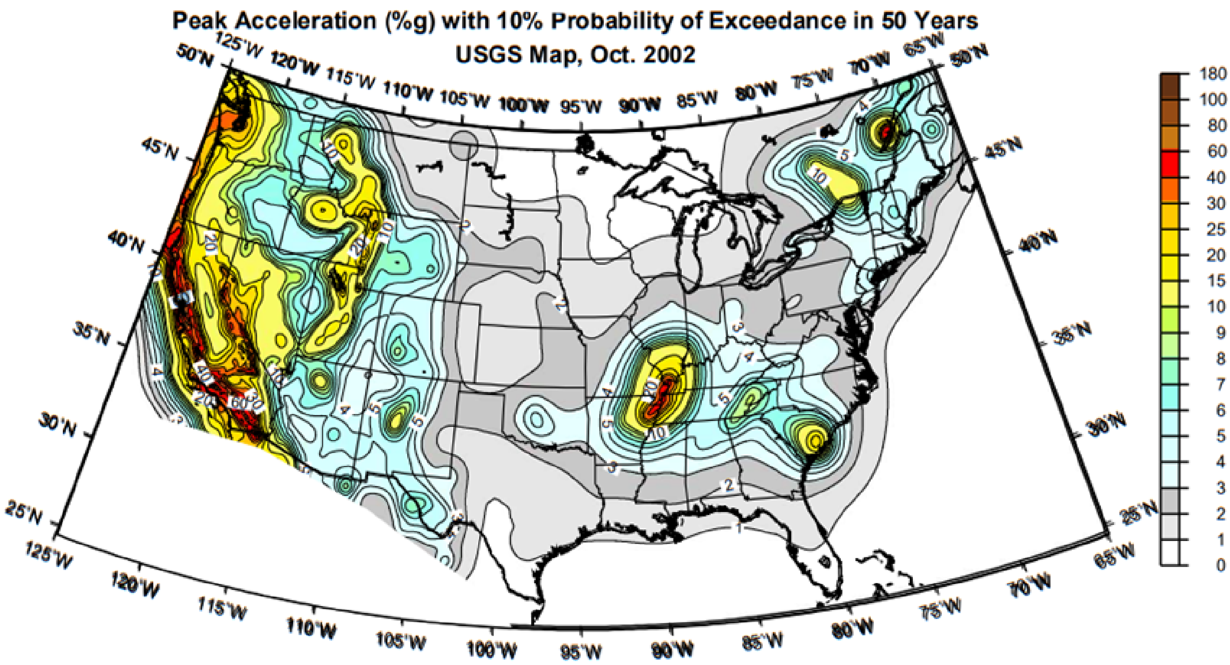
September 20, 1931: In this event, Anna and Sidney in Shelby County experienced toppled chimneys and cracked plaster. Store merchandise and crockery were knocked off shelves, and stones were jarred loose from the foundation of the Lutheran church in Anna. A ceiling collapsed in a school at Botkins, north of Anna. An MMI of VII and a magnitude of 4.7 have been assigned to this earthquake.

March 2 and 9, 1937: These two earthquakes are the most damaging to have struck Ohio. Maximum intensities were experienced at Anna (Shelby County), where an MMI of VII was associated with the March 2 event and an MMI of VIII with the March 9 event. In Anna, chimneys were toppled, organ pipes were twisted in the Lutheran church, the masonry school building was so badly cracked that it was razed, water wells were disturbed, and cemetery monuments were rotated. Both earthquakes were felt throughout a multi-state area—plaster was cracked as far away as Fort Wayne, Indiana. The March 9th event was felt throughout an area of about 150,000 square miles. Analysis of seismograms from these earthquakes by the U.S. Geological Survey (Stover and Coffman, 1993) assigned magnitudes of 4.7 and 4.9, respectively, to these events. On the basis of felt area, these earthquakes have been assigned magnitudes of 4.9 and 5.4, respectively.

January 31, 1986: This earthquake, which had a magnitude of 5.0 and an MMI in the high VI range, occurred in Lake County, east of Cleveland, in the general vicinity of a 1943 event with 4.5 magnitude. The 1986 earthquake cracked plaster and masonry, broke windows, and caused changes in water wells. The epicenter was only a few miles from the Perry nuclear power plant. It is the most intensively studied earthquake in Ohio and was the subject of several scientific reports (i.e., Nicholson and others, 1988).

PROBABILITY OF FUTURE EVENTS

Map 2.9c



Source: https://pubs.usgs.gov/of/2002/ofr-02-420/USpga500v3-508.pdf

Earthquakes have affected Ohio as early in history as written and oral records exist. There is clear precedence to expect Ohio will continue to experience seismic events for the foreseeable future. Probabilities of future events have been developed and mapped by the USGS (Map 2.9.c). The measurement used in this estimation is based on the chance of ground shaking (e.g. peak ground acceleration) as a percentage of the natural force of gravity over time. In this analysis the extreme southwestern portion of Ohio has one in ten chance of experiencing an earthquake equal in force to three percent of the earth's gravity in the next 50 years due to its proximity to the New Madrid seismic zone.

Since 1950, Ohio experienced 233 earthquakes across the three regions. Region 1 had the least number of earthquakes at 34 events, Region 2 had 77 events, and Region 3 had 121 events. Dividing the number of events by the 68 years since 1950, we get a 50 percent (.50) probability of an earthquake happening in Region 1, 100 percent (.113) in Region 2, and a 100 percent (1.78) probability of an earthquake happening in the region in any given year. The average magnitude for Region 1 is 2.76, Region 2 is 2.56, and Region 3 is 2.49. Although future earthquake events are highly likely to occur in Ohio, fortunately the state has not experienced any recorded loss of life due to earthquakes. Damages are commonly limited to poorly built structures.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHODOLOGY

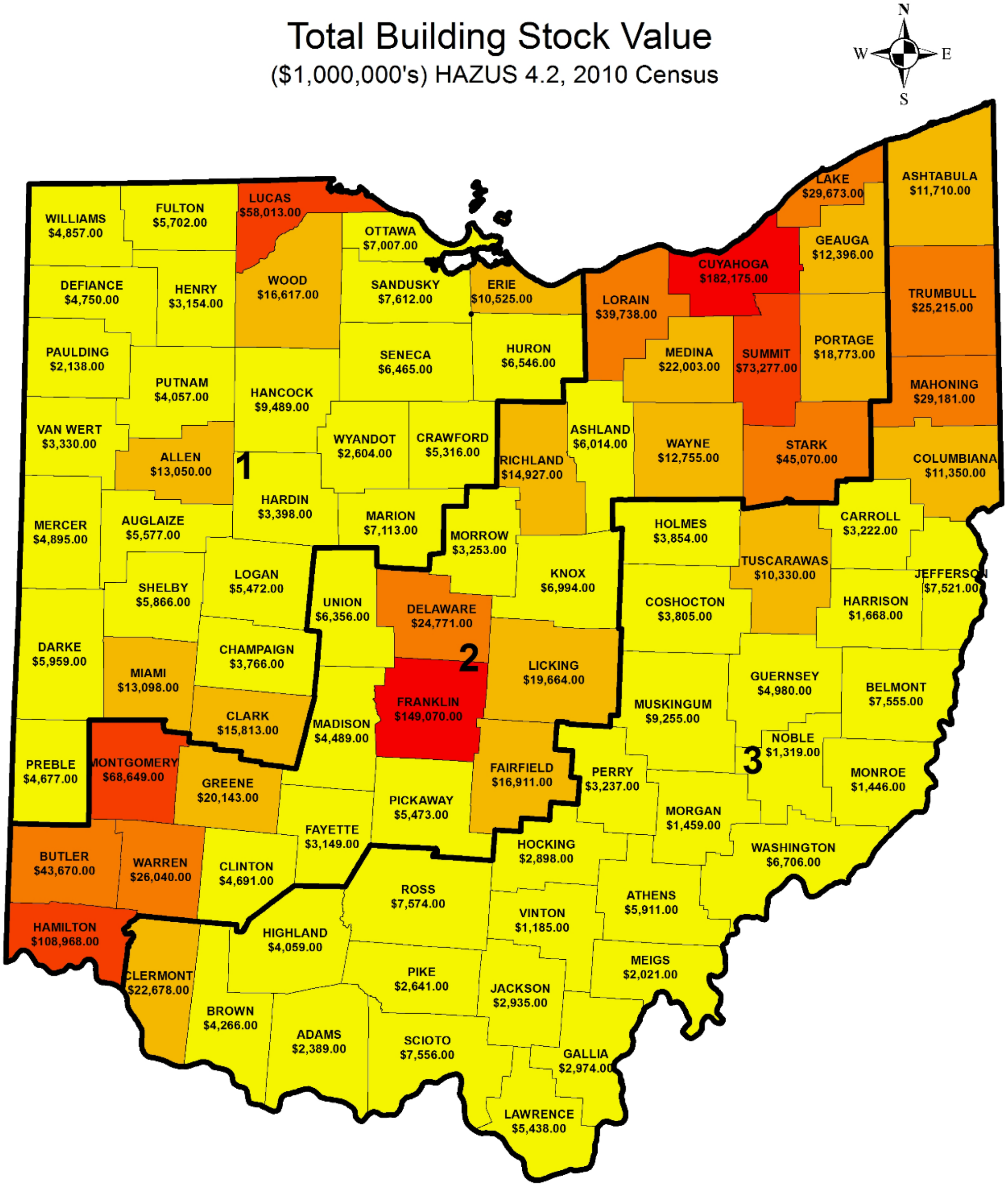
Loss estimates for Ohio's earthquake hazard were developed using FEMA's hazard analysis and loss estimation software HAZUS-MH 4.2 and its ability to simulate arbitrary events. HAZUS has been used successfully for over a decade in California's earthquake preparation and response efforts. For the purpose of this initial effort, level one analyses were completed using the program; un-manipulated, census-tract-level data were used. Results should be interpreted as estimates and cannot be considered precise losses.

There were two methods used in analyzing the vulnerabilities and loss estimates of all counties across Ohio. Because the largest earthquake that happened in Ohio was measured at a 5.4 magnitude and the average magnitude of all 384 earthquakes since 1776 is 2.58, both methods involved simulating an arbitrary event at the program's minimum magnitude of 5.0, and the depth at 5 kilometers.

The first method assessed Map 2.9a for historical hotspots of seismic activity. Based on this information, HAZUS was used to simulate events within a Lake County in Northeast Ohio, and Shelby County in Western Ohio. Shelby County had experienced Ohio's strongest earthquake to date at 5.4 magnitude while Lake County had experienced the state's second strongest at 5.0 magnitude. The epicenters of the simulated events will be set at the projected locations of their respective historical events. It is expected that losses will expand outward contiguously to other counties across the state. The cost of the damage is to the surrounding area will vary greatly on which county the earthquake is located. According to HAZUS and the 2010 census, the total building stock for Shelby County is $5,866,000,000 and is surrounded by six counties whose total building stock adds up to an estimated $38,767,000,000. Lake County has a total estimated building stock at $29,673,000,000 and is surrounded by 3 counties whose total building stock adds up to $206,281,000,000. This method estimates the damages to all Ohio counties from the earthquake event.

Unlike the first method, the second method runs an individual earthquake analysis for each county. Each analysis set the epicenter at the county seat of their respective county. These individual runs assessed only the damages specific to that county. For the total building stock value for each county, see Map 2.9d or "Total Building Value" column on the tables in the results.

Map 2.9d



Source: HAZUS 4.2 County Data based on 2010 Census

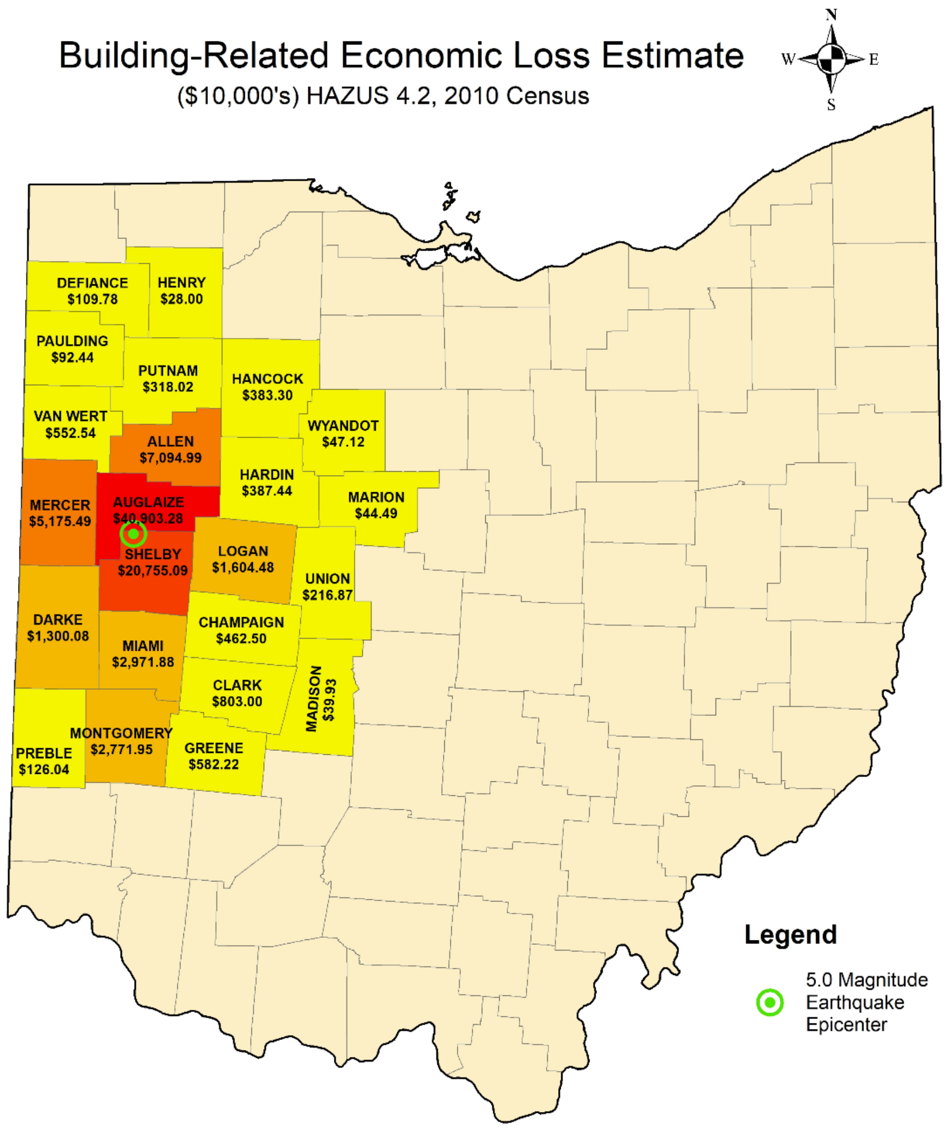
According to HAZUS and the 2010 census, the total building stock for the entire state is an estimated $1,434,296,000,000. The distribution of building stock values are generally clustered in three areas: Southwest, Central, and Northeast Ohio. These three areas are also the largest populated areas within the state including the cities of Cincinnati, Columbus, and Cleveland. The areas also all fall within Region 2 designated this plan. Region 2 has a total building stock value of $969,092,000,000 while Regions 1 and 3 are at $246,866,000,000 and $218,338,000,000 respectively.

There are four damage classifications used for each HAZUS run: Slight, Moderate, Extensive, and Complete. The descriptions for each would vary depending on the type of building damaged. For the complete definitions for different types of building category, refer to section 5.3.1 of the HAZUS Earthquake Model Technical Manual.

RESULTS

Method 1, Scenario A: Shelby County 5.0 Magnitude Earthquake Event (40.47°, -84.28°)

Map 2.9e



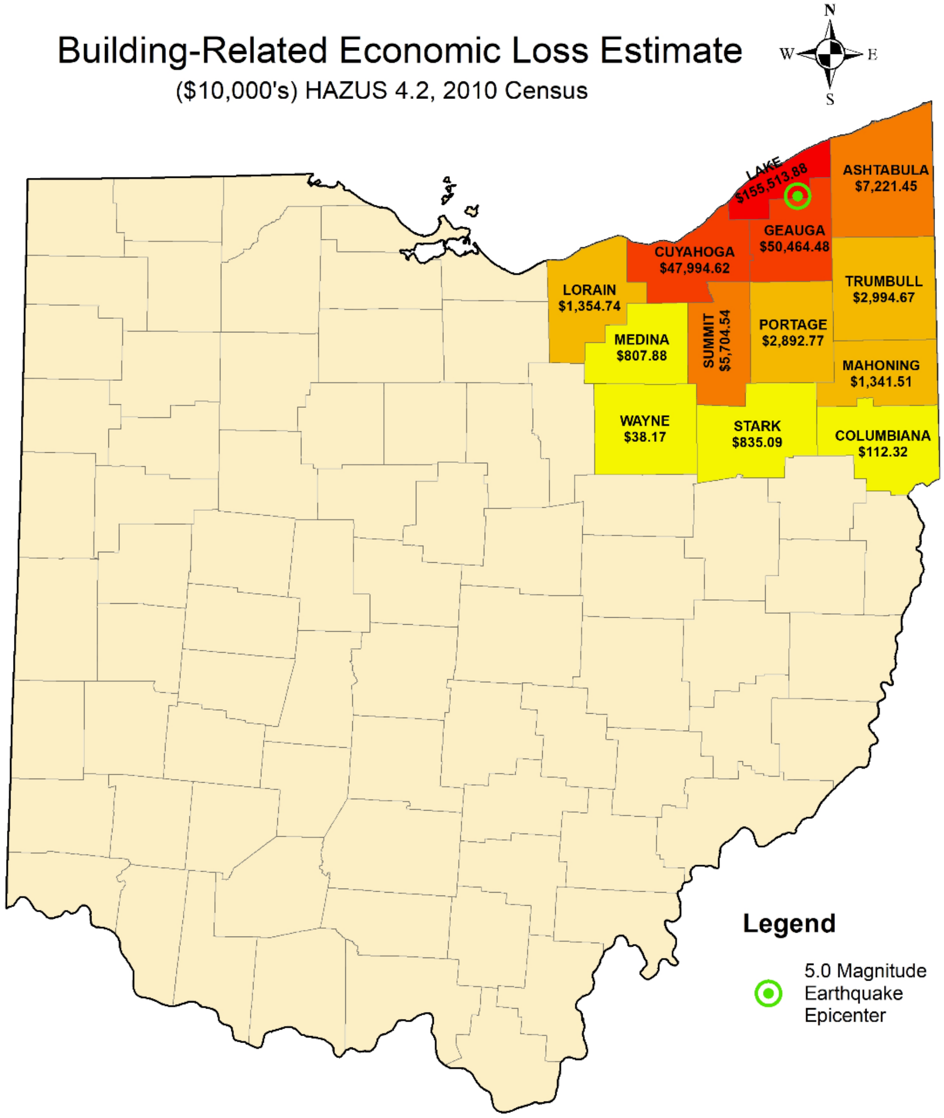
Estimate of Potential Losses to Earthquake									
Shelby County 5.0 Magnitude Earthquake Event (40.47°, -84.28°)									
County	2010 Population	Total Building Value	Slight Damage Count	Moderate Damage Count	Extensive Damage Count	Complete Damage Count	Income Loss	Property Loss	Total Building-Related Loss
Auglaize	45,949	$5,577,000,000	4,057	2,165	639	143	$72,156,000	$336,877,000	$409,033,000
Shelby	49,423	$5,866,000,000	2,849	1,342	339	72	$34,139,000	$173,412,000	$207,551,000
Allen	106,331	$13,050,000,000	2,106	690	106	11	$17,878,000	$53,072,000	$70,950,000
Mercer	40,814	$4,895,000,000	1,423	530	87	10	$10,812,000	$40,943,000	$51,755,000
Miami	102,506	$13,098,000,000	1,093	331	47	4	$7,837,000	$21,882,000	$29,719,000
Montgomery	535,153	$68,649,000,000	1,456	402	42	3	$10,467,000	$17,252,000	$27,719,000
Logan	45,858	$5,472,000,000	867	293	34	3	$4,025,000	$12,020,000	$16,045,000
Darke	52,959	$5,959,000,000	597	185	23	2	$3,312,000	$9,689,000	$13,001,000
Clark	138,333	$15,813,000,000	529	146	13	1	$2,752,000	$5,278,000	$8,030,000
Greene	161,573	$20,143,000,000	320	88	9	1	$1,955,000	$3,867,000	$5,822,000
ALL OTHER COUNTIES			1,741	495	53	5	$8,562,900	$19,519,200	$28,082,100
TOTAL			17,038	6,667	1,392	255	$173,895,900	$693,811,200	$867,707,100

HAZUS results for building counts indicate 17,038 slight, 6,667 moderate, 1,392 extensive and 255 completely impacted structures. The total loss of income is estimated at $173,895,900 and total property losses are estimated at $693,811,200. Auglaize, Shelby, Allen, Mercer, Miami, Montgomery, Logan, Darke, Clark, and Greene are the top ten of 23 counties estimated to see damages from this event. These ten counties have a total population of 1,278,899 people. Auglaize and Shelby had the highest losses and together accounted for 71 percent of the estimated $867,707,100 in total building-related losses. Damage is likely to extend out to counties located in eastern Indiana.

Results indicated minimal losses of utility, transportation and critical facilities. HAZUS estimates that there will be one hospital, two schools, one police station, and two fire stations that will see at least moderate damage (>50 percent). Additionally, there will be three bridges, one railway facility, and one airport facility that will see at least moderate damage. On the first day, 103 households will be without potable water service and 7,353 households without electric power. Within one week, the numbers will drop to 0 and 1,295 households respectively.

Method 1, Scenario B: Lake County 5.0 Magnitude Earthquake Event (41.65°, -81.16°)

Map 2.9f



HAZUS results for building counts indicate 43,983 slight, 17,127 moderate, 3,783 extensive and 751 completely impacted structures. The total loss of income is estimated at $542,298,760 and total property losses are estimated at $2,230,462,376. Lake, Geauga, Cuyahoga, Ashtabula, Summit, Trumbull, Portage, Lorain, Mahoning, and Stark are the top ten of 13 counties estimated to see damages from this event. These ten counties have a total population of 3,534,326 people. Lake, Geauga, and Cuyahoga had the highest losses and together accounted for 92 percent of the estimated $2,772,761,136 in total building-related losses. The building-related losses in the Lake County Scenario are much greater than in the Shelby County Scenario due to having much greater building stock values in the general area. The total number of impacted counties are less than that of the Shelby County event as Lake County is situated along the southern shores of Lake Erie. Damages are likely to extend out to counties located in western Pennsylvania.

Estimate of Potential Losses to Earthquake									
Lake County 5.0 Magnitude Earthquake Event (41.65°, -81.16°)									
County	**2010 Population**	**Total Building Value**	**Slight Damage Count**	**Moderate Damage Count**	**Extensive Damage Count**	**Complete Damage Count**	**Income Loss**	**Property Loss**	**Total Building-Related Loss**
Lake	230,041	$29,673,000,000	15,769	7,517	2,008	459	$268,296,148	$1,286,842,603	$1,555,138,751
Geauga	93,389	$12,396,000,000	5,344	2,704	827	201	$82,706,223	$421,938,582	$504,644,805
Cuyahoga	1,280,122	$182,175,000,000	12,755	3,864	577	57	$125,551,130	$354,395,097	$479,946,228
Ashtabula	101,497	$11,710,000,000	2,328	812	122	14	$15,852,078	$56,362,452	$72,214,530
Summit	541,781	$73,277,000,000	2,398	679	80	6	$17,529,907	$39,515,443	$57,045,350
Trumbull	210,312	$25,215,000,000	1,562	459	53	5	$9,155,358	$20,791,374	$29,946,732
Portage	161,419	$18,773,000,000	1,322	402	45	4	$7,549,739	$21,377,938	$28,927,676
Lorain	301,356	$39,738,000,000	682	187	19	1	$4,685,319	$8,862,076	$13,547,395
Mahoning	238,823	$29,181,000,000	789	218	23	2	$4,964,738	$8,450,316	$13,415,054
Stark	375,586	$45,070,000,000	482	132	14	1	$2,973,399	$5,377,504	$8,350,903
ALL OTHER COUNTIES			552	152	16	1	$3,034,719	$6,548,993	$9,583,712
TOTAL			43,983	17,127	3,783	751	$542,298,760	$2,230,462,376	$2,772,761,136

Results indicated minimal losses of utility, transportation and critical facilities. HAZUS estimates that there will be one hospital, two schools, and three fire stations that will see at least moderate damage (>50 percent). Additionally, there will be one bridge and one airport facility that will see at least moderate damage. On the first day, 468 households that will be without potable water service and 27,451 households without electric power. Within one week, the numbers will drop to 0 and 5,204 households respectively.

Method 2: Epicenter in County Seat

Estimate of Potential Losses to Earthquake											
Region 1											
County	2010 Population	Total Building Value	5.0 Magnitude Earthquake Epicenter	Slight Damage Count	Moderate Damage Count	Extensive Damage Count	Complete Damage Count	Income Loss	Property Loss	Total Building-Related Loss	Percentage of Total Building Value
Allen	106,331	$13,050,000,000	Lima	10,731	6,727	2,420	718	$340,039,700	$1,439,687,900	$1,779,727,600	11.03%
Auglaize	45,949	$5,577,000,000	Wapakoneta	3,943	2,263	769	212	$71,750,000	$361,590,000	$433,340,000	7.77%
Champaign	40,097	$3,766,000,000	Urbana	3,786	2,316	808	226	$74,620,000	$378,820,000	$453,440,000	12.04%
Clark	138,333	$15,813,000,000	Springfield	14,231	8,695	2,988	880	$358,740,000	$1,623,060,000	$1,981,800,000	12.53%
Crawford	43,784	$5,316,000,000	Bucyrus	3,916	2,172	700	189	$67,860,100	$353,616,300	$421,476,400	7.93%
Darke	52,959	$5,959,000,000	Greenville	5,214	3,052	1,023	272	$100,500,600	$454,991,900	$555,492,500	9.32%
Defiance	39,037	$4,750,000,000	Defiance	3,639	2,334	864	254	$105,843,400	$488,064,700	$593,908,100	12.50%
Erie	77,079	$10,525,000,000	Sandusky	7,852	4,694	1,609	468	$243,047,800	$977,979,100	$1,221,026,900	11.60%
Fulton	42,698	$5,702,000,000	Wauseon	3,914	2,412	836	216	$93,335,300	$478,339,000	$571,674,300	10.03%
Hancock	74,782	$9,489,000,000	Findlay	7,578	4,854	1,787	515	$230,190,100	$1,041,613,300	$1,271,803,400	13.40%
Hardin	32,058	$3,398,000,000	Kenton	2,917	1,775	601	166	$60,016,800	$280,151,800	$340,168,600	10.01%
Henry	28,215	$3,154,000,000	Napolean	2,742	1,722	621	165	$56,832,500	$270,484,900	$327,317,400	10.38%
Huron	59,626	$6,546,000,000	Norwalk	4,834	2,897	983	260	$101,017,000	$448,546,000	$549,563,000	8.40%
Logan	45,858	$5,472,000,000	Bellefontaine	5,076	3,064	981	262	$102,276,900	$459,393,100	$561,670,000	10.26%
Lucas	441,815	$58,013,000,000	Toledo	42,442	24,769	8,211	2,341	$1,201,811,700	$5,298,319,500	$6,500,131,200	11.20%
Marion	66,501	$7,113,000,000	Marion	6,955	4,377	1,545	453	$173,421,200	$771,246,000	$944,667,200	13.28%
Mercer	40,814	$4,895,000,000	Celina	4,281	2,698	987	277	$92,836,100	$434,887,200	$527,723,300	10.78%
Miami	102,506	$13,098,000,000	Troy	10,366	5,874	1,892	520	$250,053,200	$1,242,551,000	$1,492,604,200	11.40%
Ottawa	41,428	$7,007,000,000	Port Clinton	4,914	3,343	1,259	302	$94,156,800	$405,834,600	$499,991,400	7.14%
Paulding	19,614	$2,138,000,000	Paulding	2,208	1,456	519	125	$36,283,600	$196,514,800	$232,798,400	10.89%
Preble	42,270	$4,677,000,000	Eaton	4,236	2,423	780	210	$69,693,900	$375,902,700	$445,596,600	9.53%
Putnam	34,499	$4,057,000,000	Ottawa	3,200	1,900	636	173	$60,648,600	$312,804,000	$373,452,600	9.21%
Sandusky	60,944	$7,612,000,000	Fremont	5,846	3,569	1,255	353	$152,490,600	$715,835,900	$868,326,500	11.41%
Seneca	56,745	$6,465,000,000	Tiffin	5,126	2,964	971	261	$108,406,800	$491,019,500	$599,426,300	9.27%
Shelby	49,423	$5,866,000,000	Sidney	4,302	2,599	908	255	$95,385,600	$516,262,900	$611,648,500	10.43%
Van Wert	28,744	$3,330,000,000	Van Wert	3,289	2,053	720	205	$72,727,900	$342,020,600	$414,748,500	12.45%
Williams	37,642	$4,857,000,000	Bryan	3,821	2,423	864	236	$88,186,000	$468,580,200	$556,766,200	11.46%
Wood	125,488	$16,617,000,000	Bowling Green	6,443	3,479	1,059	247	$128,857,300	$594,686,000	$723,543,300	4.35%
Wyandot	22,615	$2,604,000,000	Upper Sandusky	2,456	1,545	555	156	$55,477,600	$256,189,100	$311,666,700	11.97%

Estimate of Potential Losses to Earthquake											
Region 2											
County	2010 Population	Total Building Value	5.0 Magnitude Earthquake Epicenter	Slight Damage Count	Moderate Damage Count	Extensive Damage Count	Complete Damage Count	Income Loss	Property Loss	Total Building-Related Loss	Percentage of Total Building Value
Ashland	53,139	$6,014,000,000	Ashland	5,154	3,221	1,068	288	$111,583,600	$540,923,000	$652,506,600	8.99%
Butler	368,130	$43,670,000,000	Hamilton	28,806	15,846	4,955	1,355	$624,184,500	$30,870,858,000	$3,087,085,800	7.07%
Clinton	42,040	$4,691,000,000	Wilmington	3,815	2,352	812	218	$85,237,400	$386,703,200	$471,940,600	10.06%
Cuyahoga	1,280,122	$182,175,000,000	Cleveland	101,005	51,979	15,495	4,064	$2,961,934,500	$12,808,180,500	$15,770,115,000	8.66%
Delaware	174,214	$24,771,000,000	Delaware	12,994	6,787	2,090	550	$248,588,700	$1,389,884,900	$1,638,473,600	6.61%
Fairfield	146,156	$16,911,000,000	Lancaster	10,940	6,152	2,032	573	$236,586,300	$1,053,697,200	$1,290,283,500	7.63%
Fayette	29,030	$3,149,000,000	Washington CH	3,230	2,028	717	206	$71,509,100	$354,333,600	$425,842,700	13.52%
Franklin	1,163,414	$149,070,000,000	Columbus	93,203	50,401	15,713	4,262	$2,707,203,600	$11,494,786,200	$14,201,989,800	9.53%
Geauga	93,389	$12,396,000,000	Chardin	7,319	3,888	1,209	308	$133,999,300	$681,662,200	$815,661,500	6.58%
Greene	161,573	$20,143,000,000	Xenia	13,904	7,318	2,174	563	$252,201,800	$1,311,451,700	$1,563,653,500	7.76%
Hamilton	802,374	$108,968,000,000	Cincinnati	60,895	31,815	9,580	2,545	$1,818,884,300	$7,769,951,900	$9,588,836,200	8.80%
Knox	60,921	$6,994,000,000	Mt. Vernon	5,782	3,380	1,106	296	$128,390,000	$588,422,600	$716,812,600	10.25%
Lake	230,041	$29,673,000,000	Painesville	19,503	40,488	3,195	873	$405,108,700	$2,080,489,600	$2,485,598,300	8.38%
Licking	166,492	$19,664,000,000	Newark	13,236	7,701	2,530	700	$329,645,000	$1,398,438,400	$1,728,083,400	8.79%
Lorain	301,356	$39,738,000,000	Elyria	28,256	15,921	5,165	1,421	$667,101,000	$3,173,150,400	$3,840,251,400	9.66%
Madison	43,435	$4,489,000,000	London	3,278	1,910	615	164	$64,493,900	$327,032,600	$391,526,500	8.72%
Medina	172,332	$22,003,000,000	Medina	15,555	8,326	2,529	687	$306,796,500	$1,688,169,300	$1,994,965,800	9.07%
Montgomery	535,153	$68,649,000,000	Dayton	52,232	29,290	9,392	2,657	$1,405,237,800	$5,902,113,100	$7,307,350,900	10.64%
Morrow	34,827	$3,253,000,000	Mt. Gilead	3,326	2,098	714	169	$48,484,000	$237,263,900	$285,747,900	8.78%
Pickaway	55,698	$5,473,000,000	Circleville	4,635	2,856	973	263	$87,323,700	$411,002,400	$498,326,100	9.11%
Portage	161,419	$18,773,000,000	Ravenna	13,162	7,875	2,705	702	$282,285,500	$1,417,867,300	$1,700,152,800	9.06%
Richland	124,475	$14,927,000,000	Mansfield	12,608	7,699	2,680	780	$333,128,700	$1,469,984,200	$1,803,112,900	12.08%
Stark	375,586	$45,070,000,000	Canton	35,574	20,105	6,427	1,813	$935,438,900	$3,845,042,300	$4,780,481,200	10.61%
Summit	541,781	$73,277,000,000	Akron	51,673	29,334	9,502	2,738	$1,424,697,000	$6,346,478,100	$7,771,175,100	10.61%
Union	52,300	$6,356,000,000	Marysville	4,509	2,788	1,000	286	$106,640,000	$596,520,000	$703,160,000	11.06%
Warren	212,693	$26,040,000,000	Lebanon	16,959	8,628	2,513	643	$276,483,500	$1,623,221,600	$1,899,705,100	7.30%
Wayne	114,520	$12,755,000,000	Wooster	9,324	5,606	1,892	496	$207,515,400	$952,870,100	$1,160,385,500	9.10%

Estimate of Potential Losses to Earthquake

Region 3

County	2010 Population	Total Building Value	5.0 Magnitude Earthquake Epicenter	Slight Damage Count	Moderate Damage Count	Extensive Damage Count	Complete Damage Count	Income Loss	Property Loss	Total Building-Related Loss	Percentage of Total Building Value
Adams	28,550	$2,389,000,000	West Union	2,694	2,037	832	215	$45,890,000	$183,830,000	$229,720,000	9.62%
Ashtabula	101,497	$11,710,000,000	Jefferson	7,891	4,096	1,105	232	$113,116,000	$509,387,600	$622,503,600	5.32%
Athens	64,757	$5,911,000,000	Athens	5,249	3,798	1,451	364	$137,544,200	$593,587,700	$731,131,900	12.37%
Belmont	70,400	$7,555,000,000	St. Clairsville	661	3,770	1,179	291	$119,834,500	$507,205,900	$627,040,400	8.30%
Brown	44,846	$4,266,000,000	Georgetown	3,776	2,453	855	208	$59,778,100	$256,354,900	$316,133,000	7.41%
Carroll	28,836	$3,222,000,000	Carrollton	3,432	2,263	801	188	$55,473,600	$257,928,800	$313,402,400	9.73%
Clermont	197,363	$22,678,000,000	Batavia	16,230	9,401	3,013	762	$332,814,500	$1,678,040,300	$2,010,854,800	8.87%
Columbiana	107,841	$11,350,000,000	Lisbon	8,493	4,697	1,437	325	$118,951,900	$538,422,700	$657,374,600	5.79%
Coshocton	36,901	$3,805,000,000	Coshocton	3,958	2,716	1,028	273	$86,426,400	$374,156,000	$460,582,400	12.10%
Gallia	30,934	$2,974,000,000	Gallipolis	3,011	2,057	691	173	$70,628,000	$260,583,900	$331,211,900	11.14%
Guernsey	40,087	$4,980,000,000	Cambridge	4,655	3,261	1,261	339	$145,872,400	$542,275,200	$688,147,600	13.82%
Harrison	15,864	$1,668,000,000	Cadiz	1,869	1,214	440	115	$30,972,200	$129,899,800	$160,872,000	9.64%
Highland	43,589	$4,059,000,000	Hillsboro	4,283	2,933	1,064	246	$70,324,200	$307,422,100	$377,746,300	9.31%
Hocking	29,380	$2,898,000,000	Logan	3,186	2,355	947	244	$64,461,700	$280,080,000	$344,541,700	11.89%
Holmes	42,366	$3,854,000,000	Millersburg	3,232	2,027	712	181	$67,446,700	$308,950,100	$376,396,800	9.77%
Jackson	33,225	$2,935,000,000	Jackson	3,487	2,557	969	236	$66,671,600	$277,082,700	$343,754,300	11.71%
Jefferson	69,709	$7,521,000,000	Steubenville	7,239	4,406	1,489	414	$164,410,100	$690,997,200	$855,407,300	11.37%
Lawrence	62,450	$5,438,000,000	Ironton	5,001	3,122	1,066	281	$77,797,300	$341,092,100	$418,889,400	7.70%
Mahoning	238,823	$29,181,000,000	Youngstown	25,087	14,306	4,575	1,346	$636,105,700	$2,736,222,600	$3,372,328,300	11.56%
Meigs	23,770	$2,021,000,000	Pomeroy	2,372	1,599	568	143	$34,764,100	$144,791,900	$179,556,000	8.88%
Monroe	14,642	$1,446,000,000	Woodsfield	1,810	1,204	433	112	$24,918,700	$118,006,600	$142,925,300	9.88%
Morgan	15,054	$1,459,000,000	McConnelsville	2,033	1,550	640	162	$30,786,100	$144,818,100	$175,604,200	12.04%
Muskingum	86,074	$9,255,000,000	Zanesville	8,400	5,466	1,979	550	$230,867,000	$880,869,000	$1,111,736,000	12.01%
Noble	14,645	$1,319,000,000	Caldwell	1,468	1,014	387	105	$26,468,800	$122,858,300	$149,327,100	11.32%
Perry	36,058	$3,237,000,000	New Lexington	3,439	2,440	985	254	$54,876,500	$272,520,700	$327,397,200	10.11%
Pike	28,709	$2,641,000,000	Waverly	2,729	1,878	642	163	$64,492,500	$248,255,700	$312,748,200	11.84%
Ross	78,064	$7,574,000,000	Chillicothe	7,017	4,515	1,518	390	$170,530,000	$663,536,100	$834,066,100	11.01%
Scioto	79,499	$7,556,000,000	Portsmouth	6,809	4,231	1,371	351	$144,352,600	$592,121,000	$736,473,600	9.75%
Trumbull	210,312	$25,215,000,000	Warren	20,475	11,930	3,940	1,086	$497,402,800	$2,177,593,500	$2,674,996,300	10.61%
Tuscarawas	92,582	$10,330,000,000	New Philadelphia	9,007	5,723	2,011	527	$210,656,700	$875,000,800	$1,085,657,500	10.51%
Vinton	13,435	$1,185,000,000	McArthur	1,619	1,279	547	140	$25,479,700	$123,603,400	$149,083,100	12.58%
Washington	61,778	$6,706,000,000	Marietta	5,198	3,067	976	259	$109,787,200	$460,990,900	$570,778,100	8.51%

In Region 2, the counties with the most building-related losses are Cuyahoga County at $15,770,115,000, Franklin County at $14,201,989,800, and Hamilton County at $9,588,836,200. Relative to the total building value, the counties with the highest percentage of total building-related loss are Fayette at 13.52 percent, Richland County at 12.08 percent, and Union County at 11.06 percent.

In region 1, the counties with the most building-related losses are Lucas County at $6,500,131,200, Clark County at $1,981,800,000, and Allen County at $1,779,727,600. Relative to the total building value, the counties with the highest percentage of total building-related loss are Hancock County at 13.40 percent, Marion County at 13.28 percent, and Clark County at 12.53 percent.

In region 3, the counties with the most building-related losses are Mahoning County at $3,372,328,300, Trumbull County at $2,674,996,300, and Clermont County at Clermont. Relative to the total building value, the counties with the highest percentage of total building-related loss are Guernsey at 13.82 percent, Vinton County at 12.58 percent, and Athens County at 12.37 percent.

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

Method 2 of the Vulnerability Analysis and Loss Estimation above estimated the damage to each county with a scenario where a 5.0 magnitude earthquake occurred with the epicenter in each of their respective county seats. A "Percentage of Total Building Value" was determined by taking the Total Building-Related Losses and dividing it by the Total Building Value in that county. To estimate the losses for State-owned and State-leased critical facilities, the total value of State-owned and State-leased Critical Facilities of each county was multiplied by the county's respective percentage of Total Building Value.

RESULTS

In Region 1, Lucas County is estimated to have the most damage to State-owned and State-leased Critical Facilities at $30,991,663. In Region 2, Franklin County is estimated to have the most damage by far at $204,615,249. In Region 3, Ross County is estimated to have the most damage at $29,246,770.

With the method, the most prevalent variable in the estimated loss in the event of 5.0 magnitude earthquake is the existing value of these critical facilities.

Results

Estimate of Potential Losses of State-owned and State-leased Critical Facilities to a 5.0 Magnitude Earthquake Event				
Region 1				
County	Percentage of Total Building Value	Number of State-owned and State-leased Critical Facilities	Value of State-owned and State-leased Critical Facilities	Estimated Damage to State-owned and State-leased Critical Facilities
Allen	11.03%	120	$ 90,950,176.00	$ 10,033,706.35
Auglaize	7.77%	21	$ 11,545,804.00	$ 897,123.67
Champaign	12.04%	24	$ 5,161,316.00	$ 621,441.09
Clark	12.53%	17	$ 8,868,061.00	$ 1,111,409.81
Crawford	7.93%	13	$ 10,357,812.00	$ 821,213.94
Darke	9.32%	27	$ 8,619,026.00	$ 803,457.68
Defiance	12.50%	11	$ 7,562,674.00	$ 945,585.97
Erie	11.60%	54	$ 162,265,731.00	$ 18,824,781.24
Fulton	10.03%	16	$ 4,397,188.00	$ 440,855.73
Hancock	13.40%	23	$ 16,195,898.00	$ 2,170,723.80
Hardin	10.01%	12	$ 4,141,282.00	$ 414,577.43
Henry	10.38%	14	$ 3,113,844.00	$ 323,150.07
Huron	8.40%	22	$ 10,543,997.00	$ 885,210.91
Logan	10.26%	1	$ 735,568.00	$ 75,501.91
Lucas	11.20%	47	$ 276,597,391.00	$ 30,991,662.75
Marion	13.28%	100	$ 128,613,896.00	$ 17,081,024.75
Mercer	10.78%	26	$ 7,655,738.00	$ 825,354.71
Miami	11.40%	23	$ 10,005,576.00	$ 1,140,201.92
Ottawa	7.14%	75	$ 65,291,745.00	$ 4,658,956.90
Paulding	10.89%	3	$ 1,387,796.00	$ 151,111.64
Preble	9.53%	24	$ 4,859,547.00	$ 462,988.59
Putnam	9.21%	18	$ 5,590,738.00	$ 514,635.36
Sandusky	11.41%	15	$ 5,519,069.00	$ 629,578.81
Seneca	9.27%	49	$ 33,546,722.00	$ 3,110,407.96
Shelby	10.43%	35	$ 26,824,309.00	$ 2,796,973.81
Van Wert	12.45%	13	$ 7,459,562.00	$ 929,081.73
Williams	11.46%	13	$ 5,459,757.00	$ 625,861.26
Wood	4.35%	36	$ 67,981,624.00	$ 2,960,079.95
Wyandot	11.97%	19	$ 10,280,904.00	$ 1,230,497.47

Estimate of Potential Losses of State-owned and State-leased Critical Facilities to a 5.0 Magnitude Earthquake Event				
Region 2				
County	Percentage of Total Building Value	Number of State-owned and State-leased Critical Facilities	Value of State-owned and State-leased Critical Facilities	Estimated Damage to State-owned and State-leased Critical Facilities
Ashland	8.99%	143	$ 64,539,880.00	$ 5,804,972.65
Butler	7.07%	21	$ 17,563,033.00	$ 1,241,552.32
Clinton	10.06%	22	$ 11,528,821.00	$ 1,159,863.29
Cuyahoga	8.66%	84	$ 248,840,544.00	$ 21,541,067.63
Delaware	6.61%	37	$ 46,217,477.00	$ 3,057,047.19
Fairfield	7.63%	78	$ 86,519,830.00	$ 6,601,331.03
Fayette	13.52%	26	$ 5,118,182.00	$ 692,137.33
Franklin	9.53%	249	$ 2,147,726,878.00	$ 204,615,249.31
Geauga	6.58%	24	$ 8,594,197.00	$ 565,501.42
Greene	7.76%	25	$ 10,629,296.00	$ 825,127.14
Hamilton	8.80%	35	$ 173,140,806.00	$ 15,235,838.30
Knox	10.25%	34	$ 40,507,246.00	$ 4,151,573.39
Lake	8.38%	21	$ 5,525,021.00	$ 462,810.73
Licking	8.79%	64	$ 168,043,312.00	$ 14,767,740.95
Lorain	9.66%	90	$ 110,138,241.00	$ 10,643,679.46
Madison	8.72%	109	$ 321,691,881.00	$ 28,057,673.48
Medina	9.07%	22	$ 18,601,644.00	$ 1,686,571.99
Montgomery	10.64%	71	$ 77,351,496.00	$ 8,233,689.11
Morrow	8.78%	21	$ 6,874,959.00	$ 603,905.66
Pickaway	9.11%	133	$ 195,643,558.00	$ 17,813,683.77
Portage	9.06%	25	$ 7,594,529.00	$ 687,788.83
Richland	12.08%	73	$ 109,750,465.00	$ 13,257,351.06
Stark	10.61%	41	$ 102,066,812.00	$ 10,826,014.55
Summit	10.61%	67	$ 201,182,298.00	$ 21,335,792.47
Union	11.06%	53	$ 88,869,557.00	$ 9,831,579.25
Warren	7.30%	109	$ 150,201,626.00	$ 10,957,711.02
Wayne	9.10%	6	$ 7,056,104.00	$ 641,928.72

Estimate of Potential Losses of State-owned and State-leased Critical Facilities to a 5.0 Magnitude Earthquake Event				
Region 3				
County	Percentage of Total Building Value	Number of State-owned and State-leased Critical Facilities	Value of State-owned and State-leased Critical Facilities	Estimated Damage to State-owned and State-leased Critical Facilities
Adams	9.62%	24	$ 6,622,981.00	$ 636,848.55
Ashtabula	5.32%	62	$ 20,008,110.00	$ 1,063,631.13
Athens	12.37%	31	$ 45,496,640.00	$ 5,627,481.79
Belmont	8.30%	62	$ 54,856,808.00	$ 4,552,936.44
Brown	7.41%	18	$ 36,403,605.00	$ 2,697,698.28
Carroll	9.73%	17	$ 3,661,999.00	$ 356,200.89
Clermont	8.87%	38	$ 17,885,810.00	$ 1,585,932.04
Columbiana	5.79%	38	$ 13,835,662.00	$ 801,340.33
Coshocton	12.10%	19	$ 12,943,450.00	$ 1,566,760.91
Gallia	11.14%	71	$ 35,860,837.00	$ 3,993,791.51
Guernsey	13.82%	54	$ 39,704,477.00	$ 5,486,453.93
Harrison	9.64%	30	$ 9,054,441.00	$ 873,265.01
Highland	9.31%	8	$ 9,690,902.00	$ 901,872.97
Hocking	11.89%	19	$ 7,123,096.00	$ 846,861.15
Holmes	9.77%	25	$ 10,336,112.00	$ 1,009,465.36
Jackson	11.71%	18	$ 15,130,501.00	$ 1,772,120.88
Jefferson	11.37%	37	$ 7,592,901.00	$ 863,585.02
Lawrence	7.70%	27	$ 11,760,373.00	$ 905,902.09
Mahoning	11.56%	66	$ 72,389,280.00	$ 8,365,731.73
Meigs	8.88%	18	$ 8,512,106.00	$ 756,259.13
Monroe	9.88%	22	$ 11,202,381.00	$ 1,107,263.95
Morgan	12.04%	10	$ 3,700,608.00	$ 445,402.54
Muskingum	12.01%	25	$ 10,647,135.00	$ 1,278,963.08
Noble	11.32%	31	$ 50,299,353.00	$ 5,694,508.35
Perry	10.11%	16	$ 3,884,728.00	$ 392,909.81
Pike	11.84%	10	$ 3,878,547.00	$ 459,298.97
Ross	11.01%	142	$ 265,584,512.00	$ 29,246,770.29
Scioto	9.75%	55	$ 171,351,723.00	$ 16,701,432.01
Trumbull	10.61%	60	$ 55,012,652.00	$ 5,836,154.69
Tuscarawas	10.51%	53	$ 56,132,900.00	$ 5,899,429.22
Vinton	12.58%	20	$ 5,854,782.00	$ 736,581.48
Washington	8.51%	55	$ 29,149,164.00	$ 2,481,017.66

2.10 COASTAL EROSION

The 1998 Coastal Erosions Area maps defined Coastal erosion is defined as the gradual wearing away of the earth's surface by the natural forces of wind and water. The constant action of wind, waves, and ice flow has affected the coastline of Lake Erie. Primarily, the waves and gravity cause erosion. Waves undercut the land along the shore and gravity causes the land to slip into the water. As material from the bluff or bank slides into the lake, it too is eroded by waves. As this process continues, the shore moves farther landward. Many natural factors affect erosion of the lakeshore, including shore and nearshore geology, shore relief, nearshore bathymetry, beaches, shoreline orientation, lake level fluctuations (long-term, annual, and storm surges), and climate changes (storm frequency, temperature, and precipitation).

The History of Lake Erie by Michael C. Hansen notes Lake Erie owes its fundamental existence to the presence of a basin or lowland that originated long before the Pleistocene Ice Age began 2 million years ago. This lowland was known as the valley of an east-flowing river, known as the Erigan River. This geology in the basin included Silurian and Devonian carbonates (limestone and dolomite) on the west and by Devonian shales on the east. Glacial ice was able to erode the less resistant shales (than the more resistant carbonate rocks) to a greater extent in the central basin and eastern basins. The first of the four major glacial advances during the Pleistocene obliterated this drainage system, and deepened and enlarged the basin. Succeeding glaciations further deepened and enlarged it. Lake Erie, the southernmost of the Great Lakes, is also the shallowest because the ice was relatively thin (therefore lacking significant erosive power) when it reached so far south. During the advancement of the glaciers, they eroded rock and soil and carried them with the flowing ice to the glacier edge where they were deposited as till released from melting ice. Laminated silt and clay were also deposited in proglacial lakes that formed along the margin of the glacier. These geologic materials are exposed in Lake Erie's bluffs and banks. Upon final retreat of the glacier moving out of Ohio, the water started to discharge via the Niagara River. Glacial rebound raised the Niagara outlet and increased the water level in the Lake Erie basin. Due to a rapid glacial rebound in the upper Great Lakes, these lakes began to drain through the Lake Erie Basin 6. There has been a continued slow rise following the rapid rise that has brought Lake Erie to its current mean level of 571 feet above sea level.

Per the Geologic Setting and Processes Along Lake Erie From Fairport Harbor to Marblehead, the geologic settings vary throughout the length of Ohio's coast. From the Ohio- Pennsylvania border to Huron, Ohio, moderate to high relief shore consists of bluffs and slopes composed of glaciolacustrine sands, silts, clay, till, and/or shale. From Huron around Sandusky Bay to Marblehead peninsula, the shore is a low relief plain composed of glaciolacustrine sediments and till, with shale exposed west of Huron and limestone exposed around Marblehead peninsula. At Sandusky Bay, two barrier beach complexes extend across the bay mouth. Around Marblehead Peninsula and Catawba Island, low to moderate banks/bluffs are composed of rock and till. West of Catawba Island, the landscape consists of low-relief lake plain and coastal wetlands (remnants of the Black Swamp). Nearshore slopes are generally gentle and are composed of the same materials in bluff or bank. Beaches are typically narrow (<50 feet per 15 meters wide) to non-existent along much of the shore. Manmade features have affected the longshore transport of sand trapping sand on the updrift side at harbor jetties, power plant intakes, and long groins. Shore parallel structures have altered sand transport as well.

Climate affects overall physical setting in the nearshore, beach, and shore zones. Long-term and annual fluctuations in lake level are due to changes in the volume of the lake resulting from changes in precipitation in the Great Lakes Basin. Short-term fluctuations are due to wind-driven storm surges, changes in barometric pressure, or inertial surges of water (seiches) that occur after lake level has been set up by either of the two previous agents. The greatest storm surges occur when the wind blows parallel to the long axis of the lake. Under extreme conditions, lake level at the confined ends of the lake may rise or fall more than six feet from pre-storm levels. Passage of storm systems through the Great Lakes can cause lake levels at the ends of the lake to fluctuate 10 to 11 feet over a period of several days. The most important storm surges along the western part of the Central Basin and all of the Western Basin are those generated by northeast winds because these storm surges are accompanied by large storm waves.

The size of wind-generated waves depends upon wind speed and duration, open-water fetch distance, and water depth. The largest waves affecting the Ohio lakeshore are those generated by storm winds from the west through the northeast. Wave energy is highest from late fall through spring; however, lake level is at its lowest and shorefast ice typically forms a barrier between the waves and erodible shore material. Most wave erosion occurs during storms in early spring when the greatest amount of wave energy is expended on the shore. The largest waves to strike the shore are generated by onshore storms winds from the west to the northeast. Wave erosion causes undercutting of the bluff or bank, mass wasting including block falls, rotational slumps, and debris flows, and lakebed down cutting of cohesive materials. Bedrock is not as easily eroded as the cohesive glacial sediments. Although erosion of the bluff is necessary to sustain beaches, excessive erosion of the Lake Erie shoreline can be considered a hazard exposure.

Coastal Erosion Area

A Coastal Erosion Area (CEA) is a designated area of land adjacent to Lake Erie that is anticipated to be lost to erosion in 30 years unless preventive measures are taken. Coastal erosion is measured by determining how far landward the bluff, bank, or dune has receded over time. The landward shift of the bluff, bank, or dune is called recession.

Coastal erosion area designations are a component of the Ohio Coastal Management Law passed by the Ohio Legislature in 1988 in response to the serious hazards and substantial economic losses caused by coastal erosion. The laws and rules that define the Coastal Erosion Area program are found in Ohio Revised Code Section 1506 and Ohio Administrative Code Section 1501-6. The objective of the CEA program is to identify the hazards and mitigate the economic losses of erosion-related damage.

The Ohio Department of Natural Resources (ODNR) developed standards for designating coastal erosion areas with input from geologists, engineers, local officials and landowners. CEAs are depicted on maps that are produced by ODNR. To develop coastal erosion maps, rates of recession are calculated using analytical tools, including aerial imagery and LiDAR, mathematical calculations and field visits to verify observations. The amount of recession that is calculated is used to project recession rates for a 30-year period; areas that are projected to erode greater than a given threshold amount are designated as CEAs and shown on coastal erosion maps. The maps include data tables that show the amount of recession calculated at regular 100-foot intervals along all of Ohio's Lake Erie coast, including the bays and islands.

ODNR has mapped Ohio's Lake Erie coast to identify coastal erosion areas since 1988. Maps showing the first CEA designations were finalized in 1998 and were based on the amount of recession that occurred between 1973 and 1990. Since then, ODNR has updated CEA designations in accordance with the laws and rules that define the CEA program. In 2010, ODNR released maps based on the amount of recession that occurred between 1990 and 2004. The 1998 and 2010 CEA maps now serve only as historical records.

In January 2019, ODNR released the 2018 CEA maps, which depict the most current CEA designations based on the amount of recession that occurred between 2004 and 2015. ODNR uses these maps to determine if a property is currently located within a CEA. All sets of CEA maps are available to view online at https://gis.ohiodnr.gov/MapViewer/?config=cea.

Property along Ohio's Lake Erie coast that is located within a designated CEA is subject to CEA program requirements, which address property sales and transfers and construction. Landowners selling or transferring property within a designated CEA must disclose that status on the Residential Property Disclosure Form, which is required with all residential real property transactions in Ohio. Construction within a CEA may require a CEA Permit, depending on the type and location of a structure. A permit is required to construct a new building or add 500 square feet or more (as measured at ground level) to an existing structure. This applies to residential, commercial, industrial, institutional and agricultural buildings, and septic systems. CEA Permits are issued by ODNR through the Office of Coastal Management.

RISK ASSESSMENT

LOCATION AND SELECT HISTORICAL OCCURRENCE

Lake Erie comprises 312 miles of the northern coast of Ohio bordering Lucas, Ottawa, Sandusky (Sandusky Bay), Erie, Lorain, Cuyahoga, Lake, and Ashtabula Counties. Lake Erie, the 12th largest (area) lake in the world, is about 210 miles long, 57 miles wide, and has a shoreline length of 871 miles (including the islands). With the exclusion of government-owned park and reserve areas, the coast is highly prized for commercial and residential development. In many cases, human activity has disrupted the natural function of beach formation and aquatic habitats. According to the Ohio Geological Survey, 95 percent of Ohio's Lake Erie shoreline is eroding.

Unlike many of the other hazards affecting Ohio, Lake Erie is consistently undergoing coastal erosion. Although particular storms or development creates periods of increased occurrence, the shore is eroding slowly every day. To monitor erosion, the net landward movement of the shore over a specific time is calculated. The position of characteristic shore features such as bluff lines can be determined from maps and aerial photographs. By analyzing the position of these features (recession lines) through time, the amount of recession can be determined and rates of recession can be calculated. Long-term and short-term recession data have been developed for each county (see table 2.10.a).

Table 2.10.a – Ohio Lake Erie Erosion Statistics by County from 2004 to 2015

County	Distance	Feet/year
Ashtabula	2.8	0.26
Lake	5.4	0.49
Cuyahoga	0.8	0.07
Lorain	0.3	0.02
Erie (lake)	0.3	0.03
Ottawa (lake)	0.5	0.04
Lucas	0.2	0.01
Erie (bay)	0.6	0.05
Ottawa (bay)	9.1	0.54

During 1929-30, the mid-1940s, 1952, the fall of 1972, the spring of 1973, and 1985, 1998 and 2012 storms and high lake levels caused property damage along the low-lying areas, such as low glacial till bluffs, low glaciolacustrine banks, and barrier beaches and eroded high glacial till or glaciolacustrine bluffs inducing mass wasting in Erie, Lake, Cuyahoga, and Ashtabula counties. The short-term and long-term rates indicate that the low-lying areas have been extremely affected.

LHMP DATA

All of the LHMPs for the counties that border Lake Erie (Ashtabula, Cuyahoga, Erie, Lake, Lorain, Lucas, Ottawa, and Sandusky), indicate that coastal erosion is a recognized hazard and ranked them either fourth or fifth for their county. Almost all of the plans reference the same data (Figure 2.10.a) provided by the Ohio Geological Survey. Erie County's LHMP indicated that they had completed a structural inventory in the late 1990's; but those data were not available to them at the time of writing their plan.

Ashtabula County. The HIRA of the Ashtabula County Countywide All Natural Hazards Mitigation Plan of August 2012 describes that 28 miles of Lake Erie coastline form the northern border of the County. The HIRA also explains that factors such as high lake levels, long shore currents, high winds, water runoff over cliffs, bluff recession and seasonal fluctuations are driving forces that lead to coastal erosion. The risk is classified as a Moderate Probability and Moderate Impact. The plan's vulnerability analysis determined 2,619 structures would be affected with a loss estimate of $78,295,582.

Lake County. As part of the Lake County Planning Commission's coastal management plan, breakwalls have been constructed in Mentor and North Perry. Further, individual jurisdictions have been compiling agreements with appropriate contractors, state agencies, and local partners to ensure that response measures (such as shoring up structures and filling in eroded areas) can be implemented quickly. These jurisdictions include Fairport Harbor, Painesville Township, and North Perry. While coastal erosion is likely to remain a hazard for the foreseeable future (due to the county's proximity to Lake Erie), potential losses have been lessened since previous adoptions of this plan.

Erie County. Factors that cause shoreline erosion include bluff recession, high lake levels, high winds and human activities. These cause many problems to the coastal communities of Bay View, Sandusky, Huron, Vermilion and Kelley's Island. Manmade shoreline structures that lie within a designated CEA along Lake Erie's coastline are susceptible to property damage over a 30-year period. Because of the large number of residential properties located within a CEA along the shoreline, property damages are expected to be high.

Based on the property damage expected from stream bank and lake erosion, the impact on the local economy and local government expenditures is considered to be high. Manmade shoreline structures built along the Lake Erie shoreline, trap sand supply, causing beachless shores. Lack of beaches may have an adverse effect upon tourism in Erie County. County roadways may be affected and in need of repair, but this repair does not typically have an adverse effect on the economy, as motorists will find an alternate route.

Lucas County. According to the Lucas County Countywide All Natural Hazards Mitigation Plan of March 2013, lake surges (also referred to as storm surges) are associated with extreme weather events and are responsible for coastal flooding and erosion along Lake Erie within Lucas County. The storms that generate the large waves of lake surges can develop year-round, however within Lucas County, these events have typically occurred in the early spring and late fall months. Storm surges inundate coastal floodplains, the rise in water levels in inland bays and harbors, and backwater flooding through river mouths. Coastal erosion is generally associated with storm surges, windstorms, and flooding hazards, and may be exacerbated by human activities such as boat wakes, shoreline hardening, and dredging. Conversely, actions to supplement natural coastal processes, such as beach nourishment, dune stabilization, and construction of shore protection structures can greatly modify and reduce erosion trends within an area.

Ottawa County. Within Ottawa County, the risk for coastal erosion varies by jurisdiction. The lakeshore jurisdictions in the western portion of the county have a higher coastal erosion risk than those to the east. The coastal areas in Carroll, Erie, and Bay Township are primarily beach and marsh areas with low elevations. Structures in these coastal areas are primarily residential, and include a large percentage of summer homes and seasonal cottages. Some of these areas are protected by break walls that reduce the impact of waves as they wash onshore.

The eastern municipalities of Marblehead, Port Clinton and Put-In-Bay and Catawba Island, Danbury, Portage, and Put-In-Bay Townships are susceptible to coastal erosion but, given their high elevation and rocky surface and sub-surface, erosion is less likely to impact structures than in other areas of the county. The high cliffs and rock ledges protect the homes, businesses, and infrastructure along the lakeshore from wind and water damage. In the city of Port Clinton, the highway and homes are several hundred feet from the coastline and not significantly susceptible to coastal erosion damage. While the county is significantly lakefront, there is not a large amount of beach across the shoreline. A large percentage of the coastal area is either marsh and wetland, or rocky ledge.

SHARPP. See Section 4.3 for an analysis of coastal erosion data in local hazard mitigation plans.

Coastal Barrier Resourse System

The Coastal Barrier Resources Act (CBRA) of 1982 and subsequent amendments established the John H. Chafee Coastal Barrier Resources System (CBRS). The CBRS consists of relatively undeveloped coastal barriers and other areas located the Atlantic, Gulf of Mexico, Great Lakes, U.S. Virgin Islands, and Puerto Rico coasts. The CBRS currently includes 585 System Units, which comprise nearly 1.4 million acres of land and associated aquatic habitat. There are also 277 "Otherwise Protected Areas," a category of coastal barriers that are mostly already held for conservation and/or recreation purposes that include an additional 2.1 million acres of land and associated aquatic habitat. The CBRS units are identified and depicted on a series of maps entitled "John H. Chafee Coastal Barrier Resources System." These maps are controlling and indicate which lands are affected by the CBRA. The maps are maintained by the Department of the Interior through the U.S. Fish and Wildlife Service and can be viewed at: https://www.fws.gov/cbra/Maps/Mapper.html.The Coastal Barrier Resources Act and its amendments prohibit most new federal expenditures that tend to encourage development or modification of coastal barriers. The laws do not restrict activities carried out with private or other non-federal funds and only apply to the areas that are within the defined CBRS. The main prohibition affecting property owners is the prohibition on federal flood insurance.

Examples of prohibited federal assistance within System units include subsidies for road construction, channel dredging, and other coastal engineering projects. Federal flood insurance through the National Flood Insurance Program is available in a CBRS unit if the subject building was constructed (or permitted and under construction) before the CBRS unit's effective date. If an existing insured structure is substantially improved or damaged, the federal flood insurance policy will not be renewed.

PROBABILITY OF FUTURE EVENTS

With shore structures increasing along the coastline, the shoreline becomes increasingly modified. Reports and studies suggest that wave erosion and mass wasting caused by Lake Erie will continue to erode the Ohio shore for the foreseeable future. Damage to the built environment is inevitable without intervention and will warrant the full understanding of coastal processes within each stretch to rehabilitate the shoreline.

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

Previous versions of this plan indicated that coastal erosion had limited potential to affect any state-owned structures or critical facilities. All state facilities near the Lake Erie Coast were evaluated for their proximity to coastal erosion areas using the DAS data within a GIS. No state-owned or state-leased facilities were located in the coastal erosion areas, which represents no change since the last plan update.

2.11 DROUGHT

Drought is a normal, recurrent feature of climate that originates from a deficiency of precipitation over an extended period of time, resulting in a water shortage for some activity, group, or environmental sector. Within the State of Ohio, drought is equally as possible to occur in one section of the state as it is in another. The effects of drought within the state vary though, based on land use (agricultural production as opposed to urban areas), economy (dependence on drought-impacted business such as farming), geology (presence of an aquifer or ground structure that limits well production), and water source (public water supply, private well, or cistern).

There are four primary types of drought: agricultural, hydrological, meteorological, and socioeconomic. The State of Ohio is most often affected by agricultural and hydrological types of drought, and is often affected by both simultaneously. Below, these two types of drought are described in more detail.

Agricultural Droughts— Agricultural drought links characteristics of hydrological drought to agricultural impacts, focusing on precipitation shortages, differences between actual and potential evapotranspiration, soil water deficits, and reduced groundwater or reservoir levels. The amount of water available for agricultural use demand depends on prevailing weather conditions, biological characteristics of the specific plant, its stage of growth, and the physical and biological properties of the soil. A good definition of agricultural drought accounts for the variable susceptibility of crops during different stages of crop development, from emergence to maturity. Deficient topsoil moisture at planting may hinder germination, leading to low plant populations per acre and a reduction of final yield.

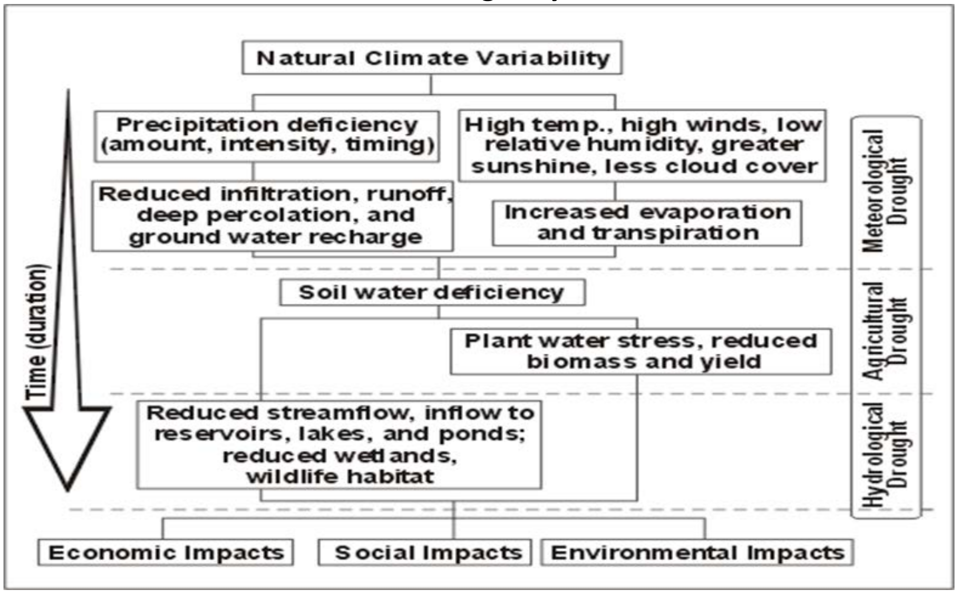
Hydrological Drought— Hydrological drought is associated with the effects of periods of precipitation (including snowfall) shortfalls on the surface or subsurface water supply – stream flow, reservoir, and lake levels and groundwater. The frequency and severity of hydrological drought are often defined on a watershed or river basin scale. Although all droughts originate with a deficiency of precipitation, hydrologists are more concerned with how this deficiency plays out through the hydrologic system.

Water in hydrologic storage systems (e.g., reservoirs, rivers) is often used for multiple and competing purposes (e.g., flood control, irrigation, recreation, navigation, hydropower, or wildlife habitat), further complicating the sequence and quantification of impacts. Competition for water in these storage systems escalates during drought and conflicts between water users increase significantly.

Although the climate is a primary contributor to hydrological drought, there are other factors such as changes in land use, deforestation, land degradation, and the construction of dams, which can all affect the hydrological characteristics of a basin. Because regions are interconnected by hydrologic systems, the impact of meteorological drought may extend well beyond the borders of the precipitation- deficient area.

The flow chart below illustrates the progression of drought and the relationship between meteorological, agricultural, and hydrological drought. Economic, social, and environmental impacts are shown at the bottom of the chart, independent of the time scale, indicating that such impacts can occur at any stage during a drought.

Figure 2.11.a
The Drought Cycle



Source: Source: National Drought Mitigation Center, University of Nebraska-Lincoln, U.S.A.
http://www.drought.unl.edu/droughtbasics/typesofdrought.aspx

MEASURING DROUGHT

The Palmer Drought Severity Index (PDSI) is a soil moisture algorithm. The PDSI was developed by W.C. Palmer in 1965. Many U.S. government agencies and states rely on the PDSI to trigger drought relief programs and responses. Most of the agency-based actions within the Ohio Emergency Operation Plan's Drought Incident Annex are triggered by the PDSI.

Figure 2.11.b

Palmer Drought Severity Index Classifications	
4.0 or greater	Extremely Wet
3.0 to 3.99	Very Wet
2.0 to 2.99	Moderately Wet
1.0 to 1.99	Slightly Wet
0.5 to 0.99	Incipient Wet Spell
0.49 to -0.49	Near Normal
-0.5 to -0.99	Incipient Dry Spell
-1.0 to -1.99	Mild Drought
-2.0 to -2.99	Moderate Drought
-3.0 to -3.99	Severe Drought
-4.0 or less	Extreme Drought

The PDSI is based on the supply-and-demand concept of the water balance equation, taking into account more than just the precipitation deficit at specific locations. The objective of the PDSI is to provide standardized measurements of moisture conditions, so that comparisons using the index can be made between locations and between time periods (usually months). The PDSI is calculated based on precipitation and temperature data, as well as the local Available Water Content of the soil. The Palmer Index is designed so that a -4.0 in South Carolina has the same meaning in terms of the moisture departure from a climatological normal as a -4.0 does in Ohio.

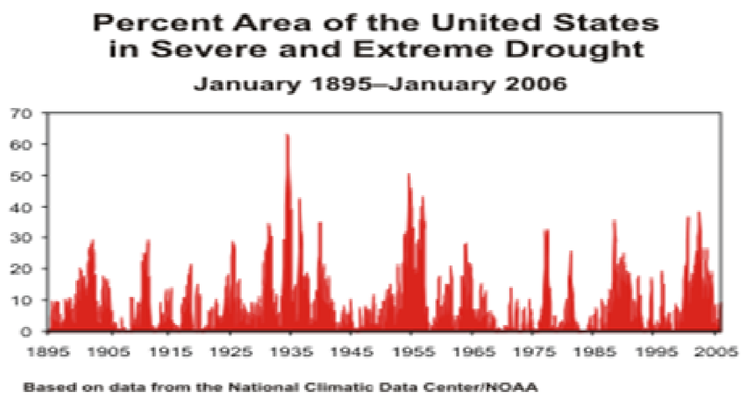
The Palmer Index is typically calculated on a monthly basis, and a long-term archive of the monthly PDSI values for every climate division in the United States exists with the National Climatic Data Center from 1895 through the present. Weekly Palmer Index values are calculated for climate divisions (the State of Ohio has ten climate divisions) during every growing season.

RISK ASSESSMENT

LOCATION

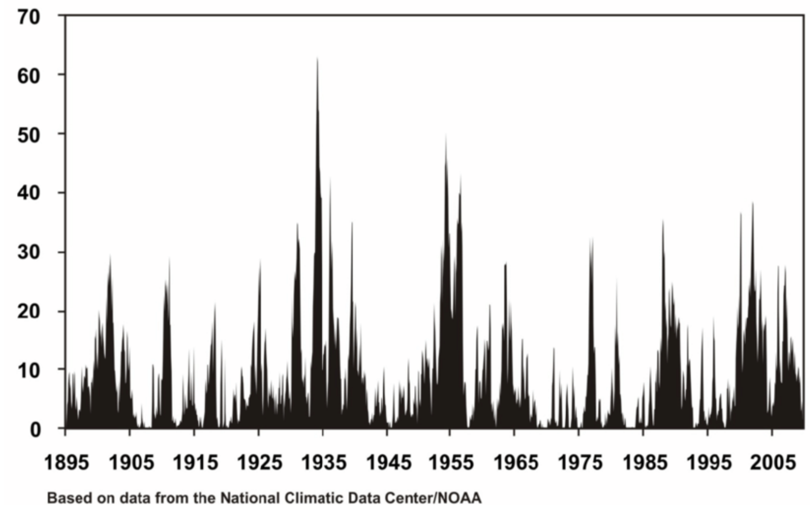
The National Drought Mitigation Center (NDMC) has calculated values showing the spatial extent of drought based on historical Palmer Drought Severity Index (PDSI) data. The annual average of 18.1% was calculated by selecting the month of each year from 1895 to 1995 with the greatest spatial extent of severe or extreme drought and averaging the values. Using PDSI data, the NDMC created data indicating the percent of time each climate division in the United States was in severe or extreme drought, from 1896–1994. The data show the spatial extent of drought for various time periods.

Figure 2.11.c



The worst recent drought event occurred in July 1988, with 36% of the country in severe or extreme drought. The worst drought event ever recorded occurred in July 1934, with 65% of the United States experiencing severe to extreme drought.

Percent Area of the United States in Severe and Extreme Drought
January 1895 – May 2010



Source: Quantification of Agricultural Drought for Effective Drought Mitigation and Preparedness: Key Issues and Challenges
https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1081&context=droughtfacpub

LHMP DATA

Hamilton County

The Hamilton County 2018 Hazard Mitigation Plan states that while the hazard is considered "Not Probable/Not Frequent", there are some areas in the county that may have special vulnerabilities for the hazard. In Crosby Township, there are four major farms that are vulnerable to drought. Similarly, a drought would greatly impact the township with its large agricultural economy in Whitewater Township.

Richland County

According to the Richland County 2017 Hazard Mitigation Plan, Agriculture is a major contributor to Richland County's economy. The county's 160,000 acres of farmland account for 40% of all land use in the county. Corn, soybeans, and wheat are the most prevalent crops. While Richland County rarely experiences drought conditions, the County's greatest vulnerability to drought is a reduction in crop yields.

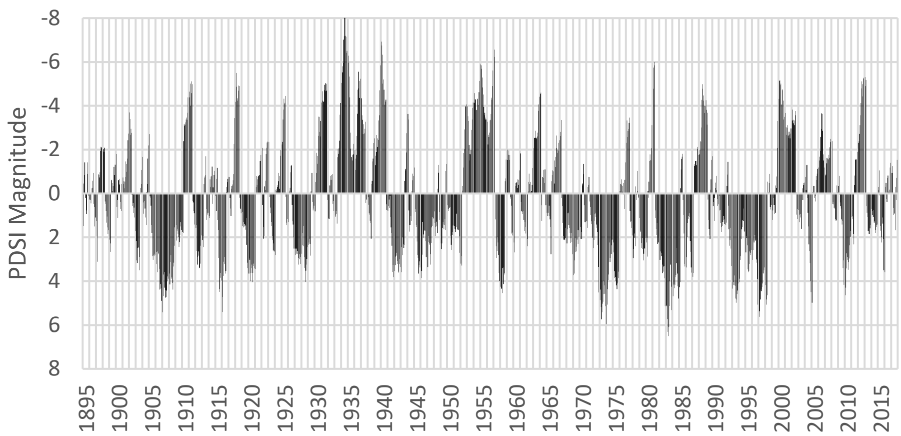
Shelby County

The Shelby County 2017 Hazard Mitigation Plan states Shelby County has a low risk of incurring damage from droughts and extreme heat. By itself, a drought does not damage developed property. However, over a long period of time, certain soils can expand and contract resulting in some structural damage to buildings. A small percentage of buildings in areas with such soils suffer minor damage during their "useful lives." Therefore, the overall impact on the County's infrastructure will be very low. When droughts do occur, the economic losses will be countywide affecting the farming community the most.

PAST OCCURRENCES

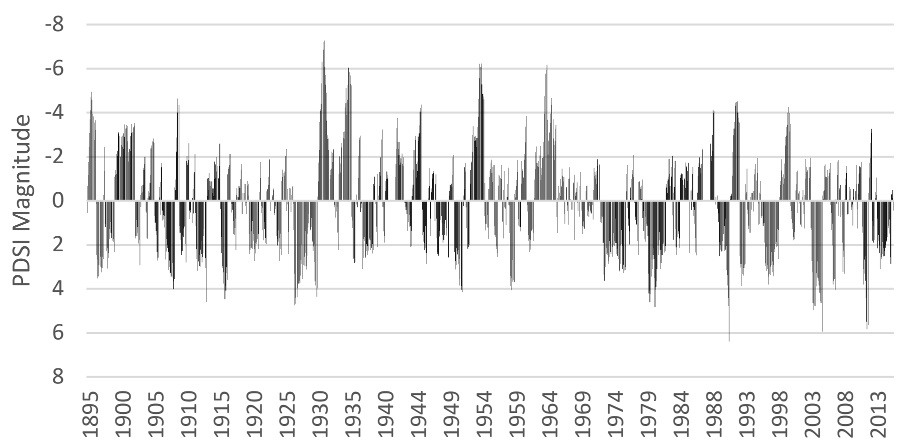
The NOAA National Climatic Data Center has calculated values showing the spatial extent of drought based on historical Palmer Drought Severity Index (PDSI) data. The period of record is from 1895 through the latest month (February 2018). Data was derived from area-weighted averages from interpolated estimates across the United States. Table 2.11.a tabulates the PDSI in Ohio since from January 1985 to February 2018 by month.

US PDSI Recorded
1895-2018 (Present)



Source: Monthly Palmer Drought Severity Index for States and Climate Divisions; NOAA National Climatic Data Center
https://www.drought.gov/drought/data/noaa-national-climatic-data-center/monthly-palmer-drought-severity-index-states-and-climate

Ohio PDSI Recorded
1895-2018 (Present)



Source: Monthly Palmer Drought Severity Index for States and Climate Divisions; NOAA National Climatic Data Center
https://www.drought.gov/drought/data/noaa-national-climatic-data-center/monthly-palmer-drought-severity-index-states-and-climate

Table 2.11.a: Ohio PDSI Recorded by Month, January 1985 to February 2018

Year	January	February	March	April	May	June	July	August	September	October	November	December
1895	0.57	-0.65	-1.16	-1.76	-2.45	-3.07	-3.7	-4.1	-4.72	-4.95	-4.58	-3.94
1896	-3.83	-3.55	-2.76	-3.22	-3.65	0.16	2.45	2.68	3.54	3.41	3.45	2.94
1897	2.55	3	3.26	3.04	3.06	2.54	2.65	-0.26	-1.34	-2.44	1.06	1.21
1898	2.29	2.16	3.08	2.6	2.37	1.74	1.28	1.46	0.97	1.47	1.69	1.81
1899	1.87	1.73	2.32	-1.1	-1.18	-1.4	-1.21	-2.11	-2.03	-2.27	-3.03	-3.1
1900	-2.96	-2.01	-1.98	-2.52	-2.91	-2.96	-2.45	-2.35	-3.05	-3.47	-2.9	-3.28
1901	-3.29	-3.44	-3.4	-2.69	-2.21	-1.77	-2.33	-2.34	-2.26	-2.92	-3.48	-3.09
1902	-3.11	-3.35	-3.3	-3.41	-3.53	1.62	1.71	0.87	1.61	1.45	1.21	1.95
1903	1.78	2.94	-0.25	0.29	-0.67	-0.34	-0.38	-0.71	-1.5	-1.4	-1.68	-2
1904	0.5	0.55	1.68	1.75	-0.14	-0.43	-0.19	-0.36	-0.81	-1.16	-2.37	-2.5
1905	-2.69	-2.68	-2.83	-2.64	0.7	1.02	0.97	1.38	1.57	2.33	2.72	2.59
1906	-0.15	-0.62	0.65	-0.86	-1.52	-1.71	0.45	0.9	0.66	0.85	0.7	1.22
1907	2.67	1.75	2.31	2.15	2	2.32	3.16	2.72	3.03	3.27	3.3	3.45
1908	2.82	3.49	4.01	3.66	3.55	-0.6	-0.48	-0.96	-2.23	-2.87	-4	-4.64
1909	-4.35	1.46	1.16	1.46	1.78	2.45	2.3	2.29	1.59	1.66	1.26	1.18
1910	1.96	2.8	-1.8	-2.03	-1.61	-1.71	-1.84	-2.6	0.45	0.83	0.53	0.43
1911	1.02	-0.13	-0.52	0.58	-1.24	-1.29	-2.13	0.57	1.16	2.21	2.64	3.19
1912	2.76	2.46	2.96	3	2.22	1.81	2.42	2.8	2.56	2.38	1.61	1.28
1913	3.07	2.61	4.61	-0.02	-0.2	-1.01	-0.48	-1.02	-1.27	-0.89	-0.66	-0.88
1914	-0.87	-0.34	-0.56	-0.21	-0.56	-0.97	-1.77	-1.04	-1.64	-1.33	-2	-1.58
1915	-0.99	-1.02	-1.57	-2.59	-0.02	0.38	1.64	2.39	2.98	3.06	3.25	3.76
1916	4.48	3.87	4.09	3.28	3.03	3.59	-1.2	-1.44	-1.54	-1.62	-2.12	-2.11
1917	0.54	0.15	0.4	0.42	0.91	1.52	1.55	1.24	0.81	2.25	-0.27	-0.58
1918	-0.18	-0.13	-0.65	-0.6	-0.59	-0.97	-1.41	-1.67	0.6	0.6	-0.35	-0.04
1919	-0.34	-0.76	0.25	0.08	0.61	-0.68	-0.91	-0.23	-0.77	1.53	2.43	2.25
1920	2.14	1.39	0.92	2.19	1.51	1.82	2.19	2.73	2.4	1.93	1.98	1.89
1921	1.75	1.52	2.2	-0.02	-0.41	-1.02	-1.75	0.23	0.57	0.32	1.34	1.8
1922	1.3	0.96	1.68	1.94	1.96	-0.42	-0.51	-0.54	-0.72	-1.1	-1.9	-1.85

Table 2.11.a: Ohio PDSI Recorded by Month, January 1985 to February 2018 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December
1923	0.46	-0.05	-0.02	-0.25	-0.19	-0.49	-0.56	0.56	0.64	0.37	0.24	1.6
1924	2.03	1.74	1.86	1.35	1.7	2.73	2.2	1.49	2.46	-0.91	-1.41	-1.07
1925	-1.25	-1.14	-1.33	-2.01	-2.02	-2.34	0.46	-0.53	0.17	1.43	2.42	-0.58
1926	-0.56	0.51	-0.25	-0.03	-0.62	-0.65	0.16	1.33	3.31	4.76	4.69	4.41
1927	4.38	3.98	3.73	3.8	3.79	3.63	3.74	3.4	2.71	1.99	2.9	3.55
1928	2.92	2.95	2.54	2.38	1.38	2.97	3.13	2.53	1.5	1.22	1.03	0.6
1929	1.35	1.31	0.78	1.2	1.89	1.81	2.29	2.08	1.99	2.79	3.67	3.86
1930	4.36	3.99	-0.19	-0.88	-1.74	-2.3	-3.56	-4.07	-4.15	-4.4	-5.33	-6.31
1931	-6.86	-7.21	-7.28	-6.09	-5.7	-5.27	-4.91	-3.64	-2.97	-2.79	-2.83	-2.3
1932	-0.97	-1.41	-1.17	-1.46	-2.23	-2.15	-1.76	-2.34	-2.32	0.2	0.3	0.77
1933	0.49	0.28	1.45	1.43	2.25	-1.21	-2.02	-1.98	-1.28	-1.69	-2.42	-2.62
1934	-2.84	-3.11	-2.81	-3.15	-4.24	-4.42	-5.11	-4.46	-3.89	-4.59	-5.27	-6.04
1935	-5.84	-5.69	-5.3	-5.24	0.73	0.9	1.24	2.64	2.63	2.6	2.84	2.78
1936	-0.28	0.17	0.28	0.31	-1.04	-2.04	-2.77	-2.87	-2.95	0.51	0.35	0.13
1937	3.1	2.62	1.75	1.83	1.66	2.55	2.62	2.28	1.98	2.47	2.06	2.27
1938	1.71	1.78	2.26	1.8	2.13	2.17	2.4	1.97	2.26	-0.76	-0.66	-1.09
1939	0.14	1.18	1.43	2.11	-1.22	-0.24	-0.03	-0.66	-1.3	-1.13	-1.97	-2.78
1940	-3.23	0.28	0.28	1.39	1.61	1.9	-0.9	-0.46	-0.97	-1.32	-1.18	-1.01
1941	-1.08	-1.68	-2.36	-3.3	-3.76	-2.67	-2.35	-2.07	-2.66	-1.63	-1.73	-1.92
1942	-2.14	-1.68	-1.57	-1.96	-0.02	0.08	0.12	0.28	0.44	0.27	0.61	1.36
1943	0.98	0.65	1.17	1.15	2.09	1.37	2.08	-0.2	-0.56	-0.73	-1.41	-2.32
1944	-2.94	-2.76	-1.67	-1.05	-1.35	-1.78	-2.91	-2.72	-3.06	-3.42	-4.05	-4.21
1945	-4.36	0.41	1.56	1.42	1.86	2.26	1.93	1.16	2.14	2.39	2.88	-0.01
1946	-0.58	-0.1	-0.65	-1.49	0.81	1.61	-0.38	-0.55	-1.23	-1	-1.25	-1.34
1947	0.93	-0.75	-1.2	0.82	1.68	2.42	2.34	2.5	2.42	1.63	1.36	0.87
1948	0.7	1.03	1.55	1.9	1.78	1.79	1.55	1.04	0.89	0.89	1.25	1.58
1949	2.62	2.56	-0.23	-0.45	-0.73	-0.72	-0.65	-0.78	-0.62	-1.18	-1.96	-2.08
1950	2.32	3.12	2.74	2.92	2.15	2.29	2.44	2.26	2.9	2.66	3.86	3.56
1951	3.87	4.04	4.16	0.01	-0.24	0.25	-0.52	-1.52	-1.32	-1.72	0.3	1.24
1952	2.18	1.97	2.11	2.01	-0.05	-0.78	-1.39	-1.77	-1.73	-2.22	-2.98	-3.38
1953	-2.71	-2.91	-2.93	-2.73	-2.45	-2.86	-2.84	-3.35	-3.82	-4.62	-5.56	-6.22
1954	-6.08	-6.23	-5.29	-4.86	-4.85	-4.73	-4.6	0.71	-0.8	1.35	1.04	1.05
1955	0.65	1.22	1.73	-0.54	-1.08	-1.37	-1.43	-1.74	-1.86	-1.27	-0.85	-1.55
1956	-1.62	1.15	1.56	1.65	2.19	2.07	2.37	2.56	-0.04	-0.68	-1.18	-1.11
1957	-1.04	-0.99	-1.63	0.94	0.97	1.72	-0.5	-1.36	0.31	0.34	0.36	1.1
1958	-0.18	-0.76	-1.5	0.19	0.21	1.47	3.41	3.88	4.07	3.51	3.68	2.7
1959	3.59	3.71	-0.31	-0.15	-0.48	-0.95	-0.66	-1.3	-1.85	0.83	1.13	1.18
1960	1.21	1.39	-0.77	-1.81	-1.43	-1.34	-1.04	-1.06	-1.87	-2.12	-2.65	-3.37
1961	-3.85	0.18	0.5	1.81	1.57	1.75	2.34	2.23	1.78	1.4	1.35	1.31
1962	1.46	1.85	-0.14	-0.96	-1.43	-2.2	-1.71	-2.46	-1.71	-1.56	-1.55	-1.8
1963	-2.06	-2.47	-0.93	-1.18	-1.49	-1.94	-1.93	-1.96	-2.68	-3.94	-4.74	-5.76
1964	-5.94	-6.17	-3.67	-2.09	-2.73	-2.7	-3.1	-3.08	-3.52	-3.96	-4.66	-4.35
1965	-3.7	-2.83	-2.53	-1.85	-2.72	-3.28	-3.45	0	0.74	1.47	-0.14	-0.66
1966	-0.36	-0.22	-0.98	-0.63	-0.67	-1.45	-1.14	-1.06	-0.88	-1.1	0.6	1.04
1967	-0.61	-0.6	0.47	0.22	1.09	-0.97	-1.01	-1.51	0.01	-0.08	0.04	0.41
1968	0.41	-0.79	-0.83	-1.18	1.79	-0.22	-0.37	-0.4	-0.59	-0.83	0.1	0.46
1969	0.72	-0.66	-1.29	0.02	0	0.45	1.51	1.16	1.17	0.95	1.26	1.3
1970	-0.45	-0.66	-0.68	0.69	0.41	0.49	0.74	0.11	0.26	0.53	0.45	0.58
1971	0.2	0.86	-0.5	-1.49	-1.11	-1.31	-1	-1.18	-0.75	-1.36	-1.88	-1.57
1972	-1.64	-1.63	0.03	0.96	0.82	1.01	0.69	0.76	1.93	1.9	3.36	3.63

Table 2.11.a: Ohio PDSI Recorded by Month, January 1985 to February 2018 (Continued)

Year	January	February	March	April	May	June	July	August	September	October	November	December
1973	3.03	2.41	2.15	2.37	2.45	2.75	2.87	2.57	1.83	1.98	2.33	2.42
1974	2.54	2.1	2	1.48	1.85	2.05	0.81	1.93	2.41	1.94	2.18	2.5
1975	2.65	3.17	3.22	2.86	2.03	1.96	1.34	2.05	3.09	3.29	2.91	3.17
1976	3.14	3.01	-0.43	-1.21	-1.63	0.35	0.82	1.14	1.39	1.99	-0.14	-0.6
1977	-0.99	-1.39	-1.19	-1.07	-2.07	0	0.12	0.73	0.89	1.12	1.07	1.84
1978	2.46	-0.85	-0.89	-0.85	-0.63	-0.54	-0.68	-0.08	-0.96	0.79	0.48	1.36
1979	1.76	1.86	0.73	1.05	1.15	1.1	1.61	3.31	4.22	4.08	4.61	4.25
1980	3.45	2.67	3.09	2.47	2.16	2.65	3.5	4.83	4.04	3.93	3.67	3.1
1981	2.04	2.47	1.43	1.8	2.24	3.11	2.84	2.22	2.47	2.45	1.97	1.91
1982	2.36	2.06	2.28	-0.6	-0.76	-0.35	-0.91	-0.96	-1.09	-1.89	-1.22	-0.67
1983	-1.1	-1.53	-2.04	0.67	1.77	-0.36	-0.63	-1.49	-1.81	1.3	2.12	2.46
1984	1.65	1.4	1.53	1.72	2.13	-1.04	-1.17	-1.19	-1.25	-1.23	-0.94	-0.73
1985	-1.01	-0.94	-0.58	-1.73	-1.51	-1.59	-1.34	-0.9	-1.72	0.03	2.38	-0.02
1986	-0.46	0.44	-0.51	-1.23	-1.53	0.28	0.69	0.43	1.04	1.69	2.36	2.49
1987	-0.36	-1.13	-1.53	-1.72	-1.97	-1.65	-1.49	-1.24	-1.67	-1.68	-2.3	-2.36
1988	-2.59	-1.79	-2.03	-2.27	-2.98	-4.14	-3.99	-4.06	-0.05	-0.04	0.17	-0.18
1989	-0.24	0.36	0.58	0.96	1.89	2.51	2.22	2.02	2.32	2.28	2.29	1.85
1990	1.52	2.3	1.16	0.81	2.23	2.05	3.15	3.39	3.86	4.79	4.42	6.4
1991	-0.09	-0.21	-0.23	-0.32	-1.14	-2.23	-2.97	-3.27	-3.28	-3.56	-4.31	-4.45
1992	-4.48	-4.51	-4.01	-3.77	-3.58	-3.52	2.52	2.86	3.04	2.88	3.87	3.34
1993	3.4	3.05	2.93	2.87	-0.74	-0.32	-0.4	-1.45	0.41	0.59	1.28	1.14
1994	1.45	-0.17	-0.33	0.4	-0.35	-0.34	-0.45	0.5	-0.46	-1.2	-1.46	-1.67
1995	-0.92	-1.25	-1.94	0.13	1.09	1.06	-0.36	-0.29	-0.91	0.7	0.78	0.69
1996	1.16	1.03	1.02	1.9	2.85	2.97	3.19	2.1	3.09	2.94	3.44	3.81
1997	3.35	3	3.37	2.34	2.94	3.25	2.76	3.43	2.93	2.34	2.19	1.96
1998	2.11	1.88	1.3	2.06	1.34	2.66	-0.18	-0.04	-0.9	-0.72	-1.37	-1.88
1999	-1.06	-0.77	-1.2	-1	-1.69	-2.5	-2.89	-2.95	-3.37	-3.43	-4.01	-4.25
2000	-3.98	-3.14	-3.48	0.25	0.47	0.84	1	1.29	1.8	1.64	1.43	1.76
2001	-0.47	-0.75	-1.29	-1.37	0.57	-0.31	-0.37	-0.43	0.13	1.08	1.12	1.18
2002	-0.18	-0.49	0.2	0.6	1.27	-0.26	-1	-1.9	-1.53	-1.29	-1.39	-1.32
2003	-1.52	-1.02	-1.53	-1.95	1.25	1.34	2.74	3.26	4.64	4.67	4.96	4.77
2004	4.78	3.89	3.3	2.76	3.49	3.52	3.63	3.85	4.18	4.21	4.57	4.64
2005	5.95	-0.23	-0.42	-0.09	-0.47	-1.57	-1.65	-1.1	-1.06	-1.06	-1.05	-1.39
2006	-1.12	-1.27	-1.45	-1.71	0.19	0.57	1.32	1.05	2.03	3.81	3.63	3.55
2007	4.04	-0.06	0.13	0.15	-1.17	-1.77	-1.83	0.68	-0.51	-0.59	-0.71	0.75
2008	0.65	1.91	3.23	2.27	2.54	3.32	-0.06	-0.7	-1.01	-1.25	-1.58	0.62
2009	0.59	-0.07	-0.61	-0.45	-0.53	0.07	0.43	0.31	0.17	1.13	-0.53	-0.18
2010	-0.43	-0.45	-0.76	-1.62	0.39	1.27	-0.3	-0.77	-1.22	-1.56	-1.27	-1.51
2011	-1.75	1.17	1.45	3.09	3.81	3.31	2.68	2.52	3.64	4.44	5.5	5.84
2012	5.64	-0.34	-1.05	-1.7	-1.95	-2.63	-3.08	-3.26	0.92	1.81	1.16	1.91
2013	1.8	-0.14	-0.4	-0.25	-1.05	0.82	2.17	1.81	1.57	2.04	2.39	3.09
2014	2.64	2.58	1.88	2.42	2.14	2.53	2.3	2.52	2.02	2.13	1.89	1.81
2015	1.65	1.14	1.23	1.5	0.86	2.57	2.87	-0.26	-0.31	-0.14	-0.48	0.45
2016	-0.44	0.49	-0.02	-0.1	-0.25	-0.61	-1.04	-0.97	-0.83	-0.86	-1.84	-1.84
2017	0.58	0.21	0.67	0.47	1.02	1.22	2.34	1.79	1.11	1.44	2.47	1.99
2018	1.74	2.95										

Source: Monthly Palmer Drought Severity Index for States and Climate Divisions; NOAA National Climatic Data Center
https://www.drought.gov/drought/data/noaa-national-climatic-data-center/monthly-palmer-drought-severity-index-states-and-climate

The table 2.11.b lists the number of years that the United States has had a severe or extreme drought in the 100 years from 1896 to 1995, based on the Palmer Drought Severity Index (PDSI). The data is divided and analyzed based on NOAA river basins. The chart shows that some part of the United States has experienced a severe or extreme drought in each year from 1896 to 1995, and that in 72 years, droughts covered more than 10% of the country.

Table 2.11.b

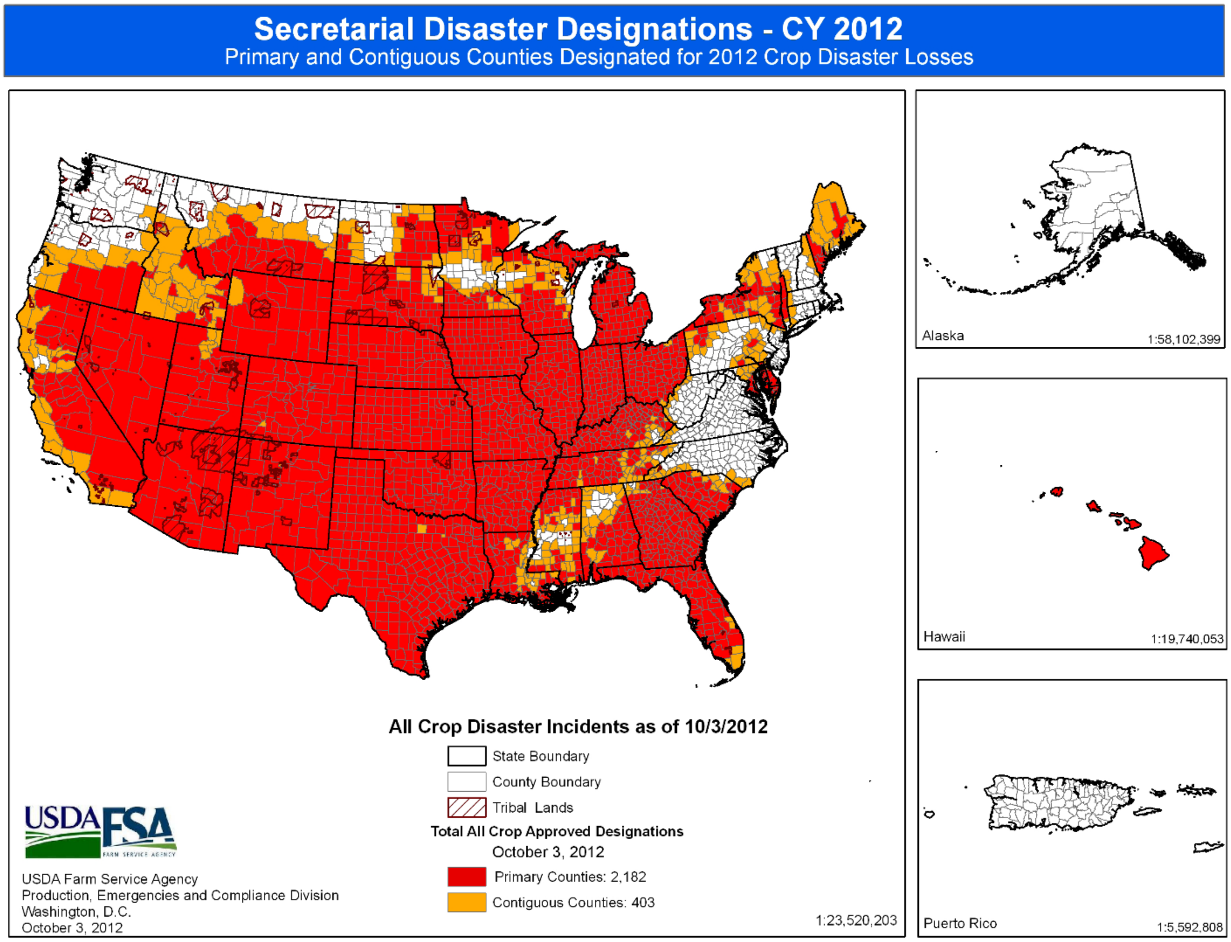
Number of Years with Severe or Extreme Drought between 1896 and 1995									
% area of basin/region	>0%	>10%	>25%	>33%	>50%	>66%	>75%	>90%	100%
United States	100	72	27	13	1	0	0	0	0
Upper Mississippi	77	55	43	30	19	12	9	3	1
Mid-Atlantic	69	49	32	24	12	5	4	0	0
South Atlantic/Gulf	79	47	25	15	9	3	3	0	0
Ohio	67	51	34	28	16	12	9	4	3
Missouri	90	70	43	33	17	10	4	3	0
Pacific Northwest	86	61	42	33	23	14	9	1	0
California	53	45	40	30	14	9	5	3	3
Great Basin	71	65	43	37	19	6	3	1	1
Lower Colorado	56	54	35	28	16	11	10	4	3
Upper Colorado	50	50	42	34	27	25	16	9	8
Rio Grande	58	47	32	24	15	8	5	2	2
Texas Gulf Coast	49	48	38	26	22	13	10	9	7
Arkansas–White–Red	65	48	27	23	14	7	4	0	0
Lower Mississippi	56	38	19	15	4	1	0	0	0
Souris–Red–Rainy	66	57	38	29	19	10	8	5	2
Great Lakes	73	58	32	23	9	3	2	2	0
Tennessee	31	31	27	24	21	16	13	5	5
New England	56	44	27	13	8	5	4	0	0

Source: National Climatic Data Center, Understanding Your Risk and Impacts – A Comparison of Droughts, Floods, and Hurricanes in the United States. *http://www.drought.unl.edu/risk/us/compare.html.*

2012 NORTH AMERICAN DROUGHT

The 2012-2013 North American Drought was an expansion of the 2010-2012 United States Drought which began in the spring of 2012 when the lack of snow caused very little meltwater to absorb into the soil. The drought included most of the United States and all of Ohio. Several counties in the state were designated with moderate drought conditions by mid-June of 2012. Its effects were equal to similar droughts which occurred in the 1930s and 1950s, but the 2012 event did not last as long. Nonetheless, the 2012 North American Drought inflicted catastrophic economic ramifications on the state. In most measures, the 2012 drought exceeded the 1988-1989 North American Drought, which was the most recent comparable drought.

On July 30th, 2012, the Governor of Ohio sent a memorandum to the U.S. Department of Agriculture State Executive Director requesting primary county natural disaster designations for eligible counties due to agricultural losses caused by drought during the 2012 crop year. The USDA reviewed the Loss Assessment Reports and determined that there were sufficient production losses in 85 counties to warrant a Secretarial disaster designation on September 5th, 2012. By December 2012, all 88 counties received such a designation.


Secretarial Disaster Designations - CY 2012
Primary and Contiguous Counties Designated for 2012 Crop Disaster Losses
Alaska
1:58,102,399
Hawaii
1:19,740,053
Puerto Rico
1:5,592,808
All Crop Disaster Incidents as of 10/3/2012
State Boundary
County Boundary
Tribal Lands
Total All Crop Approved Designations
October 3, 2012
Primary Counties: 2,182
Contiguous Counties: 403
1:23,520,203
USDA Farm Service Agency
Production, Emergencies and Compliance Division
Washington, D.C.
October 3, 2012

The USDA – National Agricultural Statistics Service (NASS) was used to compare a regular crop production period (Crop Year 2011) and the affected crop production period during drought conditions. Commodities were selected through the NASS Program Survey, Crops sector and then by Group: Field Crops, Vegetables, and Fruit & Tree Nuts. Table 2.11.c shows the difference in crop production in Ohio.

Table 2.11.c

Field Crop Losses						
Commodity	Measurement	2011 Quantity	2012 Quantity	Difference	% Change	Trend
Grain Corn - Planted	Acres	3,400,000	3,900,000	500,000	15%	More
Grain Corn - Harvested	Acres	3,220,000	3,650,000	430,000	13%	More
Grain Corn- Production	Bushels	508,760,000	448,950,000	-59,810,000	-12%	Less
Grain Corn - Yield	BU/Acre	158	123	-35	-22%	Less
Hay - Harvested	Acres	1,120,000	1,100,000	-20,000	-2%	Less
Hay - Production	Tons	2,772,000	2,330,000	-442,000	-16%	Less
Hay - Yield	Tons/Acre	2.48	2	0	-19%	Less
Maple Syrup	Number of Taps	405,000	410,000	5,000	1%	More
Maple Syrup - Production	Gallons	125,000	100,000	-25,000	-20%	Less
Maple Syrup - Yield	Gallons/Tap	0.309	0	0	-100%	Less
Soybeans - Planted	Acres	4,550,000	4,600,000	50,000	1%	More
Soybeans - Harvested	Acres	4,540,000	4,590,000	50,000	1%	More
Soybeans - Production	Bushels	217,920,000	206,550,000	-11,370,000	-5%	Less
Soybeans - Yield	BU/Acre	48	45	-3	-6%	Less
Tobacco, air-cured light burley - Harvested	Acres	1,600	1,800	200	13%	More
Tobacco, air-cured light burley - Production	Bushels	3,360,000	3,600,000	240,000	7%	More
Tobacco, air-cured light burley - Yield	BU/Acre	2,100	2,000	-100	-5%	Less
Fruit Losses						
Commodity	Measurement	2011 Quantity	2012 Quantity	Difference	% Change	Trend
Apples	Acres Bearing	4,300	4,000	-300	-7%	Less
Apples - Production	Pounds	66,600,000	33,000,000	-33,600,000	-50%	Less
Apples - Yield	Pounds/Acre	15,500	8,250	-7,250	-47%	Less
Grapes	Acres Bearing	1,900	1,900	0	0%	(No Change)
Grapes - Production	Tons	7,480	5,335	-2,145	-29%	Less
Grapes - Yield	Tons/Acre	3.94	2.81	-1	-29%	Less
Peaches	Acres Bearing	1,200	1,400	200	17%	More
Peaches - Yield	Tons	6,030	4,960	-1,070	-18%	Less
Peaches - Production	Tons/Acre	5.03	3.54	-1	-30%	Less
Vegetable Losses						
Vegetable	Measurement	2011 Quantity	2012 Quantity	Difference	% Change	Trend
Cucumbers - Planted	Acres	2,600	7,100	4,500	173%	More
Cucumbers - Harvested	Acres	2,600	7,000	4,400	169%	More
Cucumbers - Production	Cwt (Hundredweight)	17,910	31,290	13,380	75%	More
Cucumbers - Yield	Cwt/Acre	6.89	4.47	-2	-35%	Less
Bell Peppers - Planted	Acres	3,200	3,200	0	0%	(No Change)
Bell Peppers - Harvested	Acres	3,100	3,100	0	0%	(No Change)
Bell Peppers -Production	Cwt (Hundredweight)	1,004,000	567,000	-437,000	-44%	Less
Potatoes - Planted	Acres	2,000	1,500	-500	-25%	Less
Potatoes - Harvested	Acres	1,700	1,400	-300	-18%	Less
Potatoes - Production	Cwt (Hundredweight)	459,000	308,000	-151,000	-33%	Less
Potatoes - Yield	Cwt/Acre	270	220	-50	-19%	Less
Squash - Planted	Acres	1,900	1,800	-100	-5%	Less
Squash - Harvested	Acres	1,800	1,700	-100	-6%	Less
Squash - Production	Cwt (Hundredweight)	360,000	304,000	-56,000	-16%	Less
Squash - Yield	Cwt/Acre	200	180	-20	-10%	Less
Sweet Corn - Planted	Acres	15,900	16,400	500	3%	More
Sweet Corn- Harvested	Acres	15,100	15,100	0	0%	(No Change)
Sweet Corn - Production	Cwt (Hundredweight)	1,737,000	1,586,000	-151,000	-9%	Less
Sweet Corn - Yield	Cwt/Acre	115	105	-10	-9%	Less
Fresh Market Tomatoes - Planted	Acres	4,500	4,300	-200	-4%	Less
Fresh Market Tomatoes - Harvested	Acres	3,200	4,100	900	28%	More
Fresh Market Tomatoes - Production	Cwt (Hundredweight)	752,000	697,000	-55,000	-7%	Less
Fresh Market Tomatoes - Yield	Cwt/Acre	235	170	-65	-28%	Less

Source: U. S. Department of Agriculture - National Agricultural Statistics Service

PROBABILITY OF FUTURE EVENTS

The probability of future occurrences of drought in Ohio is difficult to predict; however, there are two factors that may influence future drought conditions: The El Niño–Southern Oscillation (ENSO), and climate change.

EL NINO AND LA NINA SOUTHERN OSCILLATION

A great deal of research has been conducted in recent years on the role of interacting systems, or teleconnections, in explaining regional and even global patterns of climatic variability. These patterns tend to recur periodically with enough frequency and with similar characteristics over a sufficient length of time that they offer opportunities to improve our ability for long-range climate prediction, particularly in the tropics.

Every 2 to 7 years, off the western coast of South America, ocean currents and winds shift, bringing warm water westward, displacing the nutrient-rich cold water that normally wells up from deep in the ocean. The invasion of warm water disrupts both the marine food chain and the economies of coastal communities that are based on fishing and related industries. Because the phenomenon peaks around the Christmas season, the fishermen who first observed it named it El Niño ("the Christ Child"). In recent decades, scientists have recognized that El Niño is linked with other shifts in global weather patterns. The intensity and duration of an ENSO event is varied and hard to predict. Typically, it lasts anywhere from 14-to-22 months, but it can be much longer or shorter. El Niño often begins early in the year and peaks between the following November.

During an El Niño–Southern Oscillation (ENSO) event, the Southern Oscillation is reversed. Generally, when pressure is high over the Pacific Ocean, it tends to be low in the eastern Indian Ocean, and vice versa. It is measured by gauging sea-level pressure in the east (at Tahiti) and west (at Darwin, Australia) and calculating the difference. El Niño and Southern Oscillation often occur together, but also happen separately. High positive values of the SOI indicate a La Niña, or "cold event". La Niña is the counterpart of El Niño and represents the other extreme of the ENSO cycle. La Niña years often (but not always) follow El Niño years.

Table 2.11.d, ENSO Phases 1900 to 2005

		Negative PDO: 1900-1924, 1947-1976, 1999-2002	Warm phase PDO: 1925-1946, 1977-1998, 2003- 2005
ENSO PHASE	La Niña (Cool)	1904, 1907, 1909, 1910, 1911, 1917, 1918, 1921, 1923, 1950, 1951, 1955, 1956, 1963, 1965, 1968, 1971, 1972, 1974, 1975, 1976, 1999, 2000, 2001	1925, 1932, 1934, 1938, 1939, 1943, 1944, 1945, 1984, 1985, 1986, 1989, 1996
	ENSO Neutral	1901, 1902, 1908, 1913, 1916, 1922, 1947, 1948, 1949, 1953, 1954, 1957, 1960, 1961, 1962, 1967, 2002	1927, 1928, 1929, 1933, 1935, 1936, 1937, 1946, 1979, 1981, 1982, 1990, 1991, 1993, 1994, 1997, 2004
	El Niño (Warm)	1900, 1903, 1905, 1906, 1912, 1914, 1915, 1919, 1920, 1924, 1952, 1958, 1959, 1964, 1966, 1969, 1970, 1973	1926, 1930, 1931, 1940, 1941, 1942, 1977, 1978, 1980, 1983, 1987, 1988, 1992, 1995, 1998, 2003, 2005

Source: Climate Impacts Group, Joint Institute for the Study of the Atmosphere and the Ocean, University of Washington

Understanding the connections between ENSO (and La Niña) events and weather anomalies around the globe can help in forecasting droughts, floods, tropical storms, and hurricanes. NOAA estimates that the economic impacts of the 1982–83 El Niño, perhaps the strongest event in recorded history, conservatively exceeded $8 billion worldwide, from droughts, fires, flooding, and hurricanes. This event and its associated disasters have been blamed for 1,000 to 2,000 deaths. In addition, the extreme drought in the United States' Midwest during 1988 has been linked to the "cold event", or La Niña, of 1988 that followed the ENSO event of 1986–87.

It is possible that the direct impacts of climate change on water resources might be hidden beneath natural climate variability. With a warmer climate, droughts, and floods could become more frequent, severe, and longer-lasting. The potential increase in these hazards is a great concern given the stresses being placed on water resources and the high costs resulting from recent hazards. The drought of the late 1980s showed what the impacts might be if climate change leads to a change in the frequency and intensity of droughts across the United States. From 1987 to 1989, losses from drought in the United States totaled $39 billion. More frequent extreme events such as droughts and floods could end up being more cause for concern than the long-term change in temperature and precipitation averages.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

Drought risk is based on a combination of the frequency, severity, and spatial extent of drought and the degree to which a population or activity is vulnerable to the effects of drought. The degree of a region's vulnerability depends on the environmental and social characteristics of the region and is measured by the ability to anticipate, cope with, resist, and recover from a drought.

Society's vulnerability to drought is determined by a wide range of factors, both physical and social, such as demographic trends and geographic characteristics. People and activities will be affected in different ways by different hazards.

There is a sequence of impacts associated with meteorological, agricultural, and hydrological droughts in Ohio. When drought begins, the agricultural sector is usually the first to be affected because of its heavy dependence on stored soil water, which can be rapidly depleted during extended dry periods. If precipitation deficiencies continue, then people dependent on other sources of water will begin to feel the effects of the shortage. Those who rely on surface water (reservoirs and lakes) and subsurface water (groundwater) are usually the last to be affected. A short-term drought that persists for 3 to 6 months may have little impact on these sectors, depending on the characteristics of the hydrologic system and water use requirements.

When precipitation returns to normal and meteorological drought conditions have abated, the sequence is repeated for the recovery of surface and subsurface water supplies. Soil water reserves are replenished first, followed by stream flow, reservoirs and lakes, and groundwater. Drought impacts may diminish rapidly in the agricultural sector because of its reliance on soil water, but linger for months or even years in other sectors, dependent on stored surface or subsurface supplies. Groundwater users, often the last to be affected by drought during its onset, may be last to experience a return to normal water levels. The length of the recovery period is a function of the intensity of the drought, its duration, and the quantity of precipitation received as the episode terminates.

Socioeconomic definitions of drought associate the supply and demand of some economic goods with elements of meteorological, hydrological, and agricultural drought. It differs from the other types of drought because its occurrence depends on the time and space processes of supply and demand to identify or classify droughts. The supply of many economic goods, such as water, forage, food grains, fish, and hydroelectric power, depends on the weather. Socioeconomic drought occurs when the demand for an economic good exceeds supply as a result of a weather-related shortfall in water supply.

FEMA estimated in 1995 that drought costs the United States $6– 8 billion annually. Other studies have indicated that drought losses average $200 million to $1.24 billion annually in the Great Plains. This range is based on crop losses and other direct and indirect losses. According to NOAA's National Climatic Data Center, in 1999, a drought that affected twenty-eight Ohio counties caused $200 million in crop damages.

The Dust Bowl years of the 1930s and the drought of 1988–89 are both contenders for the worst drought on record in the United States. Economic losses are often hard to calculate and compare for a variety of reasons: lack of historical records and economic models, and past and present costs that are often based on different criteria. Today, many different types of losses are often included in an economic analysis, such as energy losses, ecosystem losses, and consumer purchasing losses, but they were not typically included in previous analyses and are difficult to assess in retrospect.

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

Drought does not pose a specific threat to state-owned or state-leased facilities. The larger threat from drought would be based on the agricultural and drinking water demands with a limited supply. Additionally, drought can play a major role in occurrences of wildfires throughout the state (Section 2.7).

2.12 SEVERE SUMMER STORMS

Severe summer storms traditionally precede an approaching cold air mass. In the northern hemisphere, the spin of the earth naturally produces weather patterns affecting North America, which travel from west to east across the continent. Key components to the formation of storms are a low-pressure zone, high-pressure zone and the jet stream.

The troposphere is the lowest portion of Earth's atmosphere containing approximately 75% of the atmosphere's mass and almost all of its water vapor. Air at this level is acted upon by the earth surface (land and water) and the heating cycle associated with sunlight. Unlike other portions of the atmosphere, which are largely homogenous, at the surface discrete areas or bubbles exist of differing temperature, water vapor content and pressure. Warm areas (low pressure) tend to rise, pressing on the borders of surrounding cool areas (high pressure). It is where the pressure zones interface that temperature changes cause water vapor in the air to condense creating precipitation. The warmer the overall temperature of the atmosphere and the greater the volume of water vapor present, the larger the associated perception event.

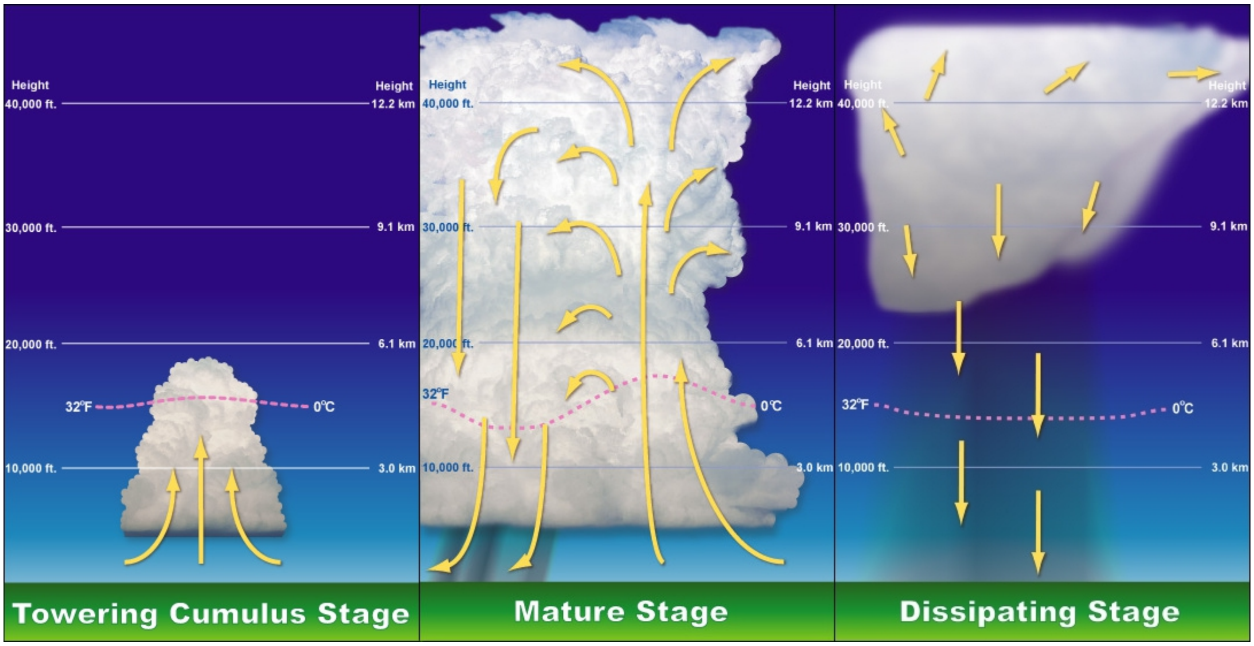
Jet streams are fast flowing, relatively narrow air currents found in the atmosphere around 11 kilometers (36,000 ft.) above the surface of the Earth. They form at the boundaries of adjacent air masses with significant differences in temperature, such as of the polar region and the warmer air toward the equator. These air currents migrate north and south in a snakelike pattern changing their relative location as the planet's axis tilts with each passing year. These winds act on the high and low-pressure zone moving them across the continent and shifting them north and south.

Thunderstorms develop when large differences exist between adjacent zones combined with significant water vapor. As warm air begins to lift, it eventually starts to cool and condensation takes place. When the moisture condenses, heat is released which further aids in the lifting process. If enough instability is present in the atmosphere, this process will continue long enough for cumulonimbus clouds to form, which supports lightning and thunder (see Diagram 2.12a). As water droplets rise into the colder air, they can freeze. When the velocity of wind becomes great enough, the ice pellets are repeatedly lifted and dropped in the storm adding layers of ice with each cycle. Once the wind cannot support the weight of the ice pellet, it falls the ground in the form of hail.

One key component to a thunderstorm is lightning, an atmospheric discharge of electricity. High-speed videos (examined frame-by frame) show that most lightning strikes are made up of multiple individual strokes. A typical strike is made of 3 to 4 strokes. The sudden increase in pressure and temperature from lightning produces rapid expansion of the air surrounding and within a bolt of lightning. In turn, this expansion of air produces a sonic shock wave, which produces the sound of thunder. Lightning, other storm components, often seeks a path though the tallest object available. Trees, utility line/poles, tall buildings and even humans can be sought as a pathway for the discharging electricity.

Summer storms are considered high wind events by the National Climactic Data Center when surface winds meet or exceed 50 knots or 57.6 miles per hour. It is possible for winds in strong storms to exceed 100 miles per hour, with gusts even stronger.

Figure 2.12a



Source: Wikipedia http://en.wikipedia.org/wiki/Thunderstorm

RISK ASSESSMENT

LOCATION

Severe summer storms and associated thunderstorm/high winds, lightning, and hail events are common throughout Ohio and reported hundreds of times each year. For the purpose of this plan, thunderstorm wind events, hail events, and lightning events will be assessed separately under *Severe Summer Storms* (2.12) section. Each of these are statewide hazards. For thunderstorm wind and hail events, past occurrences will be reported based on days with events unless specified otherwise. For lightning, each reported event will be counted as a single event.

PAST OCCURRENCES

According to the NCDC Storm Database, there has been 453 thunderstorm wind events from January 1, 2008 to December 31, 2017. From these events, about $145,609,158 (2017 dollars) in property and crop damages have been reported and have directly caused 8 deaths and 100 injuries. For hail during the same timeframe, there were 359 days with events that resulted in $187,455,392 (2017 dollars) in property and crop damage and have directly caused zero deaths and two injuries.

From January 1, 1996 to December 31, 2017, there were 229 reported lightning events that resulted in $18,204,489 in property and crop damages and have directly caused 25 deaths and 120 injuries. However, based on the NCDC data from the period of January 1, 1996 to December 31, 2017, it could be assumed that an event was not recorded unless damages were reported or resulted in the death or injury of a person. According to National Geographic, lightning detecting systems in the United States monitor an average of 25 million strokes of lightning and about 100,000 thunderstorms per year.

Within the January 2008 to December 2017 analysis period, the costliest hail event from happened on May 25, affecting Hancock County and had cost $85,000,000 in damages. The event had produced hail as large as baseballs. The western half of the city of Findlay was especially hard hit. As many as 4,000 homes and business in this area may have been damaged by the hail. Thousands of automobiles also sustained damage from the hail. This event could end up being one of costliest hailstorms in Ohio history.

On November 5, 2017, a cold front moved across the Ohio Valley and southern Great Lakes resulting in thunderstorm wind events affecting many. These winds caused $18,032,500 in property and crop damages within Ohio counties. The costliest high wind event happened on September 14, 2008 as a result of Hurricane Ike. High winds affected most parts of the state. The NCDC Storm Database reports that $771,955,000 had been caused in property and crop damage.

Table 2.12.a

Thunderstorm Events by County (January 1, 2008 to December 31, 2017)

Region 1

County	Number of Events	Number of Deathes	Number of Injuries	Total Property and Crop Damage (2017 Dollars)
ALLEN	50	0	0	$ 54,093
AUGLAIZE	79	0	2	$ 1,018,487
CHAMPAIGN	44	0	0	$ 413,232
CLARK	78	0	0	$ 438,238
CRAWFORD	51	0	0	$ 1,412,685
DARKE	72	0	0	$ 680,641
DEFIANCE	37	0	0	$ 303,920
ERIE	49	0	1	$ 3,266,554
FULTON	37	0	0	$ 119,490
HANCOCK	70	0	0	$ 7,617,705
HARDIN	29	0	0	$ 415,186
HENRY	57	0	1	$ 38,970
HURON	70	0	0	$ 1,878,667
LOGAN	55	0	0	$ 355,037
LUCAS	92	1	0	$ 2,373,721
MARION	42	0	1	$ 5,312,356
MERCER	41	0	2	$ 478,753
MIAMI	57	0	1	$ 682,945
OTTAWA	56	0	5	$ 2,075,367
PAULDING	38	0	0	$ 214,200
PREBLE	54	0	0	$ 361,302
PUTNAM	39	0	1	$ 283,652
SANDUSKY	59	0	0	$ 4,794,635
SENECA	69	0	0	$ 3,635,084
SHELBY	53	0	0	$ 215,542
VAN WERT	61	0	0	$ 466,957
WILLIAMS	32	1	1	$ 315,840
WOOD	76	0	0	$ 2,514,480
WYANDOT	25	0	0	$ 2,206,990
TOTAL		2	15	$ 43,944,727

Region 2

County	Number of Events	Number of Deathes	Number of Injuries	Total Property and Crop Damage (2017 Dollars)
ASHLAND	50	0	0	$ 1,359,403
BUTLER	96	0	0	$ 437,804
CLINTON	100	0	0	$ 599,913
CUYAHOGA	122	0	0	$ 11,381,899
DELAWARE	69	0	4	$ 329,520
FAIRFIELD	78	0	0	$ 427,608
FAYETTE	48	0	1	$ 349,108
FRANKLIN	185	0	7	$ 1,857,879
GEAUGA	57	0	0	$ 1,676,326
GREENE	93	0	0	$ 302,650
HAMILTON	132	0	1	$ 1,260,551
KNOX	52	0	1	$ 2,328,393
LAKE	48	0	0	$ 1,154,940
LICKING	99	2	4	$ 722,624
LORAIN	112	0	0	$ 3,097,829
MADISON	37	0	0	$ 306,518
MEDINA	59	1	3	$ 2,084,871
MONTGOMERY	168	0	2	$ 542,686
MORROW	34	0	0	$ 2,380,416
PICKAWAY	49	0	1	$ 439,594
PORTAGE	56	0	0	$ 3,840,670
RICHLAND	69	0	2	$ 2,450,743
STARK	62	0	0	$ 766,638
SUMMIT	77	0	0	$ 8,465,984
UNION	38	0	0	$ 149,309
WARREN	110	0	1	$ 1,019,811
WAYNE	57	0	0	$ 492,966
TOTAL		3	27	$ 50,226,651

Region 3

County	Number of Events	Number of Deathes	Number of Injuries	Total Property and Crop Damage (2017 Dollars)
ADAMS	57	0	0	$ 408,154
ASHTABULA	69	0	0	$ 1,591,711
ATHENS	56	0	6	$ 5,319,926
BELMONT	44	0	0	$ 1,306,337
BROWN	79	0	0	$ 743,335
CARROLL	74	0	0	$ 1,285,670
CLERMONT	100	0	0	$ 638,244
COLUMBIANA	102	0	2	$ 2,090,858
COSHOCTON	56	0	0	$ 1,688,786
GALLIA	38	0	0	$ 2,827,548
GUERNSEY	53	0	0	$ 1,609,770
HARRISON	43	0	0	$ 1,002,081
HIGHLAND	91	0	1	$ 517,609
HOCKING	51	0	0	$ 298,045
HOLMES	40	0	0	$ 1,085,380
JACKSON	36	0	1	$ 2,069,534
JEFFERSON	51	1	2	$ 1,630,829
LAWRENCE	60	0	1	$ 2,354,513
MAHONING	55	0	0	$ 2,537,080
MEIGS	22	0	0	$ 2,653,249
MONROE	19	0	0	$ 412,702
MORGAN	33	0	0	$ 720,113
MUSKINGUM	63	1	1	$ 1,929,222
NOBLE	29	0	0	$ 383,735
PERRY	68	0	0	$ 2,230,567
PIKE	63	0	5	$ 491,191
ROSS	59	0	0	$ 529,848
SCIOTO	107	1	1	$ 719,654
TRUMBULL	112	0	38	$ 2,999,909
TUSCARAWAS	89	0	0	$ 2,464,457
VINTON	33	0	0	$ 641,756
WASHINGTON	54	0	0	$ 4,255,968
TOTAL		3	58	$ 51,437,780

Statewide High Winds – September 2008 (FEMA DR-1805-OH) - *https://www.fema.gov/disaster/1805*

Usually, tropical storms and hurricanes directly affecting other states result in extended rainfall in Ohio. NOAA Operational Significant Event Imagery shows that the windstorms of 2008 were a legacy from Hurricane IKE, which arced clockwise from the Gulf of Mexico to the western basin of Lake Erie and the Saint Lawrence Seaway. Ohio was affected from Hamilton County in southwest Ohio to the northeastern counties of Ashland, Carroll and Summit. Unlike other secondary effects of a diminishing hurricane, high winds in excess of 65 miles per hour were primarily the cause of damage for many counties, causing power outages across these portions of the state. It was reported that winds equal to a Category 1 hurricane (winds up to 74 miles per hour) caused at least $1.255 billion in insured losses.

The Ohio Insurance Institute (OII) Windstorm Loss Survey - FEMA DR-1805-OH

Following the statewide High Winds event of September 2008 (FEMA DR-1805-OH), the Ohio Insurance Institute (OII) conducted a windstorm loss survey in which 24 property and casualty companies participated. This represented:

- 68% of Ohio's personal auto insurance market
- 72% of the homeowners' market
- 33% of the state's commercial lines market based on 2007 Ohio premium volume

The OII survey concluded Ohio's insured losses totaled $1.255 billion and government costs for protection and clean up were $38.6 million. Insurance companies reported a record-high number of claims filed across the state. At least 270,000 were filed in Ohio, including 220,000 homeowners, 30,000 commercial and 20,000 auto insurance claims.

Severe Storms, Flooding and Landslides – April & May 2011 (FEMA DR- 4002-OH) -
https://www.fema.gov/disaster/4002

The impact of this event was widespread and costly due to the prolonged and record-setting spring rainfall during the months of March, April and May. According to the National Weather Service (NWS), a persistent upper valley weather channel over the eastern U.S. led to an active storm track over the Ohio Valley. During the month of April and into mid-May, the local NWS offices serving Ohio issued flood watches, flood warnings, flash flood watches and advisories and/or special weather statements for the Ohio River Watershed and Drainage Basin for 31 of the 44 days. Eighty-one percent of the watches, warnings and advisories were issued directly for the impacted counties; however, all of the counties had high stream levels on their watersheds. Also during this time period, there were road closures almost every day due to flooding and/or high water. A notable incident was a small plane crashed near Ravenna, Ohio with three injuries due to saturated soil absorbing much of the impact. According to the Highway Patrol, had it not been for soft, soaked earth and mud, all three on board would have perished upon impact. Other incidents included 7,630 customers in power outages, trees uprooted, parts of buildings sustaining moderate damage and the loss of a countywide 911 system. As a result, the 21 affected Ohio counties received $44,506,071 in public assistance funds.

Severe Storms and Straight Line Winds – June 2012 (FEMA DR-4077-OH) - *: https://www.fema.gov/disaster/4077*

An anomalously strong storm ridge centered across the Southeast and brought record heat to the Upper Ohio Valley with the area in a flow on the northern edge of the ridge. A weak frontal boundary extended from northern Indiana into western Pennsylvania. Abundant moisture, strong instability, moderate shear, and a short wave just south of the boundary provided the ingredients for a long-tracked mesoscale convective system, classified by the Storm Prediction Center as a derecho, to track all the way from northern Indiana across eastern Ohio, southwestern Pennsylvania, northern WV, and western Maryland. As the system crossed the area, widespread wind damage was reported across areas primarily south and west of Pittsburgh. There were several reports of structural damage and damage led to a fatality when a barn collapsed in Muskingum County. Power outages were widespread with up to 130,000 outages reported immediately after the storms passage, most of which, were in Ohio. Muskingum and Guernsey counties sustained $712,000 and $500,000 in damages respectively. This also became one of the costliest disasters to hit Ohio, right behind Hurricane Ike in 2008. Two fatalities and eight injuries occurred during this event with $40,440,000 in property damage and $105,000 in damage to crops. As a result, of this event, 37 affected Ohio counties received $22,538,519 in public assistance funds.

Hurricane SANDY – October 2012 (FEMA DR-4098-OH) - *https://www.fema.gov/disaster/4098*

On October 29, 2012, Hurricane Sandy made landfall near Atlantic City, New Jersey, however, the storm continued to produce significant wind, storm surge, rainfall and inland-flooding hazards across the Northeastern United States. High wind warnings as well as flood and flash flood watches and warnings for portions of Ohio and Indiana. The National Weather Service reported winds up to 80 miles per hour during the height of the storm system. First Energy Nuclear Operating Company reported sirens without AC power near Perry Nuclear Power Plant (Lake County-15 sirens, Geauga County-1 siren, Ashtabula-1siren) and Beaver Valley Power Station (Beaver County, PA-1siren). In Cuyahoga County, 80 people with functional needs were evacuated to a high school in Cleveland Heights, while another 11 shelters were being opened. The storm delivered a blow to Ashtabula County, but it was not the big uppercut some people had feared. As expected, strong wind toppled trees and dropped power lines, causing power outages across the county. Incessant rain toppled trees and flooded some thoroughfares in the area. Some of the hardest-hit areas were along the lakeshore, including Conneaut, North Kingsville, and Saybrook Township. Outages were reported in every city, village and township in the county, according to Illuminating Company information. Trees and limbs that collapsed on power lines were a big culprit, officials said. Lake County had residents from 142 homes near the mouth of the Chagrin River evacuated to the Mentor Community Center with another 70 evacuated to a shelter in Painesville. First Energy reported 55,516 customers without power in northeast Ohio. No fatalities were reported; however, one occurred. Property damage was estimated at $55,234,000 with no damage to crops. As a result, of this event, 37 affected Ohio counties received $17,810,815 in public assistance funds.

Severe Storms, Landslides, and Mudslides – February 2018 (FEMA DR-4360-OH) -
https://www.fema.gov/disaster/4360

Beginning on February 14, 2018, and continuing through February 25, 2018, a persistent band of moderate to severe storms moved across Region V impacting Illinois, Indiana, Michigan, Ohio, and Wisconsin. While precipitation levels and storm-related damages varied, Ohio experienced a significant amount of flooding and subsequent damage along the southern portion of the state. The snowmelt and continued rain throughout the incident period, combined with the frozen soils, led to flooding along area streams, rivers, and low-lying areas. Numerous flood gauges in this area rose to moderate flood stage, and rainfall totals in the impacted areas during the incident period ranged from a total of five to nine inches. Following these storms, there were several road closures as well as reports of inaccessible areas throughout southern Ohio due to standing water.

On March 26, the Governor requested a Presidential Disaster Declaration. On April 17, 2018, a disaster was declared for the State of Ohio, due to severe storms, flooding, and landslides that occurred during the incident period of February 14, 2018, through February 25, 2018. As a result of that declaration, Public Assistance has been made available for Adams, Athens, Belmont, Brown, Columbiana, Gallia, Hamilton, Jackson, Lawrence, Meigs, Monroe, Muskingum, Noble, Perry, Pike, Scioto, Vinton, and Washington Counties. The Disaster impact data is fluid as only half of the Public Assistance projects have been awarded as of January 2019.

HURRICANES AND TROPICAL STORMS

In more recent years, a number of disaster declarations for Ohio was declared in result of remnants from hurricanes and tropical storms. Notably, wind events caused by remnants of Hurricane IKE in September 2008 had resulted in large damages across Ohio. High winds, rain, and flooding events from Hurricane SANDY followed through to portions of Ohio.

PROBABILITY OF FUTURE EVENTS

The historical period used for thunderstorm winds and hail analysis began with January 1, 2008 and closed December 31, 2017 based on statistics tabulated by the NCDC. During this period, there were 453 days with thunderstorm wind events and 359 days with hail events. For the period from January 1, 1996 to December 31, 2017, there were 229 lightning events. Based on available documented occurrences, severe summer storms are the most prevalent natural hazard events in Ohio with a 100% chance of occurring any given year. According to National Geographic, the odds of being a lightning victim in the U.S. in any given year is about one in 700,000.

LHMP DATA

Henry County: The County's Hazard Mitigation Plan of 2018 states that from January of 1950 to June of 2017 in Henry County. These events have caused two injuries, over $800,000 in property damage, $600,000 in crop damage, and no deaths. Based on historical information, Henry County can expect to endure at least three severe storms in any given year.

Darke County: The 2011 Updated Hazard Mitigation Plan cites that there have been a total of 2 lightning events, 64 hail events, and 148 thunderstorm/wind events in Darke County from June 9, 1958 through December 31, 2010. Based on NCDC data, Darke County can expect at least four severe summer storm events each year along with smaller events. Some of the significant events are described in the following paragraphs.

Fairfield County: The 2016 Fairfield County Natural Hazards Mitigation Plan references 219 severe thunderstorm events from 1968 to 2016. From the period of 1961 to 2016, the County experienced 58 Hail events creating $52,000.00 in property damages. No deaths or injuries as a result of Hailstorms.

VULNERABILITY ANALYSIS AND LOSS ESTIMATION

METHDOLOGY

THUNDERSTORM WINDS AND HAIL

During data development for the thunderstorm/high wind and hail hazard, it quickly became apparent the two must be addressed separately. Hail events have a much greater financial impact in urbanized areas. Events of the same magnitude can create substantially more damage in an urban setting, or as it would in forested or agricultural area. The extreme range of the data for hail would skew any useful thunderstorm/high wind analysis. As a result, there will be one analysis for lightning, thunderstorm/high winds, and heavy rainfall and another separate analysis for hail events.

To determine the estimated annual damage down to the county level, a hybrid approach was taken using historical data and the taxable value of real property for each county within the state. First, a historical analysis was done first for each county. The total reported property damage of each event was adjusted to 2017 dollars and summed up to for each county. This was then divided by 10 for the number of years assessed. The result of this is the estimated annual damage for each county. This number was then divided by the total taxable value of real property within the county to determine the percentage of estimated damage for each of the 88 county in any given year.

To offset the possibility of under-reporting damages, the sum of the ten-year damages across the state $145,609,158 for thunderstorm winds, and $187,455,392 for hail was divided by 10 to determine the annual loss. This figure as well as the statewide real value of property was respectively divided by the 88 (counties in the state) to determine the average damage per county and the average taxable value per county in the state. The first was then divided by the latter resulting in the percentage of estimated damage the average county, 0.006116% for thunderstorm and 0.007874% for hail, in Ohio in any given year. These percentages were then used for any county that reported less than average damages relative to their value of taxable real property.

LIGHTNING
Determining the dollar loss estimate for lightning events is extremely difficult because it is an extremely common hazard that is also greatly under-reported. It could be assumed based on the NCDC data from the period of January 1, 1996 to December 31, 2017 that an event was not recorded unless damages were reported or resulted in the death or injury of a person. Based on what was reported, however, the average damage to property is approximately $827,477 per year statewide. On average, one person is killed and six injured from lightning events in any given year.

RESULTS - THUNDERSTORM WINDS (TABLE 2.12.A)

The total estimated annual severe thunderstorm winds loss for Region 1 is $5,129,520. Within the Region, Marion County is estimated to have the highest annual loss each at approximate $531,236. Hancock, however, had the highest estimate per capita loss at $10.06 per person.

Region 2 has the highest estimated annual summer storm loss in the state at a total of $10,711,819. While it is the most populated region in the state with the highest total taxable value of real property, the region also exhibits the lowest estimated annual per-capita loss of $1.39. Within the Region, Morrow County has the highest estimated annual summer storm per-capita loss at $1.88. Cuyahoga County has the highest estimated total damage at $1,623,120 but an estimated per-capita loss of only $1.30.

Region 3 is estimated to have $5,308,796 in annual damages with an annual per-capita of loss of $2.66. Athens County is estimated to have the highest loss at a total of $531,993. Meigs County is estimated have the highest annual per-capita loss of $11.50.

Table 2.12.a

Estimate of Potential Losses to Thunderstorm Winds by Region											
Region 1				Region 2				Region 3			
County	Population	Countywide Annual Damage	Annual Damage per Capita	County	Population	Countywide Annual Damage	Annual Damage per Capita	County	Population	Countywide Annual Damage	Annual Damage per Capita
Allen	103,198	$ 111,695.39	$ 1.08	Ashland	53,628	$ 135,940.30	$ 2.53	Adams	27,726	$ 40,815.40	$ 1.47
Auglaize	45,778	$ 101,848.65	$ 2.22	Butler	380,604	$ 431,409.39	$ 1.13	Ashtabula	97,807	$ 159,171.10	$ 1.63
Champaign	38,840	$ 51,234.14	$ 1.32	Clinton	42,009	$ 55,247.40	$ 1.32	Athens	66,597	$ 531,992.60	$ 7.99
Clark	134,557	$ 136,929.05	$ 1.02	Cuyahoga	1,248,514	$ 1,623,120.46	$ 1.30	Belmont	68,029	$ 130,633.65	$ 1.92
Crawford	41,746	$ 141,268.50	$ 3.38	Delaware	200,464	$ 412,757.80	$ 2.06	Brown	43,576	$ 74,333.45	$ 1.71
Darke	51,536	$ 73,648.32	$ 1.43	Fairfield	154,733	$ 206,701.02	$ 1.34	Carroll	27,385	$ 128,567.00	$ 4.69
Defiance	38,156	$ 49,556.80	$ 1.30	Fayette	28,752	$ 42,904.11	$ 1.49	Clermont	204,214	$ 241,864.01	$ 1.18
Erie	74,817	$ 326,655.40	$ 4.37	Franklin	1,291,981	$ 1,596,431.89	$ 1.24	Columbiana	103,077	$ 209,085.80	$ 2.03
Fulton	42,289	$ 58,868.11	$ 1.39	Geauga	93,918	$ 182,631.81	$ 1.94	Coshocton	36,544	$ 168,878.60	$ 4.62
Hancock	75,754	$ 761,770.50	$ 10.06	Greene	166,752	$ 233,873.68	$ 1.40	Gallia	29,973	$ 282,754.80	$ 9.43
Hardin	31,364	$ 41,518.60	$ 1.32	Hamilton	813,822	$ 1,069,320.31	$ 1.31	Guernsey	39,093	$ 160,977.00	$ 4.12
Henry	27,185	$ 44,883.20	$ 1.65	Knox	61,261	$ 232,839.30	$ 3.80	Harrison	15,216	$ 100,208.10	$ 6.59
Huron	58,494	$ 187,866.70	$ 3.21	Lake	230,117	$ 335,138.54	$ 1.46	Highland	42,971	$ 45,969.85	$ 1.07
Logan	45,325	$ 72,444.99	$ 1.60	Licking	173,448	$ 228,566.27	$ 1.32	Hocking	28,474	$ 33,547.05	$ 1.18
Lucas	430,887	$ 421,014.28	$ 0.98	Lorain	307,924	$ 384,814.03	$ 1.25	Holmes	43,957	$ 108,538.00	$ 2.47
Marion	64,967	$ 531,235.60	$ 8.18	Madison	44,036	$ 65,604.48	$ 1.49	Jackson	32,449	$ 206,953.40	$ 6.38
Mercer	40,873	$ 66,418.01	$ 1.62	Medina	178,371	$ 295,275.69	$ 1.66	Jefferson	66,359	$ 163,082.90	$ 2.46
Miami	105,122	$ 134,669.74	$ 1.28	Montgomery	531,542	$ 532,156.37	$ 1.00	Lawrence	60,249	$ 235,451.30	$ 3.91
Ottawa	40,657	$ 207,536.70	$ 5.10	Morrow	34,994	$ 238,041.60	$ 6.80	Mahoning	229,796	$ 235,408.12	$ 1.02
Paulding	18,845	$ 27,399.66	$ 1.45	Pickaway	57,830	$ 73,815.24	$ 1.28	Meigs	23,080	$ 265,324.90	$ 11.50
Preble	41,120	$ 53,890.19	$ 1.31	Portage	162,277	$ 384,067.00	$ 2.37	Monroe	13,946	$ 41,270.20	$ 2.96
Putnam	33,878	$ 54,746.03	$ 1.62	Richland	120,589	$ 245,074.30	$ 2.03	Morgan	14,709	$ 72,011.30	$ 4.90
Sandusky	59,195	$ 479,463.50	$ 8.10	Stark	372,542	$ 418,899.80	$ 1.12	Muskingum	86,149	$ 192,922.20	$ 2.24
Seneca	55,243	$ 363,508.40	$ 6.58	Summit	541,228	$ 683,319.46	$ 1.26	Noble	14,406	$ 38,373.52	$ 2.66
Shelby	48,759	$ 68,870.65	$ 1.41	Union	56,741	$ 96,589.41	$ 1.70	Perry	36,024	$ 223,056.70	$ 6.19
Van Wert	28,217	$ 42,329.97	$ 1.50	Warren	228,882	$ 367,661.32	$ 1.61	Pike	28,270	$ 49,119.10	$ 1.74
Williams	36,784	$ 46,102.25	$ 1.25	Wayne	116,038	$ 139,618.01	$ 1.20	Ross	77,313	$ 74,131.44	$ 0.96
Wood	130,492	$ 251,448.00	$ 1.93	Total	7,692,997	$ 10,711,818.99	$ 1.39	Scioto	75,929	$ 58,145.24	$ 0.77
Wyandot	22,029	$ 220,699.00	$ 10.02					Trumbull	200,380	$ 299,990.90	$ 1.50
Total	1,966,107	$ 5,129,520.32	$ 2.61					Tuscarawas	92,297	$ 246,445.70	$ 2.67
								Vinton	13,092	$ 64,175.60	$ 4.90
								Washington	60,418	$ 425,596.80	$ 7.04
								Total	1,999,505	$ 5,308,795.73	$ 2.66

RESULTS - HAIL (TABLE 2.12.B)

The total estimated annual loss for Region 1 is $12,430,433. Within the Region, Hancock County is estimated to have the highest annual loss each at approximate $9,317,669. This figure however, may be skewed by an event on May 25, 2011 that reported $85,000,000 in damages. Consequently, Hancock County also had the highest estimate per capita loss at $123 per person.

Region 2 has the highest estimated annual hail loss in the state at a total of $19,338,917. While it is the most populated region in the state with the highest total taxable value of real property, the region only has an estimated annual per-capita loss of $2.51. Within the Region, Stark County has the highest estimated total damage at $6,926,028 and also the highest estimated per-capita loss of $18.59.

Region 3 is estimated to have $2,741,032 in annual damages to hail with an annual per-capita of loss of $1.37. Clermont County is estimated to have the highest loss at a total of $311,373. Harrison County is estimated have the highest annual per-capita loss at $2.58.

Table 2.12.b

Estimate of Potential Losses to Hail by Region											
Region 1				Region 2				Region 3			
County	Population	Countywide Annual Damage	Annual Damage per Capita	County	Population	Countywide Annual Damage	Annual Damage per Capita	County	Population	Countywide Annual Damage	Annual Damage per Capita
Paulding	18,845	$ 35,273.97	$ 1.87	Fayette	28,752	$ 55,234.22	$ 1.92	Scioto	75,929	$ 74,855.44	$ 0.99
Hardin	31,364	$ 39,221.24	$ 1.25	Morrow	34,994	$ 59,756.36	$ 1.71	Pike	28,270	$ 28,110.62	$ 0.99
Crawford	41,746	$ 53,725.09	$ 1.29	Clinton	42,009	$ 71,124.81	$ 1.69	Vinton	13,092	$ 13,412.35	$ 1.02
Van Wert	28,217	$ 54,495.07	$ 1.93	Ashland	53,628	$ 75,754.79	$ 1.41	Meigs	23,080	$ 24,877.85	$ 1.08
Henry	27,185	$ 57,782.06	$ 2.13	Madison	44,036	$ 84,458.38	$ 1.92	Athens	66,597	$ 71,910.62	$ 1.08
Williams	36,784	$ 59,351.46	$ 1.61	Pickaway	57,830	$ 95,028.81	$ 1.64	Jefferson	66,359	$ 75,971.88	$ 1.14
Defiance	38,156	$ 63,798.80	$ 1.67	Knox	61,261	$ 99,030.66	$ 1.62	Jackson	32,449	$ 37,176.01	$ 1.15
Champaign	38,840	$ 65,958.18	$ 1.70	Union	56,741	$ 124,347.98	$ 2.19	Perry	36,024	$ 42,752.16	$ 1.19
Preble	41,120	$ 69,377.56	$ 1.69	Richland	120,589	$ 149,006.85	$ 1.24	Lawrence	60,249	$ 71,888.79	$ 1.19
Putnam	33,878	$ 70,479.34	$ 2.08	Wayne	116,038	$ 179,742.46	$ 1.55	Trumbull	200,380	$ 242,200.77	$ 1.21
Fulton	42,289	$ 75,786.06	$ 1.79	Geauga	93,918	$ 235,117.89	$ 2.50	Ross	77,313	$ 95,435.88	$ 1.23
Auglaize	45,778	$ 82,354.85	$ 1.80	Portage	162,277	$ 258,589.01	$ 1.59	Columbiana	103,077	$ 128,895.17	$ 1.25
Marion	64,967	$ 85,200.87	$ 1.31	Fairfield	154,733	$ 266,104.29	$ 1.72	Mahoning	229,796	$ 303,061.45	$ 1.32
Huron	58,494	$ 85,263.96	$ 1.46	Licking	173,448	$ 294,253.33	$ 1.70	Morgan	14,709	$ 19,686.86	$ 1.34
Mercer	40,873	$ 85,505.70	$ 2.09	Greene	166,752	$ 301,086.03	$ 1.81	Muskingum	86,149	$ 117,339.66	$ 1.36
Seneca	55,243	$ 86,316.04	$ 1.56	Medina	178,371	$ 380,134.19	$ 2.13	Gallia	29,973	$ 40,965.44	$ 1.37
Shelby	48,759	$ 88,663.21	$ 1.82	Lake	230,117	$ 431,453.12	$ 1.87	Ashtabula	97,807	$ 134,528.33	$ 1.38
Wyandot	22,029	$ 89,586.80	$ 4.07	Warren	228,882	$ 473,322.54	$ 2.07	Brown	43,576	$ 59,944.98	$ 1.38
Logan	45,325	$ 93,264.76	$ 2.06	Lorain	307,924	$ 495,404.72	$ 1.61	Highland	42,971	$ 59,181.00	$ 1.38
Darke	51,536	$ 94,813.91	$ 1.84	Delaware	200,464	$ 531,379.18	$ 2.65	Coshocton	36,544	$ 51,360.06	$ 1.41
Sandusky	59,195	$ 121,999.60	$ 2.06	Butler	380,604	$ 555,391.00	$ 1.46	Tuscarawas	92,297	$ 136,838.93	$ 1.48
Ottawa	40,657	$ 134,219.14	$ 3.30	Montgomery	531,542	$ 685,091.39	$ 1.29	Hocking	28,474	$ 43,188.05	$ 1.52
Allen	103,198	$ 143,795.23	$ 1.39	Summit	541,228	$ 990,636.40	$ 1.83	Washington	60,418	$ 91,737.16	$ 1.52
Erie	74,817	$ 153,383.81	$ 2.05	Hamilton	813,822	$ 1,376,629.47	$ 1.69	Clermont	204,214	$ 311,372.67	$ 1.52
Miami	105,122	$ 173,372.12	$ 1.65	Franklin	1,291,981	$ 2,055,226.26	$ 1.59	Guernsey	39,093	$ 60,681.33	$ 1.55
Clark	134,557	$ 176,280.72	$ 1.31	Cuyahoga	1,248,514	$ 2,089,584.79	$ 1.67	Belmont	68,029	$ 108,302.45	$ 1.59
Wood	130,492	$ 231,485.92	$ 1.77	Stark	372,542	$ 6,926,027.80	$ 18.59	Holmes	43,957	$ 75,493.60	$ 1.72
Lucas	430,887	$ 542,008.47	$ 1.26	Total	7,692,997	$ 19,338,916.74	$ 2.51	Noble	14,406	$ 26,699.43	$ 1.85
Hancock	75,754	$ 9,317,669.20	$ 123.00					Adams	27,726	$ 60,124.20	$ 2.17
Total	1,966,107	$ 12,430,433.16	$ 6.32					Monroe	13,946	$ 31,222.42	$ 2.24
								Carroll	27,385	$ 62,595.68	$ 2.29
								Harrison	15,216	$ 39,221.24	$ 2.58
								Total	1,999,505	$ 2,741,032.48	$ 1.37

Property damage is not the only loss associated with summer storms and hail. Over the analysis period, 13 deaths and 98 injuries were attributed to these events. Of the injuries reported, 20 are attributed to a single event in Franklin County, which involved a campground.

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

The Vulnerability Analysis and Loss Estimation above estimated the damage to each county by using the historical available for that county and the average statewide loss to determine an annual "total building value loss" percentage. This percentage was multiplied by the countywide taxable value of real property to determine an estimated annual damage. To estimate the losses for State-owned and State-leased critical facilities, the total value of State-owned and State-leased Critical Facilities of each county was multiplied by the county's respective percentage of Total Building Value loss. The results are tabulated in Tables 2.12.c and 2.12.d below.

Results- Thunderstorm Winds (Table 2.12.c)

Estimated Annual Damage to State-owned and State-leased Critical Facilities- Thunderstorm Winds											
Region 1				Region 2				Region 3			
County	Number of Critical Facilities	Value of State Critical Facilities	Estimated Annual Damage	County	Number of Critical Facilities	Value of State Critical Facilities	Estimated Annual Damage	County	Number of Critical Facilities	Value of State Critical Facilities	Estimated Annual Damage
Allen	120	$ 90,950,176.00	$ 5,562.47	Ashland	143	$ 64,539,880.00	$ 9,118.85	Adams	24	$ 6,622,981.00	$ 653.42
Auglaize	21	$ 11,545,804.00	$ 1,124.25	Butler	21	$ 17,563,033.00	$ 1,074.15	Ashtabula	62	$ 20,008,110.00	$ 1,863.93
Champaign	24	$ 5,161,316.00	$ 315.66	Clinton	22	$ 11,528,821.00	$ 705.10	Athens	31	$ 45,496,640.00	$ 26,501.19
Clark	17	$ 8,868,061.00	$ 542.37	Cuyahoga	84	$ 248,840,544.00	$ 15,218.98	Belmont	62	$ 54,856,808.00	$ 5,209.80
Crawford	13	$ 10,357,812.00	$ 2,144.42	Delaware	37	$ 46,217,477.00	$ 2,826.64	Brown	18	$ 36,403,605.00	$ 3,554.26
Darke	27	$ 8,619,026.00	$ 527.14	Fairfield	78	$ 86,519,830.00	$ 5,291.51	Carroll	17	$ 3,661,999.00	$ 592.21
Defiance	11	$ 7,562,674.00	$ 462.53	Fayette	26	$ 5,118,182.00	$ 313.03	Clermont	38	$ 17,885,810.00	$ 1,093.89
Erie	54	$ 162,265,731.00	$ 27,208.88	Franklin	249	$ 2,147,726,878.00	$ 131,354.03	Columbiana	38	$ 13,835,662.00	$ 1,767.10
Fulton	16	$ 4,397,188.00	$ 268.93	Geauga	24	$ 8,594,197.00	$ 525.62	Coshocton	19	$ 12,943,450.00	$ 3,350.99
Hancock	23	$ 16,195,898.00	$ 6,872.05	Greene	25	$ 10,629,296.00	$ 650.08	Gallia	71	$ 35,860,837.00	$ 19,488.86
Hardin	12	$ 4,141,282.00	$ 345.17	Hamilton	35	$ 173,140,806.00	$ 10,589.22	Guernsey	54	$ 39,704,477.00	$ 8,293.19
Henry	14	$ 3,113,844.00	$ 190.44	Knox	34	$ 40,507,246.00	$ 7,498.82	Harrison	30	$ 9,054,441.00	$ 1,821.45
Huron	22	$ 10,543,997.00	$ 1,829.21	Lake	21	$ 5,525,021.00	$ 337.91	Highland	8	$ 9,690,902.00	$ 592.69
Logan	1	$ 735,568.00	$ 44.99	Licking	64	$ 168,043,312.00	$ 10,277.45	Hocking	19	$ 7,123,096.00	$ 435.65
Lucas	47	$ 276,597,391.00	$ 16,916.57	Lorain	90	$ 110,138,241.00	$ 6,736.01	Holmes	25	$ 10,336,112.00	$ 1,170.04
Marion	100	$ 128,613,896.00	$ 63,140.00	Madison	109	$ 321,691,881.00	$ 19,674.53	Jackson	18	$ 15,130,501.00	$ 6,631.88
Mercer	26	$ 7,655,738.00	$ 468.22	Medina	22	$ 18,601,644.00	$ 1,137.67	Jefferson	37	$ 7,592,901.00	$ 1,283.33
Miami	23	$ 10,005,576.00	$ 611.94	Montgomery	71	$ 77,351,496.00	$ 4,730.78	Lawrence	27	$ 11,760,373.00	$ 3,032.74
Ottawa	75	$ 65,291,745.00	$ 7,949.00	Morrow	21	$ 6,874,959.00	$ 2,156.32	Mahoning	66	$ 72,389,280.00	$ 4,427.30
Paulding	3	$ 1,387,796.00	$ 84.88	Pickaway	133	$ 195,643,558.00	$ 11,965.47	Meigs	18	$ 8,512,106.00	$ 7,147.86
Preble	24	$ 4,859,547.00	$ 297.21	Portage	25	$ 7,594,529.00	$ 888.12	Monroe	22	$ 11,202,381.00	$ 1,165.88
Putnam	18	$ 5,590,738.00	$ 341.93	Richland	73	$ 109,750,465.00	$ 14,212.53	Morgan	10	$ 3,700,608.00	$ 1,065.79
Sandusky	15	$ 5,519,069.00	$ 2,222.72	Stark	41	$ 102,066,812.00	$ 6,242.36	Muskingum	25	$ 10,647,135.00	$ 1,378.30
Seneca	49	$ 33,546,722.00	$ 11,123.63	Summit	67	$ 201,182,298.00	$ 12,304.22	Noble	31	$ 50,299,353.00	$ 5,692.01
Shelby	35	$ 26,824,309.00	$ 1,640.56	Union	53	$ 88,869,557.00	$ 5,435.22	Perry	16	$ 3,884,728.00	$ 1,595.85
Van Wert	13	$ 7,459,562.00	$ 456.22	Warren	109	$ 150,201,626.00	$ 9,186.27	Pike	10	$ 3,878,547.00	$ 533.61
Williams	13	$ 5,459,757.00	$ 333.92	Wayne	6	$ 7,056,104.00	$ 431.55	Ross	142	$ 265,584,512.00	$ 16,243.03
Wood	36	$ 67,981,624.00	$ 5,814.18	Total	1,683	$ 4,431,517,693.00	$ 290,882.42	Scioto	55	$ 171,351,723.00	$ 10,479.80
Wyandot	19	$ 10,280,904.00	$ 4,293.17					Trumbull	60	$ 55,012,652.00	$ 5,364.99
Total	871	$ 1,001,532,751.00	$ 163,132.66					Tuscarawas	53	$ 56,132,900.00	$ 7,959.81
								Vinton	20	$ 5,854,782.00	$ 2,205.71
								Washington	55	$ 29,149,164.00	$ 10,647.63
								Total	1,181	$ 1,105,568,576.00	$ 163,244.16

Results- Hail (Table 2.12.d)

Estimated Annual Damage to State-owned and State-leased Critical Facilities- Hail

Region 1

County	Number of Critical Facilities	Value of State Critical Facilities	Estimated Annual Damage
Allen	120	$ 90,950,176.00	$ 7,161.06
Auglaize	21	$ 11,545,804.00	$ 909.07
Champaign	24	$ 5,161,316.00	$ 406.38
Clark	17	$ 8,868,061.00	$ 698.24
Crawford	13	$ 10,357,812.00	$ 815.53
Darke	27	$ 8,619,026.00	$ 678.63
Defiance	11	$ 7,562,674.00	$ 595.46
Erie	54	$ 162,265,731.00	$ 12,776.16
Fulton	16	$ 4,397,188.00	$ 346.22
Hancock	23	$ 16,195,898.00	$ 84,056.18
Hardin	12	$ 4,141,282.00	$ 326.07
Henry	14	$ 3,113,844.00	$ 245.17
Huron	22	$ 10,543,997.00	$ 830.19
Logan	1	$ 735,568.00	$ 57.92
Lucas	47	$ 276,597,391.00	$ 21,778.18
Marion	100	$ 128,613,896.00	$ 10,126.55
Mercer	26	$ 7,655,738.00	$ 602.78
Miami	23	$ 10,005,576.00	$ 787.80
Ottawa	75	$ 65,291,745.00	$ 5,140.81
Paulding	3	$ 1,387,796.00	$ 109.27
Preble	24	$ 4,859,547.00	$ 382.62
Putnam	18	$ 5,590,738.00	$ 440.19
Sandusky	15	$ 5,519,069.00	$ 565.57
Seneca	49	$ 33,546,722.00	$ 2,641.34
Shelby	35	$ 26,824,309.00	$ 2,112.04
Van Wert	13	$ 7,459,562.00	$ 587.34
Williams	13	$ 5,459,757.00	$ 429.88
Wood	36	$ 67,981,624.00	$ 5,352.60
Wyandot	19	$ 10,280,904.00	$ 1,742.70
Total	871	$ 1,001,532,751.00	$ 162,701.95

Region 2

County	Number of Critical Facilities	Value of State Critical Facilities	Estimated Annual Damage
Ashland	143	$ 64,539,880.00	$ 5,081.61
Butler	21	$ 17,563,033.00	$ 1,382.84
Clinton	22	$ 11,528,821.00	$ 907.73
Cuyahoga	84	$ 248,840,544.00	$ 19,592.72
Delaware	37	$ 46,217,477.00	$ 3,638.98
Fairfield	78	$ 86,519,830.00	$ 6,812.23
Fayette	26	$ 5,118,182.00	$ 402.99
Franklin	249	$ 2,147,726,878.00	$ 169,103.51
Geauga	24	$ 8,594,197.00	$ 676.67
Greene	25	$ 10,629,296.00	$ 836.91
Hamilton	35	$ 173,140,806.00	$ 13,632.42
Knox	34	$ 40,507,246.00	$ 3,189.38
Lake	21	$ 5,525,021.00	$ 435.02
Licking	64	$ 168,043,312.00	$ 13,231.07
Lorain	90	$ 110,138,241.00	$ 8,671.85
Madison	109	$ 321,691,881.00	$ 25,328.75
Medina	22	$ 18,601,644.00	$ 1,464.62
Montgomery	71	$ 77,351,496.00	$ 6,090.35
Morrow	21	$ 6,874,959.00	$ 541.31
Pickaway	133	$ 195,643,558.00	$ 15,404.20
Portage	25	$ 7,594,529.00	$ 597.96
Richland	73	$ 109,750,465.00	$ 8,641.32
Stark	41	$ 102,066,812.00	$ 103,210.28
Summit	67	$ 201,182,298.00	$ 17,837.94
Union	53	$ 88,869,557.00	$ 6,997.24
Warren	109	$ 150,201,626.00	$ 11,826.28
Wayne	6	$ 7,056,104.00	$ 555.57
Total	1,683	$ 4,431,517,693.00	$ 446,091.75

Region 3

County	Number of Critical Facilities	Value of State Critical Facilities	Estimated Annual Damage
Adams	24	$ 6,622,981.00	$ 962.53
Ashtabula	62	$ 20,008,110.00	$ 1,575.36
Athens	31	$ 45,496,640.00	$ 3,582.23
Belmont	62	$ 54,856,808.00	$ 4,319.21
Brown	18	$ 36,403,605.00	$ 2,866.28
Carroll	17	$ 3,661,999.00	$ 288.33
Clermont	38	$ 17,885,810.00	$ 1,408.26
Columbiana	38	$ 13,835,662.00	$ 1,089.37
Coshocton	19	$ 12,943,450.00	$ 1,019.12
Gallia	71	$ 35,860,837.00	$ 2,823.54
Guernsey	54	$ 39,704,477.00	$ 3,126.17
Harrison	30	$ 9,054,441.00	$ 712.91
Highland	8	$ 9,690,902.00	$ 763.02
Hocking	19	$ 7,123,096.00	$ 560.84
Holmes	25	$ 10,336,112.00	$ 813.82
Jackson	18	$ 15,130,501.00	$ 1,191.32
Jefferson	37	$ 7,592,901.00	$ 597.83
Lawrence	27	$ 11,760,373.00	$ 925.97
Mahoning	66	$ 72,389,280.00	$ 5,699.65
Meigs	18	$ 8,512,106.00	$ 670.21
Monroe	22	$ 11,202,381.00	$ 882.03
Morgan	10	$ 3,700,608.00	$ 291.37
Muskingum	25	$ 10,647,135.00	$ 838.31
Noble	31	$ 50,299,353.00	$ 3,960.37
Perry	16	$ 3,884,728.00	$ 305.87
Pike	10	$ 3,878,547.00	$ 305.38
Ross	142	$ 265,584,512.00	$ 20,911.07
Scioto	55	$ 171,351,723.00	$ 13,491.56
Trumbull	60	$ 55,012,652.00	$ 4,331.48
Tuscarawas	53	$ 56,132,900.00	$ 4,419.68
Vinton	20	$ 5,854,782.00	$ 460.98
Washington	55	$ 29,149,164.00	$ 2,295.09
Total	1,181	$ 1,105,568,576.00	$ 87,489.16

2.13 INVASIVE SPECIES

The National Wildlife Federation defines invasive species as any living organism, whether amphibian, plant, insect, fish, fungus, bacteria, or even an organism's seeds or eggs, that is not native to an ecosystem and causes harm. These species can harm the environment, the economy, and even human health. In addition, species that can grow and reproduce quickly, spread aggressively, and have potential to cause harm are identified as "invasive".

According to the ODNR, Division of Natural Areas & Preserves, of the approximately 2,300 species of plants known to occur in Ohio, about 78% are native or have occurred in Ohio before the time of substantial European settlement (1750). The other 22% of species are not native to the state. Non-native plants have been introduced for erosion control, horticulture, forage crops, medicinal use, wildlife foods, or by accident. Most of these species never stray far from where they are introduced, but some become very invasive and displace native plants throughout the state.

Without natural predators or controls, invasive, non-native plants are able to spread quickly and force out native plants. Other non-native plants are impacting our wetlands by creating monocultures. Native plant diversity is important for wildlife habitat, as many animals depend on a variety of native plants for food and cover.

More information about invasive species in Ohio can be found on ODNR's website: http://ohiodnr.gov/invasivespecies, USFWS' website: https://www.fws.gov/invasives/, Early Detection & Distribution Mapping System (EDDMapS) website: https://www.eddmaps.org/, and the USDA National Invasive Species Information Center: https://www.invasivespeciesinfo.gov/index.shtml.

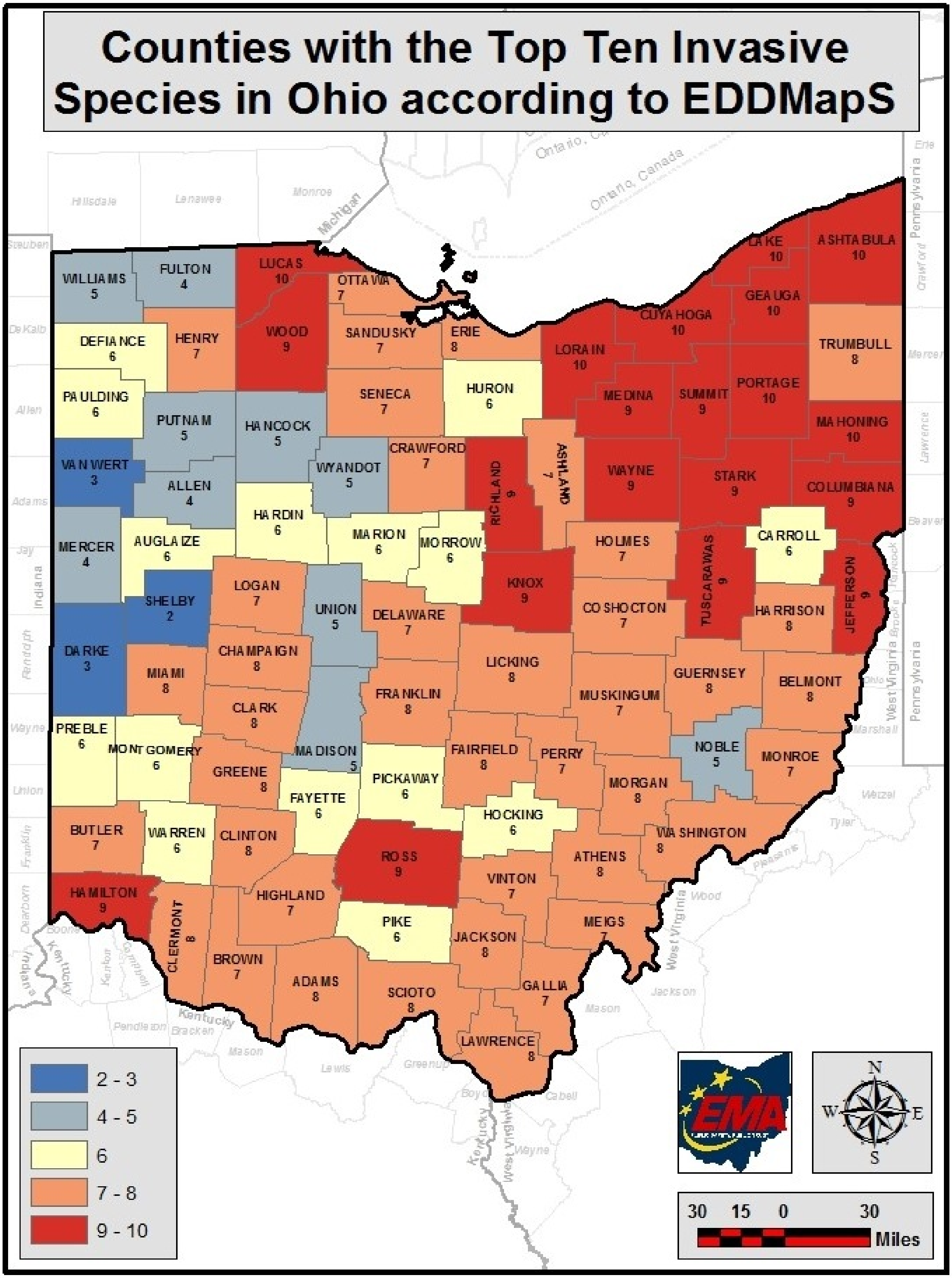
The top ten invasive plant species in Ohio are:

- Bush Honeysuckles
- Autumn – Olive
- Buckthorns
- Common Reed Grass
- Garlic Mustard
- Japanese Honeysuckle
- Japanese Knotweed
- Multiflora Rose
- Purple Loosestrife
- Reed Canary Grass

Per ODNR, aquatic invasive species (AIS) include both plants and animals that have been introduced to our waterways and have become harmful to native species and their habitats. AIS may live entirely within or partially in an aquatic habitat. Below is a list of some Ohio's top AIS threats. The list is not fully inclusive and the USGS maintains an additional list of AIS in the U.S.

Some of Ohio's top AIS are:

- Asian Carp (Bighead Carp, Silver Carp, Black Carp, Diploid Grass Carp)
- Curlyleaf Pondweed
- Hydrilla
- Round Goby
- Ruffe
- Red Swamp Crayfish
- Sea Lamprey
- White Perch
- Zebra Mussel


Counties with the Top Ten Invasive Species in Ohio according to EDDMapS
WILLIAMS 5
FULTON 4
LUCAS 10
OTTAWA 7
LAKE 10
ASHTABULA 10
DEFIANCE 6
HENRY 7
WOOD 9
SANDUSKY 7
ERIE 8
LORAIN 10
CUYAHOGA 10
GEAUGA 10
TRUMBULL 8
PAULDING 6
PUTNAM 5
HANCOCK 5
SENECA 7
HURON 6
MEDINA 9
SUMMIT 9
PORTAGE 10
MAHONING 10
VAN WERT 3
ALLEN 4
WYANDOT 5
CRAWFORD 7
RICHLAND 9
ASHLAND 7
WAYNE 9
STARK 9
COLUMBIANA 9
MERCER 4
AUGLAIZE 6
HARDIN 6
MARION 6
MORROW 6
HOLMES 7
TUSCARAWAS 9
CARROLL 6
JEFFERSON 9
SHELBY 2
LOGAN 7
UNION 5
DELAWARE 7
KNOX 9
COSHOCTON 7
HARRISON 8
DARKE 3
MIAMI 8
CHAMPAIGN 8
LICKING 8
GUERNSEY 8
BELMONT 8
CLARK 8
FRANKLIN 8
MUSKINGUM 7
PREBLE 6
MONTGOMERY 6
GREENE 8
MADISON 5
FAIRFIELD 8
PERRY 7
NOBLE 5
MONROE 7
PICKAWAY 6
FAYETTE 6
MORGAN 8
HOCKING 6
BUTLER 7
WARREN 6
CLINTON 8
ROSS 9
WASHINGTON 8
ATHENS 8
VINTON 7
HAMILTON 9
HIGHLAND 7
PIKE 6
JACKSON 8
MEIGS 7
CLERMONT 8
BROWN 7
ADAMS 8
SCIOTO 8
GALLIA 7
LAWRENCE 8
2 - 3
4 - 5
6
7 - 8
9 - 10
N
W
E
S
30 15 0 30
Miles

Lastly, according to the ODNR, Division of Forestry, one of the most invasive insect species in Ohio is the Emerald Ash Borer. This Asian pest is part of a group of insects known as metallic wood-boring beetles. Emerald Ash Borer affects all species of native ash found in Ohio. Because North American ash trees did not coexist in association with this pest, they have little or no resistance to its attack. This ash tree-killing insect from Asia was unintentionally introduced to southeastern Michigan several years ago. Emerald Ash Borer larvae feed on the living portion of the tree, directly beneath the bark. This eating habit restricts the tree's ability to move essential water and nutrients throughout the plant. In three to five years, even the healthiest tree is unable to survive an attack.

RISK ASSESSMENT

The area invaded by each plant species varies based on its preferred environment. Those with the fewest limitations have spread to nearly every county in Ohio. The Emerald Ash Borer is currently found in all 88 counties in Ohio, six neighboring states and the province of Ontario.

The State Management Plan for AIS, produced by the Ohio Department of Natural Resources, prioritizes AIS into two categories based on the degree of negative impact. High-risk species are those that currently cause or could potentially cause significant harm, while medium risk species are those that have a lesser impact, but are still a cause for concern. Below are the high-risk and medium-risk AIS that are the most concerning in the United States. While not all of these AIS are currently present in the State of Ohio, there is still a potential risk for the future.

The high-risk AIS are:

- Asian Carp
- Northern Snakehead
- Sea Lamprey
- Round & Tubenose Goby
- Zebra & Quagga Mussels

The medium-risk AIS are:

- Alewife
- River Ruffe
- Spiny & Fishhook water flea

LHMP DATA

Mercer County

The most recent invasive species to impact Mercer County is the Emerald Ash Borer (EAB). EAB is an ash-tree killing insect native to Asia; it kills trees within three to five years of infestation. It was first discovered in Ohio in 2003. Since that time, the Ohio Department of Agriculture and partner agencies have worked to protect the state's 3.8 billion ash trees. Mercer County is not the most impacted area of Ohio but it has experienced effects of the EAB infestation. As diseased trees along waterways have died, they have fallen into the waterways, impacting drainage and the flow of water. Diseased trees along the public right-of-way have also impacted infrastructure, as they are more likely to fall during a storm or high wind event. The Mercer County Engineer and jurisdiction street and road departments have aggressively removed diseased trees along the public right-of-way, which has been effective at reducing the impact on utility lines and other infrastructure

In recent years, Grand Lake St. Marys has been affected by multiple blue-green algae blooms. The algae, which is thought to be caused by increased quantities of phosphorous and nitrogen in runoff water, can produce toxic bacteria that is harmful to plants, animals, and humans. In 2010, the lake was declared unsafe for contact, including boating and swimming, due to an algal bloom. Because of the lake's importance to the economy of the region, this had a serious impact on businesses in the region. In October 2010, the U.S. Small Business Administration issued a declaration of economic injury for Mercer County and the region surrounding the lake. This declaration made loans available to small businesses and non-profit organizations negatively impacted by the algal bloom on the lake. While algal blooms have occurred on the lake since 2010, none have reached the magnitude and economic impact of this incident.

Putnam County

According to searches and reviews of online information provided by the Ohio Division of Forestry and the Ohio Department of Agriculture, Putnam County is susceptible to several infestations: European Gypsy Moth; Asian long horned beetles; mosquitoes infected with the West Nile Virus; spider mites; cicadas; the pine shoot beetle; and the Emerald Ash Borer.

Currently affecting the county is a European strain of gypsy moth which is one of the most destructive defoliating insects to attack the trees and forests of the northeastern United States. Impacts of a gypsy moth infestation include economic losses through timber mortality, loss of recreational opportunities in severely defoliated areas, and nuisances from gypsy moth caterpillars. A State Gypsy Moth quarantine was established in 1987. The Division of Forestry mitigation efforts have been successful in containing the gypsy moth infestation. Putnam County has yet to experience significant damages as a result of an infestation.

According to the Division of Forestry, the spring of 2004 saw an infestation of Brood X Cicadas in the southern portion of Putnam County. These cicadas were last seen in 1987. Adult cicadas damage deciduous trees especially when the female cicada lays her eggs. Cicada infestation can be mitigated against by careful pruning, covering smaller trees with cheesecloth, or spraying insecticide. The pine shoot beetle infests many species of pine, but Scotch pine is the preferred host. Cosmetic damage to pines growing on Christmas tree farms and nurseries may result in reduced product quality and substantial economic loss.

Emerald Ash Borer, an ash tree-killing insect from Asia, was identified in Ohio in 2003. Despite the fact that the Ohio quarantine has been lifted, to prevent the spread of EAB and other pests, it is still recommended that Ohioans continue to exercise caution when moving firewood. EAB kills ash trees within three to five years of infestation. Adults are dark metallic green, 1/2 inch in length and 1/8 inch wide, and fly only from mid-May to September. Larvae spend the rest of the year developing beneath the bark

HAZARD PROFILE

The probability of a large-scale infestation actually occurring in Putnam County is relatively low, with only moderate associated risk to human life. The recurrence frequency interval for this type of event is difficult to calculate, as infestations are not a rapid onset and subsidence type of event. Infestation is a long term invasion on an area and therefor assigning a statistical frequency of infestation would inaccurately assess the impact of such an event.

INVENTORY ASSETS EXPOSED TO INFESTATION

Infestation does not directly pose a threat to county facilities or human life at this time. This does not preclude the potential for a life threatening infestation or structurally damaging one in the future.

POTENTIAL LOSSES

Infestation is most likely to occur in the acres of forested or farmland and will likely cause no damage to structural assets; however, it may cause significant economic loss. Infestation is considered as a hazard in Putnam County due to the high percentage of agricultural and forestland in the county.

HIRA SUMMARY

Putnam County is susceptible to several infestations that may impact agricultural and forested portions of the county. Economic losses pose the greatest threat to the county and as such mitigation efforts

Clark County

Clark County is subject to both insect and plant evasive species. Although there are over 3,000 species of plants known to occur in Ohio, about 75% are native or have occurred in Ohio before the time of Europeans (1750). Some of those that have invaded Ohio displace native plants and disrupt woodlands, prairies, wetlands, and natural areas.

Those plants that typically have been the most invasive for Clark County residents include:

- Bush Honeysuckle
- Garlic Mustard
- Multiflora Rose
- Autumn Olive
- Callery Pear (Bradford Pear)

According to the ODNR Division of Forestry, one of the most prevalent invasive insect species is the Emerald Ash Borer. It is an Asian wood-boring beetle and affects all species of native ash trees found in Ohio. In 2003, other invasive species to affect Clark County include the Gypsy Moth Caterpillars and Spider Mites. Most recently found in southwest Ohio is the Asian Longhorned Beetle (AJB) which attacks broadleaf trees, particularly maples. An infestation is to spread or swarm in or over in a troublesome manner. Also, to live in or on as a parasite.

The probability of an infestation hazard event actually occurring in Clark County is relatively low, with only moderate risk associated with it. Infestation is most likely to occur in the 30,720 acres of forested or the 257,920 acres of farmland and will likely cause no damage to structural assets. Infestation is considered as a hazard in Clark County due to the high percentage of agricultural and forestland in the county. The Asian Long-Horned Beetle (ALB) has been discovered in Southwest Ohio east of Cincinnati by the U.S. Department of Agriculture. Ohio is the 5th state to detect ALB. These beetles attack a wide variety of broadleaf trees particularly Maples.

There are about 60 species of invasive plants identified in Ohio. Invasive species can cause economic and environmental damages in communities. Clark County is currently participating in a 22 county Woodland Invasive Species Program launched to promote healthier forests. Invasive Bush Honeysuckle is one of the most prevalent invasive species in Clark County. Invasive species plants are usually characterized by fast growing, rapid vegetation spread, and efficient speed dispersal and germination. Since these plants are not native to Ohio, they lack the natural predators and disease which would naturally control them in their native habitats.

Past Occurrences

Invasive species have been around since the settlers of the 1750's. Movement of people and transportation has made the spread of invasive species more prevalent. The Emerald Ash Borer was introduced in the U.S. in the 1990's from wood packing material from China, first being discovered in Lower Michigan, spreading to Ohio, Maryland, Pennsylvania, northern Indiana, and Chicago.

Probability of Future Events

Invasive species will continue to affect Ohio. With the increase in worldwide trade and the fast modes of transportation, the invasive species will continue to occur. Just as the Asian Longhorned Beetle has recently been discovered in southwest Ohio, new species of unwanted pests will come. The importance of controlling the natural environment native to Clark County will require local, state, nationwide, and international cooperation to avoid unwanted infestations of invasive species.

PAST OCCURRENCES

Invasive species of plants, fish, and insects have been arriving in Ohio since the establishment of European settlers in the 1750s. With each improvement in the scale and speed of human transportation, the potential for unintended introduction of invasive species has increased. Organisms which could not survive the month-long journey from Europe or Africa to America can make the journey in a matter of hours today. Several examples of species introduction pathways follow.

The Round Goby species was introduced from Eurasia into the St. Clair River and vicinity on the Michigan-Ontario border where several collections were made in 1990 on both the U.S. and the Canadian side. Speculation exists the Goby was transported from its native Caspian Sea by way of ballast tanks on ocean-going vessels. Today, the Goby is found in all the Great Lakes and is making inroads in all contiguous state watersheds.

The Multiflora Rose was introduced to the U.S. from Japan in 1886 as an under-stock for ornamental roses. Birds are responsible for spreading the seeds, which remain viable for a number of years. In the 1930s, the Soil Conservation Services advocated the use of Multiflora Rose for erosion projects and as a way to confine livestock. Hedges of Multiflora Rose have also been used as a crash barrier and to reduce headlight glare in highway medians.

The Emerald Ash Borer was introduced into North America sometime in the 1990's. The insect is believed to have been introduced into the U.S. in wood packing material from China. It was first reported killing ash trees in the Detroit and Windsor areas in 2002. Only species of ash are hosts for the beetle, which usually kill infested trees within a couple of years. Since then, infestations have been found throughout Lower Michigan, Ohio, Indiana, the Chicago area, Maryland and recently in Pennsylvania.

Considering the thousands of plant, dozens of aquatic and unknown number of insect species introduced into Ohio over the past 250 years, samples of the most often cited transfer media are provided here. Exotic species can arrive by a nearly endless number of vectors making a complete listing impossible.

PROBABILITY OF FUTURE EVENTS

Since the beginning of European colonization, non-native species have been arriving in Ohio. With the increase in global trade and travel, the probability of new and unexpected species arriving in Ohio will continue to grow. Legislation is in place around the world in an attempt to control the migration of unwanted species between ecosystems.

ODNR is currently battling the entrance of wild boars from Kentucky and West Virginia. The greatest concentration of verified populations can be found in the unglaciated region of southeastern Ohio. In addition, there are several species of carp currently migrating up the Mississippi watershed from the Gulf

Coast. Per the ODNR, Division of Fish Management and Research, silver and bighead carp are already present in the upper reaches of the Ohio River system in Ohio. The state hopes to seal off all areas where the Ohio River basin and the Lake Erie basin meet. None of the species considered Asian Carp have yet to establish themselves in the Lake Erie basin.

It is certain that new wanted and unwanted species will arrive in Ohio. The importance of controlling the integrity of existing ecosystems will require ongoing state, national and international efforts to avoid unwanted infestations. To this end, the State enacted new rules in January 2018 to make the sale and distribution of 38 invasive species illegal. In addition to the newly illegal plants, the Department of Agriculture assembled an invasive plant committee to review potential future additions to the no-sale list. The 2018 list is available at http://www.agri.ohio.gov/divs/Plant/Forms/InvasivePlantsNewsletter.pdf

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHODOLOGY

Impacts of invasive species tend to have commercial operational impacts, as opposed to many built environment impacts of the other hazards covered. Due to this unique situation, rather than a matrix listing county losses, the loss estimates will be presented using historical response costs to predict future losses in unadjusted dollars.

RESULTS

From the perspective of invasive plant species, the Multiflora Rose is one of most expensive to combat in Ohio. Each individual plant's ability to produce 500,000 seeds a year allows this invasive species to spread over large areas with incredible speed. Agricultural groups are facing the highest exposure and expense in the form of infiltration of croplands and eradication programs. According to agricultural experts associated with the Ohio State University, Ohioans are estimated to spend millions of dollars combating the Multiflora Rose. Precise dollar figures are not available due to the majority of response activities being performed by non-governmental entities.

Turning to invasive aquatic species, the Zebra Mussel is one of the most expensive to control. The mussels naturally collect on any solid surface and create significant problems for drinking water processing facilities and utilities. All in-water structures are impacted including, but not limited to, piers, breakwalls, vessel hulls and vessel engines cooled with external water. Estimates for controlling infestations run between $2 and $10 million per year depending on how many sources are aggregated. Should the Zebra Mussel effectively invade the river systems of Ohio, it is suggested the annual control costs could rise 10-fold.

Invasive insect species are both the direct source of damage to trees and a vector for other parasites. In the last century, the North American population of Elm trees was decimated by a fungus which arrived on infected trees shipped to an Ohio furniture company. One of the primary transport methods is though beetles which the fungus uses as a host to move from tree to tree. The beetle's ability to fly exponentially increased the number of trees impacted. Trees located in non-urban areas posed financial impact only to loggers; however, the Elm was a popular urban tree and the cost to remove them ran into the millions over the years.

The Emerald Ash Borer, which is currently impacting the North American Ash tree, has already cost millions of dollars in attempts to identify and isolate infected trees. In Ohio alone, there are an estimated 5 billion Ash trees at risk. Although many research centers are searching for an effective means of combating the insect, the only method currently available is the use of insecticides which have to be applied annually. The uncaptured cost to treat Ash trees in Ohio will likely reach into the millions, as urban areas combat the insect.

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

Similar to drought in Section 2.11, invasive species have a very limited impact on state-owned or state-leased facilities. The most prominent impact to state facilities relates to the maintenance of marinas in Zebra Mussel impacted areas. These mussels can clog inlets that could affect facilities, but not in the same manner as many of the other hazards. Also, Emerald Ash Borer could result in significant increases in fuel for wildfires in Region 3, which could adversely affect state facilities.

2.14 LAND SUBSIDENCE

Subsidence is the motion of the Earth's surface as it shifts downward relative to a benchmark (often sea-level) of the surrounding terrain. There are a number of causes for this effect. In Ohio, the two primary causes are abandoned underground mines (AUMs) and karst.

Underground mining of coal began in the early 1800's and continues to current day. In the 1900s, underground salt, limestone, and gypsum mining began. All mining activities create voids under the Earth's surface. Several key factors determining the potential for these voids to collapse include depth, mining technique used, types of rock and/or soils, and development on the ground surface. Abandoned underground coal mines in Ohio have the added environmental impact of discharging acidic water. If acidic mine water is discharged into creeks or streams, it can alter the chemical composition of the water habitat and cause considerable harm to sensitive aquatic life.

Per the ODNR, Division of Geological Survey, karst is a little-known, but unique and important landform that can be found throughout the state of Ohio. Regions that contain sinkholes and other solutional features, such as caves, springs, disappearing streams, and enlarged fractures, are known as karst terrains. Sinkholes form as bedrock dissolves and surface materials erode or collapse into the resulting voids. Sinkholes are the main hazard associated with karst landforms in Ohio, and there are thousands of them in the state.

The last form of land subsidence in Ohio is associated with soils, which dramatically expand when wet and contract when dry. Structures built on these soils can experience significant shifting as the ground saturates and dries.

HAZARD PROFILE

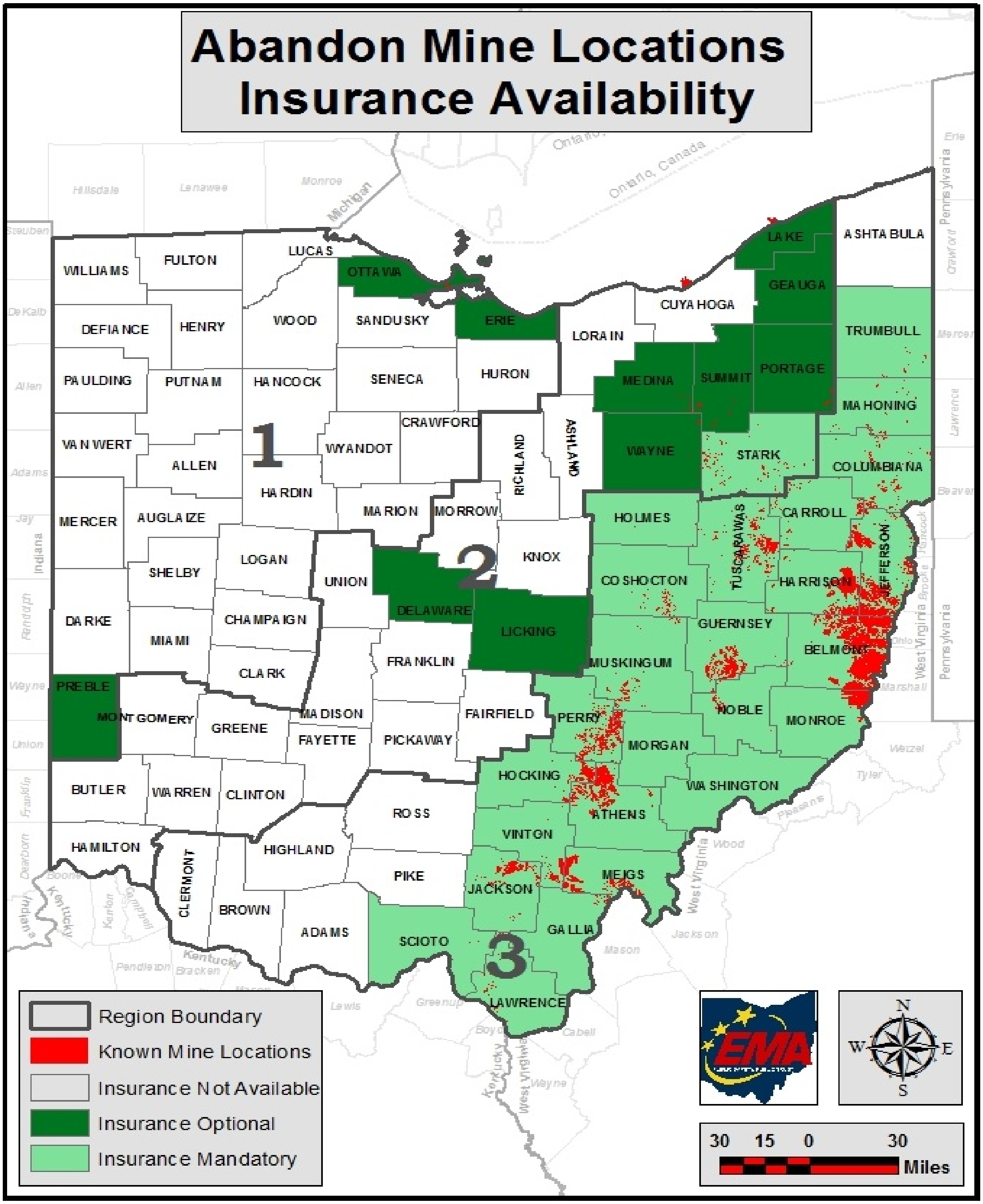
LOCATION

Beginning in the 1700s and continuing to today, there has been considerable coal mining in the Appalachian region of Ohio. In addition to coal, several salt, clay, and gypsum mines opened in counties close to Lake Erie. Finally, in central and southwestern Ohio, there are several isolated mines (Map 2.14a).

ODNR and the Ohio Department of Transportation (ODOT) actively inventories these geologic hazards and conducts risk assessments to determine the potential impact on the state's transportation infrastructure. Both mapped and unmapped underground mines pose a continued threat of subsidence to Ohio's transportation system. The statewide inventory and risk assessment of these mine sites is an ongoing process. Per the ODNR, Division of Mineral Resources Management, there are:

- 283 Surface Coal Mine Operation (203 active, 1118 released, 2502 abandoned, 2444 inactive & awaiting release)
- 26 Active Underground Coal Mines (permitted)
- 1,908 Surface IM Operations (828 active, 1080 released)
- 7 Active Underground IM Mines
- 3,606 Abandoned Underground Mines (Known)
- 6,450 Abandoned Surface Mines (based on topo maps and aerial reconnaissance)

Map 2.14a


Abandon Mine Locations
Insurance Availability
WILLIAMS
FULTON
LUCAS
OTTAWA
DEFIANCE
HENRY
WOOD
SANDUSKY
ERIE
LORAIN
CUYAHOGA
LAKE
GEAUGA
ASHTABULA
TRUMBULL
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
LOGAN
SHELBY
UNION
KNOX
COSHOCTON
HARRISON
DELAWARE
LICKING
DARKE
CHAMPAIGN
MIAMI
GUERNSEY
BELMONT
CLARK
FRANKLIN
MUSKINGUM
PREBLE
MONTGOMERY
GREENE
MADISON
FAYETTE
PICKAWAY
FAIRFIELD
PERRY
NOBLE
MONROE
MORGAN
BUTLER
WARREN
CLINTON
HOCKING
WASHINGTON
ROSS
ATHENS
HAMILTON
CLERMONT
HIGHLAND
VINTON
PIKE
JACKSON
MEIGS
BROWN
ADAMS
SCIOTO
GALLIA
LAWRENCE
1
2
3
Region Boundary
Known Mine Locations
Insurance Not Available
Insurance Optional
Insurance Mandatory
EMA
N
W
E
S
30 15 0 30
Miles

The majority of abandoned mines are located in, or directly adjacent to, Region 3, and most of these were coal mines. Coal mine depths can range from less than 100 feet below the surface to 1,000 feet or more. Deeper mines, with solid layers of rock (i.e., strata) above the void and limited soil at the surface, are less likely to fail than those closer to the surface. The ODNR, Division of Geological Survey and ODOT have developed profiles of voids, support strata composition and surface soils for a limited number mines, in order to assist in understanding the potential for subsidence events. Analysis requires experts trained in geology and significant time, which limits the number of sites assessed.

Other minerals mined include gypsum, clay and limestone, primarily in Ottawa, Preble, and Butler counties. Finally, very limited exposure to abandoned mines exists in Hamilton, Lucas, Erie, Delaware, and Licking counties, where the mineral being extracted was not available.

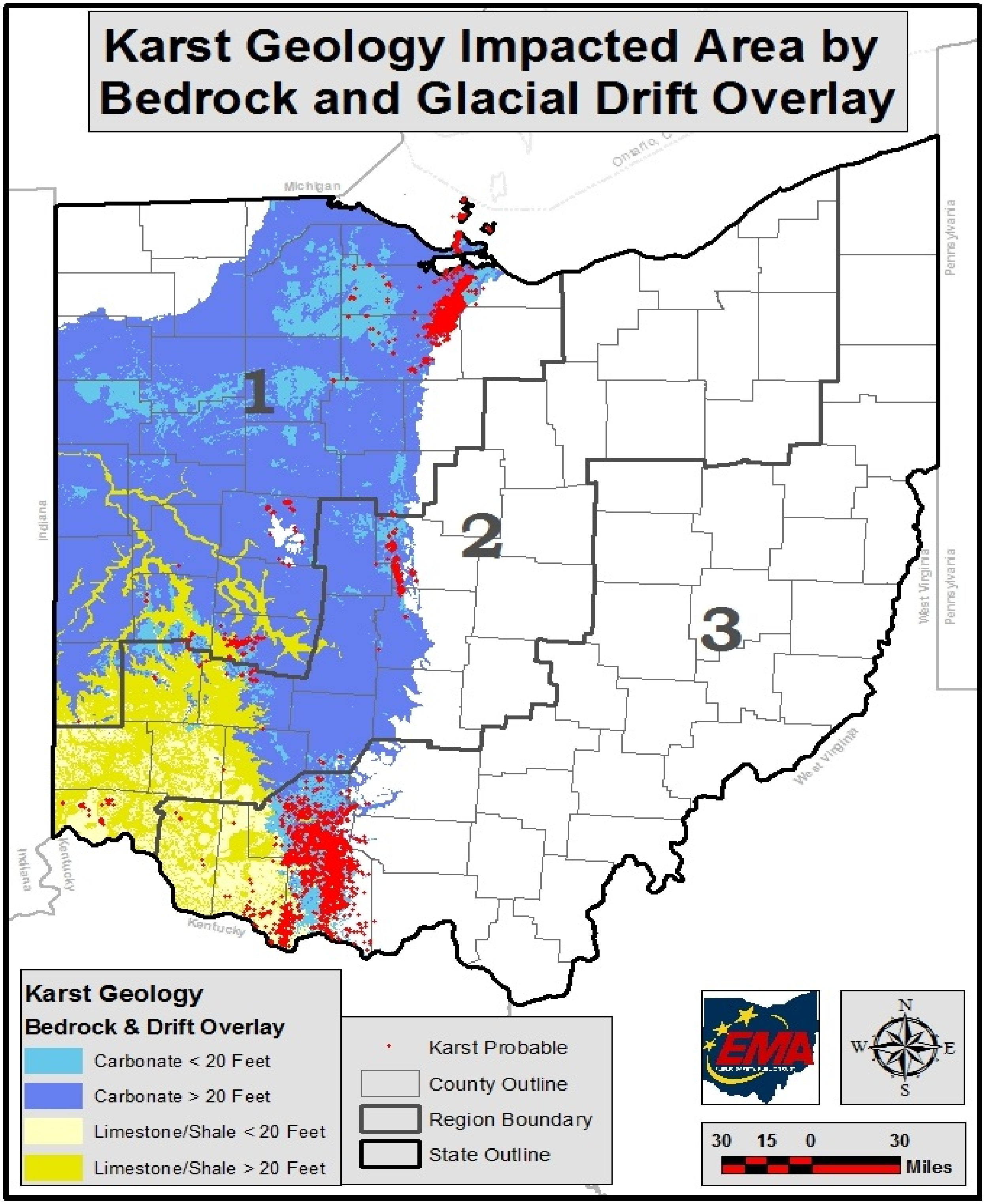
The Ohio Mine Subsidence Insurance Underwriting Association provides eligible Ohio counties with mine subsidence insurance (Map 2.14a). Under the program, 26 primarily Appalachian counties (Region 3) are required to carry mine subsidence insurance at a cost of one dollar annually. Additionally, eight counties in Region 2 and three counties in Region 1 are eligible to obtain insurance at the owner’s discretion at a cost of five dollars annually. The remaining 51 counties are not eligible for mine subsidence insurance.

Karst features are associated with the western third of Ohio, excluding the far northwestern counties of Williams, Fulton, and Defiance (Map 2.14b). Nearly all of Region 1 and the far western sections of Regions 2 and 3 are impacted by karst geology. The limestone, shale, and dolomite layers were deposited between 408 and 505 million years ago as the floor of an ancient sea. Later, the continental plate would rise above the existing sea level creating dry land and vast salt deposits. These sedimentary rock layers are naturally porous and dissolve into the water which passes through them.

The current landscape in the karst region of Ohio was created by glaciers as they advanced from the north reaching to the Ohio River roughly 14,000 years ago. When the last glacier receded, it left behind a layer of unconsolidated material in a wide range of depths. The shallower the loose material layer, the greater the chance of water penetrating to the underlying bedrock, resulting in a void or ground deformation occurring. This is represented by the probable karst areas on the map which group into two significant clusters. In the south, the greatest impacted counties include Brown, Adams, and Highland. In the north, the greatest impacted counties include Seneca, Huron, Erie, Sandusky, and Ottawa.

Areas which are reclaimed strip mines and other type of soils poorly suited for development are often mapped by local communities and the Ohio Department of Natural Resources. Ohio’s built environment exposure to this type of hazard is very limited.

Map 2.14b


Karst Geology Impacted Area by Bedrock and Glacial Drift Overlay
Michigan
Ontario
Indiana
Pennsylvania
West Virginia
Kentucky
1
2
3
Karst Geology
Bedrock & Drift Overlay
Carbonate < 20 Feet
Carbonate > 20 Feet
Limestone/Shale < 20 Feet
Limestone/Shale > 20 Feet
Karst Probable
County Outline
Region Boundary
State Outline
EMA
N
W
E
S
30 15 0 30
Miles

LHMP DATA

The City of Bellevue is located within the Bellevue-Castalia Karst Plain and resides within four counties; Erie, Huron, Sandusky, and Seneca. Three of the four counties (Huron did not) indicated that land subsidence was a hazard risk. They recognized that land subsidence, in the form of sinkholes, has a potential to occur, but also notes that there have been no incidents of land subsidence that have resulted in the damage of structures, personal injury, or loss of life. An area of concern for Sandusky County, in regards to land subsidence, is a Class I dam that is located in the southeastern portion of the county.

Sandusky, Erie, and Seneca Counties all have specific mitigation action items related to karst and land subsidence, such as to identify high-risk areas and evaluate land-use planning techniques to mitigate future events.

PAST OCCURRENCES

Abandoned underground mines in Ohio are monitored by the ODNR, Division of Mineral Resources Management, which is primarily federally funded. Within the division, two programs exist to address mine subsidence, one for emergencies and a second for non-emergencies. The emergency program gives priority to events which are directly affecting a structure (within 300 feet) or transportation route. Each year between 50 and 60 investigations are completed generating 25 to 30 projects. The time between the event and response is often within a week. Projects are undertaken to protect lives and property, and can range from simple precautions to filling the void with cement to stabilize the area affected.

Repeated emergency incidents can lead to larger non-emergency response. The City of North Canton (Region 2), Village of Cadiz (Region 3) and Village of New Lexington (Region 3) each experienced repeated emergency events culminating in area-wide engineering studies to address the problems. In each case, comprehensive mitigation activities, including the installation of in-mine support columns and the filling of voids, stabilized large areas which were subsidence-prone.

The most notable transportation-related event occurred in 1986 when an abandoned mine located in Guernsey County collapsed underneath Interstate 70 resulting in the closure of the entire interstate. Remediation included stabilizing the void and repairing the damaged roadway costing over $10 million dollars.

Underground salt mining under Lake Erie has not generated any known subsidence to date; however, solution mining in Lake, Summit and Medina Counties has. The most dramatic case in Ohio is in the Lake County community of Painesville, where an abandoned mine is responsible for a six-foot surface depression. Due to the proximity of the impacted area to Lake Erie, it is now filled with water.

Until recently, Karst events in Ohio had very little direct impact from a subsidence perspective on the built environment; however, they have been very costly in terms of pollution and flooding. Two well-documented karst-related events deal with contamination of aquifers. The oldest researched event in Ohio is associated with the Village of Bellevue, straddling the Huron / Sandusky County border. The 1961 study documents how from 1919 to 1946 the community permitted untreated wastewater injection wells and unimpeded groundwater runoff into sinkholes as an acceptable water management program. In 1946, after the groundwater was determined unfit for human consumption, the Village abandoned its last well and has since spent millions of dollars to develop a potable system based on piping water from safe sources. In February 2008, more than 200 homes experienced flooding in Bellevue when runoff from heavy snows and spring rains flooded underground karst chambers. Experts believed building pressure caused the pent-up water to surge up existing sinkholes and cracks, flooding homes and yards. A section of State Route 269 was swamped from February through June 2008.

The Village of Put-In-Bay, located on South Bass Island in Lake Erie, was the site of an extensive gastrointestinal illness outbreak in 2004. The island is a popular, warm-weather tourist destination and, at the height of the season, over 1,000 cases of digestive related maladies were documented in people who had recently vacationed there. The investigation began with the municipal systems and quickly shifted to a number of transient, non-community, public water systems used for geothermal cooling, flushing toilets, and outdoor cleaning. These systems were found interconnected to the main water system. The karst topography allowed groundwater to travel quickly between locations and is easily affected by seasonal precipitation.

The only known karst-related subsidence impact to the built environment is roadway damage. In 2007 State Route 19 was closed in Crawford County when an adjacent karst feature expanded destabilizing the robed.

Some examples of the impact of karst during construction include U.S. Route 33 near East Liberty, where construction crews had to perform considerable back-filling and reinforcing, creating a land-bridge to make sure the highway was secure. Another example would be the construction of tunnels for sewage pipelines by the City of Dublin (Franklin County). Sinkholes, filled with clayey overburden caused the expensive rock-boring machinery to clog and break, resulting in tremendous cost overruns.

Finally, one housing development in the City of Westerville (Franklin County) contains homes, which have been dislodged and damaged by the effects of soils which dramatically expand when wet and contract when dry. Since 2000, the Ohio EMA has purchased 6 damaged homes; however, this is the only known impact from this form of land subsidence.

PROBABILITY OF FUTURE EVENTS

Mine-related land subsidence is an annual event impacting an average of five homes or roadways. Approximately 20 additional events occur each year that do not impact the built environment, yet may require remediation. Unlike mine-related events, karst events historically have manifested their impact in the form of groundwater contamination. Based on past exposure, a significant event occurs approximately each decade.

VULNERABILITY ANALYSIS & LOSS ESTIMATION

METHODOLOGY

The only predictable impact, which can be quantified for analysis, is damage to Ohio's roadways. The Ohio Department of Transportation, Office of Geotechnical Engineering has a comprehensive inventory of the federal and state routes which intersect with known and estimated abandoned mines. The location, length of each segment, potential for failure, along with a host of other data is maintained in a database (https://gis.dot.state.oh.us/tims/Map/Geotech).

ODOT updated their AUM Inventory and Risk Assessment Manual in January of 2018. This new manual has an updated methodology for assessing the risk and impact of AUMs on federal and state routes. The new methodology makes use of an initial and detailed site evaluation process. This process then ranks the

AUM on a 4 tier scale. More detailed information about the manual is available at http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/GeoHazards.aspx

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

Land subsidence is a spatial hazard, but is spatial-specific in that it would only affect very small areas given an occurrence. Therefore, this hazard has a very limited potential of affecting any state-owned or state-leased facilities. However, it should be noted that such events could impact lifelines, which could have significant effects on the functionality of various state facilities.

2.15 FUTURE POTENTIAL AREAS OF RISK

There are several potential areas of risk which will impact the natural hazards of the state, but are not easily categorized within any of the existing natural hazards located within the HIRA. The following potential areas of risk will be addressed in this section:

- Future growth
- Harmful algal bloom
- Hydraulic fracturing
- Climate change

FUTURE GROWTH

The Ohio Development Services Agency, Office of Research publishes individual county statistics evaluating the 2010 Census and the current American Community Survey (ACS) data. The county profiles cover an array of characteristics ranging from demographics to taxable land value. These county profiles and the underlying Census projections for population change were used to determine the possible future population changes for all of the counties in the state. Overall between 2010 and 2016, the State of Ohio has seen very little change in population, showing an estimated 0.67 percent increase. This increase can be attributed to the significant increases in southwest and central Ohio, which include counties from Regions 1 and 2.

The projection shows significant population changes in central (Columbus Metropolitan Area) and southwest Ohio (Cincinnati Metropolitan Area). Specifically, the greatest changes in central Ohio took place in Delaware County (12.8 percent) and Franklin County (8.7 percent) (Table 2.15.a), and the greatest in southwest Ohio was Warren (6.7 percent) County.

COUNTY	Region	Census Pop (2010)	Current Population (2016 ACS)	% Change 2010-16
Delaware	**2**	**174,189**	**196,463**	**12.8%**
Franklin	**2**	**1,163,529**	**1,264,518**	**8.7%**
Warren	**2**	**212,868**	**227,063**	**6.7%**
Union	**2**	**52,267**	**55,457**	**6.1%**
Fairfield	**2**	**146,177**	**152,597**	**4.4%**

The dataset projections for 2020, 2030, and 2040 show the significant growth will continue to be focused in and around central Ohio. Four counties (Delaware, Union, Fairfield, and Licking) are projected to lead in the percentage of growth for each 10 year period between 2010 and 2040. Delaware County is projected to see the greatest increase every decade.

COUNTY	Region	Census Pop (2010)	Projection (2020)	2010-2020 Projection %
Delaware	**2**	174,189	210,630	**20.92%**
Union	**2**	52,267	59,760	**14.34%**

Fairfield	**2**	146,177	165,850	**13.46%**
Licking	**2**	166,492	180,860	**8.63%**
Morrow	**2**	34,827	37,380	**7.33%**

Morrow County is projected to see the fifth greatest increase from 2010 to 2020, but then Knox County will overtake it in the following years.

COUNTY	Region	Projection (2020)	Projection (2030)	2020-2030 Projection %
Delaware	**2**	210,630	246,000	**16.79%**
Union	**2**	59,760	68,230	**14.17%**
Fairfield	**2**	165,850	187,820	**13.25%**
Licking	**2**	180,860	196,570	**8.69%**
Knox	**2**	64,960	69,810	**7.47%**

By 2040, Delaware County is project to have a population of 282,160, an increase of 43% over the 2016 population.

COUNTY	Region	Projection (2030)	Projection (2040)	2030-2040 Projection %
Delaware	**2**	246,000	282,160	**14.70%**
Union	**2**	68,230	77,360	**13.38%**
Fairfield	**2**	187,820	210,910	**12.29%**
Licking	**2**	196,570	212,370	**8.04%**
Knox	**2**	69,810	74,850	**7.22%**

Knowing this increase in population will be an impact on the hazards in the Delaware County, the county's 2014 multi-jurisdictional mitigation plan clearly describes the difficulties associated with double digit increases in population and the associated growth of the built environment. Per the 2014 Delaware County LHMP, the great recession influenced development trends in the county and the changes of development patterns have done little to affect the vulnerability of any jurisdiction from previous to current plans. Delaware County is still the fastest growing county in Ohio.

Still large sections of farmland have been and are being developed into residential housing, retail commercial facilities and office parks with the necessary infrastructure to support them. Increased runoff and shorter time available for natural attenuation has resulted in greater water levels and flows near existing neighborhoods.

Delaware County has a clear understanding of the problems, their implications and is working to address them through mitigation planning and educational outreach. Part of the difficulty in addressing the situation is that the growth areas are creating high-value real estate for Ohio, while the impacted areas range from manufactured home parks to older, residential structures built in or near the floodplain. Over time the size of the regulatory floodplain can be expected to increase due to development. Two other central Ohio counties, Franklin and Union, experienced moderate growth; however, no adverse impacts were observed for different reasons. Union County did not sustain enough growth to cause any sizable impacts, and Franklin County's growth was driven heavily by the increase of multi-family structures acting as in-fill or redevelopment of existing developed areas.

Considering the rapid growth in southwest Ohio and the impacts on Warren County, the Warren County Regional Planning Commission has planned for structured growth, which has resulted in minimal adverse impact. The Warren County multi-jurisdictional mitigation plan outlines the program objectives to:

- Discourage small, isolated subdivisions where soil conditions and lot size are not conducive to on-site wastewater disposal systems, where applicable;
- Encourage a logical pattern of residential development where future growth would occur in proximity to existing residential areas, within the designated Urban Service Areas of the township;
- Build multi-family housing at a scale that can accommodate the need, combined with prudent use of the Planned Unit Development process, to accomplish quality development, mitigating the impact of county utilities and other public services;
- Develop adequate, well designed and affordable housing for the elderly population, the handicapped and families with children;
- Give a stronger emphasis to establishing open space/green belt areas, separating developing residential areas from incompatible uses;
- Establish a system to encourage housing maintenance through a coordinated, ongoing inspection program by county and local officials;
- Encourage the repair or removal of dilapidated/substandard structures;
- Identify, document and protect older homes or residential areas of historical and/or architectural significance from unwanted, incompatible land uses; and
- Explore the establishment of an historical zoning district to protect individual structures or neighborhoods of historical and/or architectural significance.

Mitigation planning and associated strategies have been adequately developed at the local level to minimize adverse effects from the significant growth experienced in central and southwest Ohio and aid in community resilience.

OHIO BALANCED GROWTH STRATEGY

One of the primary strategies that the State of Ohio adopted to address future growth throughout state is the Ohio Balanced Growth Strategy (http://balancedgrowth.ohio.gov). This strategy is a voluntary, incentive based program that provides local governments with a regional planning framework based upon watersheds and water resource protection. The fundamental principle to guide the action of state agencies is that if local governments within a watershed can agree upon areas where development is to be encouraged and which are to be conserved, Ohio will align state programs to support these locally based decisions and conversely will not utilize state programs to violate them.

The Ohio Water Resources Committee (OWRC) has implemented this initiative statewide based upon a previous program developed by the Ohio Lake Erie Commission (OLEC). The program has many elements that encourage balanced growth throughout the state, specifically:

- Focusing on land use and development planning in Ohio's watersheds. The goal is to link land use planning to the health of watersheds and major bodies of water.
- Creation of Watershed Planning Partnerships to encourage regional cooperation on the issues of land use planning and development.
- Production of Watershed Balanced Growth Plans, which will guide how growth and conservation would be promoted by both local and state policies.
- The development of model regulations to promote local land use practices that minimize development impacts on water quality.
- Align state policies, incentives and other resources to support Watershed Balanced Growth planning and implementation.

WATERSHED BALANCED GROWTH PLANS

One of the primary aspects of the Ohio Balanced Growth Strategy is the creation and adoption of a Watershed Balanced Growth Plan. These plans are intended to provide a framework for regional decision-making on growth, conservation, stormwater issues and water quality. Each of these plans is based upon the 10 guiding principles for sustainable Ohio watersheds, the guiding principles are:

- Maximize investment in existing core urban areas, transportation, and infrastructure networks to enhance the economic vitality of existing communities.
- Minimize the conversion of green space and the loss of critical habitat areas, farmland, forest, and open spaces.
- Limit any net increase in the loading of pollutants or transfer of pollution loading from one medium to another.
- To the extent feasible, protect and restore the natural hydrology of the watershed and flow characteristics of its streams, tributaries, and wetlands.
- Restore the physical habitat and chemical water quality of the watershed to protect and restore diverse and thriving plant communities and preserve rare and endangered species.
- Encourage the inclusion of all economic and environmental factors into cost / benefit accounting in land use and development decisions.
- Avoid development decisions that shift economic benefits or environmental burdens from one location within a region to another.
- Establish and maintain a safe, efficient, and accessible transportation system that integrates highway, rail, air, transit, water, and pedestrian networks to foster economic

growth and personal travel.

- Encourage all new development and redevelopment initiatives to address the need to protect and preserve access to historic, cultural, and scenic resources.
- Promote public access to and enjoyment of our natural resources for all Ohioans.

These Watershed Balanced Growth plans are not intended to supersede either local comprehensive plans or local hazard mitigation plans, but to harmonize with them. Each Watershed Balanced Growth Plan must identify or include the following:

- Priority Conservation Areas (PCA), which are critical areas to protect within the watershed. This includes areas which provide flood control, are susceptible to significant natural hazards and offer areas for ecological / open space restoration in urban areas.
- Priority Development Areas (PDA), which are areas where development should be encouraged. This includes areas which will maximize development potential and efficient use of infrastructure.
- The related documentation for justifying the designation of any PCAs or PDAs.
- Plans for the implementation of any developed strategies and a description of the governance structure.
- A specific statement noting how the plan will meet the 10 guiding principles for sustainable Ohio watersheds.

STATE INCENTIVES

One of the challenges of the Balance Growth Program is that the State of Ohio is a home rule State. Therefore all land use, zoning, and planning decisions are made solely at the local level. State agencies do, however, influence the location of development in many ways through infrastructure investments, economic development incentives, tax policies and other policies and programs. In order to encourage local watershed groups to undertake the Balanced Growth Program process, the state created an incentive package that is available to Watershed Planning Partners and their participating local jurisdictions with an endorsed plan. These are the 26 state programs that include special consideration for Balanced Growth participating communities these programs are offered by various state agencies including the OEPA, ODNR, ODSA, ODOT and several other State agencies. More information about the specific state sponsored incentives is available at http://balancedgrowth.ohio.gov/BalancedGrowthStrategy.aspx

BEST LOCAL LAND USE PRACTICES

In addition to providing incentives for the adoption of Balance Growth Plans, the State has created several best local land use practices that address the following subject matters:

- Stream, Floodplain, and Wetland Protection
- Storm Water Management/Erosion and Sediment Control
- Comprehensive Planning
- Compact Development
- Conservation Development

- Natural Areas Establishment and Management
- Source Water Protection

These best local land use practices are available for download at: http://balancedgrowth.ohio.gov/BestLocalLandUsePractices/BestLocalLandUseP ractices2012.aspx

LOCAL ADOPTION OF WATERSHED BALANCED GROWTH PLANS

Since 2008, 12 local State endorsed Watershed Balanced Growth Plans have been adopted throughout the State of Ohio and over half of those plans were adopted in the past three years. The plans must be adopted at the local level with support from local governments that represent at least 75% of the geographic land area of a watershed, and 75% of the local governments in the watershed and 75% of the population in the watershed. Once local support requirements are met, the state conducts a final review prior to endorsing the plan to ensure compliance with the criteria of the program.

The following Watershed Balanced Growth Plans have been adopted at the local level and endorsed by the State of Ohio:

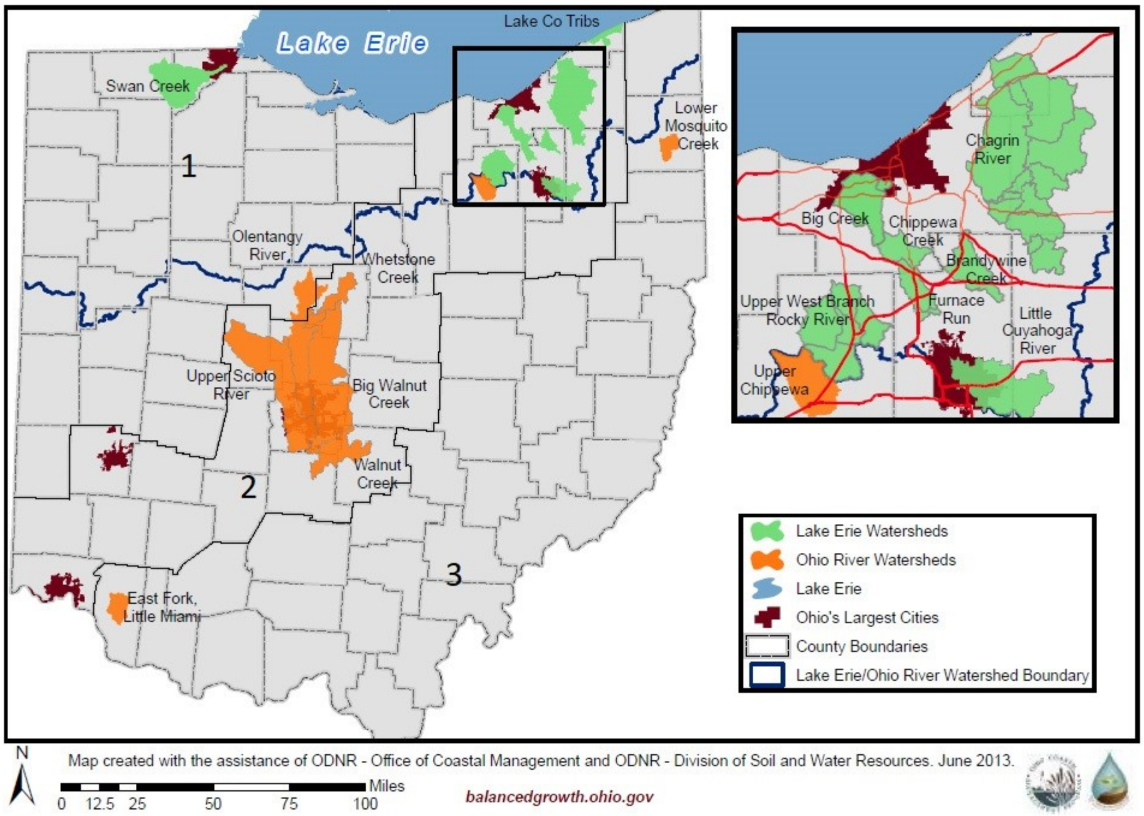
- Chippewa Creek Watershed (December 2008)
- Upper West Branch Rocky River Watershed (June 2009)
- Chagrin River Watershed (September 2009)
- Swan Creek Watershed (September 2009)
- Big Creek Watershed (June 2011)
- Furnace Run (December 2011)
- Eastern Lake County Coastal Tributaries (December 2011)
- Middle East Fork (February 2012)
- Lower Mosquito Creek (February 2012)
- Upper Chippewa Creek (April 2012)
- Olentangy River (April 2012)
- Walnut Creek (February 2013)
- Brandywine Creek (March 2014)

These 13 endorsed Watershed Balanced Growth Plans are spread across 18 different counties throughout the State. The following counties have at least one State Endorsed Watershed Balanced Growth Plan within their borders:

- Clermont
- Cuyahoga
- Delaware
- Fairfield
- Franklin
- Fulton
- Geauga
- Lake
- Licking
- Lucas
- Marion
- Medina
- Morrow
- Pickaway
- Portage
- Summit
- Trumbull
- Union

The majority of the endorsed plans in the State are primarily located within central and north eastern parts of the State. Of these 18 counties, two counties (Franklin, Medina), have specifically incorporated the State Endorsed Watershed Balanced Growth Plan into their Local Hazard Mitigation Plan and nine of counties have references to local watershed and storm water management plans throughout their Local Hazard Mitigation Plans. The continued adoption of the Watershed Balanced Growth Plans throughout the State will encourage sound planning and land use development Statewide. These activities will promote linkages between Balanced Growth Plans and local hazard mitigation plans which will minimize adverse effects of future growth and contribute to more resilient communities.

Balanced Growth Planning Partnership Watersheds



HARMFUL ALGAL BLOOMS

The Ohio Sea Grant Program states Harmful Algal Blooms (HAB) are caused by a combination of warm water temperatures (above 60 degrees Fahrenheit) and high concentrations of phosphorus in the water. Typically, a high concentration of phosphorus and nitrogen in cold weather will produce a bloom of diatoms, in cool weather we would expect a bloom of green algae, and in warm weather we often see blue-green algae.

One of the main focuses on reducing the number of HABs is to reduce the amount of phosphorus, which is one of the three major components in most fertilizers, followed by nitrogen and potassium. Phosphorus entering natural water ways is a major issues in the state. In Lake Erie, more than 65% of the phosphorus that causes HABs comes from agricultural fertilizer and manure runoff. Some phosphorus also comes from sewage treatment plants, combined sewer overflows, water treatment plants, cleaning products, faulty septic tanks and residential lawn fertilizers. The largest phosphorus load, about 80-90%, happens during heavy rain storms when fertilizer and other phosphorus sources are quickly washed into rivers and streams that flow into Lake Erie.

HABs can produce toxins that are capable of causing illness and sometimes even death. Microcystin is the most concerning toxin as it causes skin rashes, GI problems and varying degrees of nervous system, liver and kidney damage. While most healthy adults recover from contact with the toxin, it can be more problematic to children, the elderly and people with pre-existing conditions that weaken their systems. Exposure has also killed people in other parts of the world. The toxin can also be fatal to pets that drink or come in contact with contaminated water.

LAKE ERIE

Lake Erie is the southernmost, shallowest and warmest of the Great Lakes. Its watershed has the least forest, the most agricultural land and the second-most urban/suburban land. Therefore, Lake Erie gets more sediment and nutrients (fertilizer runoff, sewage, etc.) than the other lakes, while also having environmental conditions that favor algal blooms. HABs typically occur first in Maumee Bay at the mouth of the Maumee River and in Sandusky Bay at the mouth of the Sandusky River because blue-green algae prefer warm water and high concentrations of phosphorus. Both bays are very warm and shallow, and the watersheds of both rivers have very high percentages of farm land (the Maumee is the largest tributary to the Great Lakes and drains 4.2 million acres of agricultural land). As a result, both streams contain very high concentrations of phosphorus that eventually feeds into Lake Erie.

CLIMATE CHANGE

Climate change will bring more rain and snow, higher average temperatures and flooding to the Great Lakes region. More rain and snowfall increases runoff of the nutrients that fuel harmful algal blooms into the lake. The cyanobacteria that cause HABs also prefer the warmer water that comes with the higher air temperature caused by climate change. When combined, these changing conditions can increase the severity of harmful algal blooms.

OHIO'S DOMESTIC ACTION PLAN (DAP)

https://lakeerie.ohio.gov/LakeEriePlanning/OhioDomesticActionPlan2018.aspx

Ohio's Domestic Action Plan (DAP) will advance efforts toward the proposed 40 percent nutrient reduction target put forth in the Great Lakes Water Quality Agreement of 2012 (GLWQA). Ohio's DAP will expand on the collaborative implementation initiatives and will also include the Central Basin as well as the Western Basin of Lake Erie. The DAP was developed with input through meetings and conversations with various stakeholder groups and state agencies.

While the focus of the DAP is to achieve nutrient reductions from the base year of 2008, we also need to consider the potential impact of new sources of phosphorus coming into in the watershed, the increased frequency and severity of rainfall events, and how these changes pose challenges to the over-all net reduction of nutrients as we work towards the established goals.

The Goals of the Ohio Domestic Action Plan

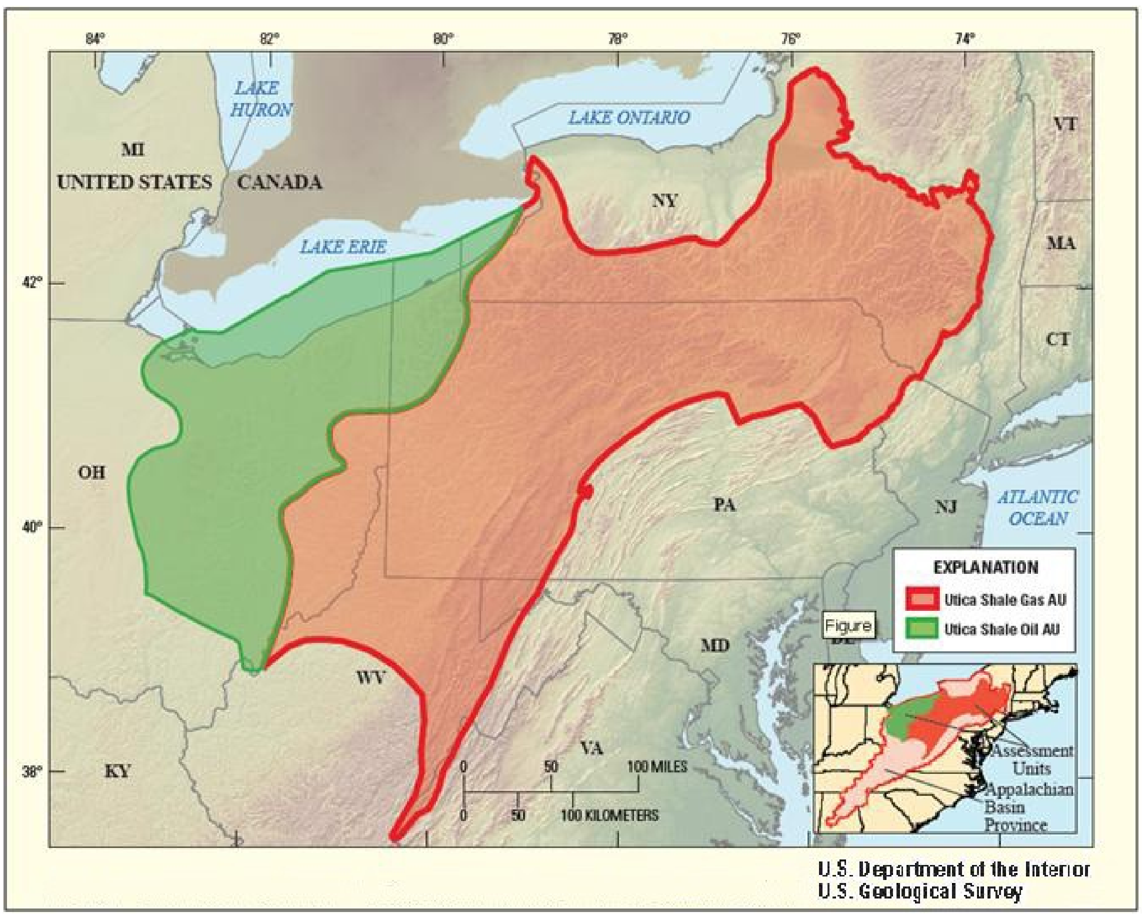
- Achieve a 40 percent total spring load reduction in the amount of total and dissolved reactive phosphorus entering Lake Erie's western basin by the year 2025 with an aspirational goal of a 20 percent reduction by 2020.
- Achieve a 40 percent total annual load reduction in the amount of total phosphorus entering Lake Erie's central basin by the year 2025 with an aspirational goal of a 20 percent reduction by 2020.

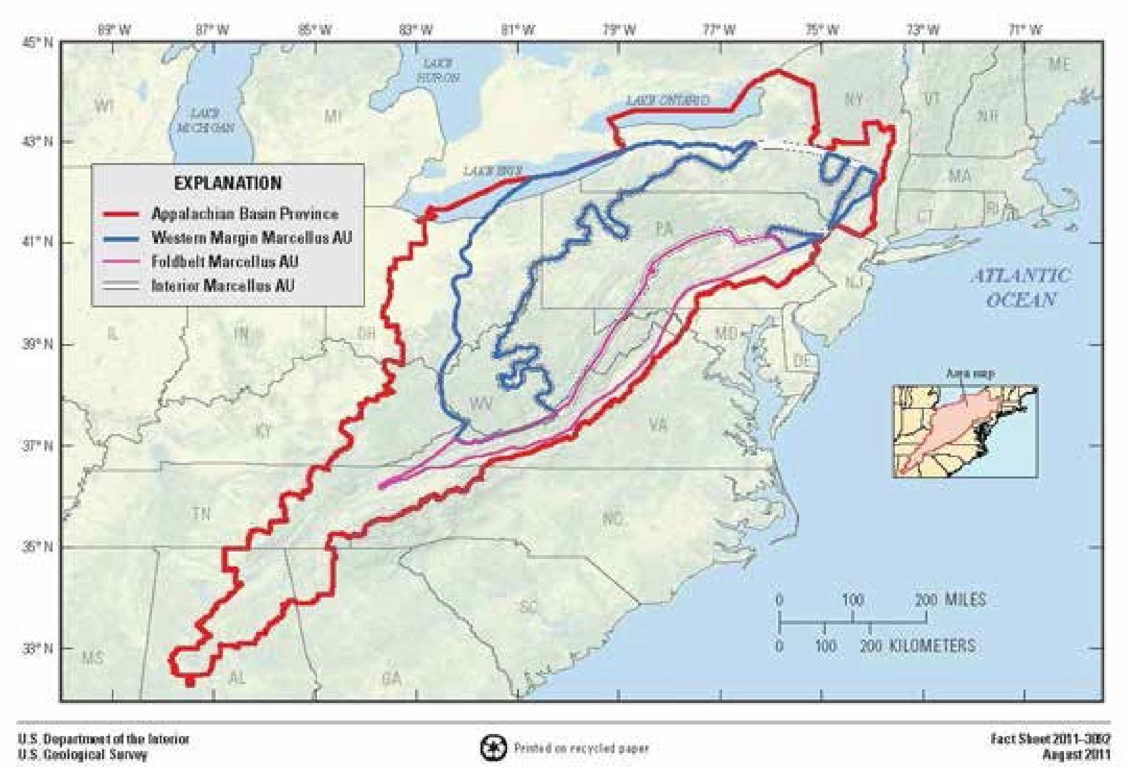
The Domestic Action Plan is based on the following guiding principles:

- Implementation of point and nonpoint nutrient reduction practices.
- Verification of targeted practice implementation and effectiveness.
- Documentation of water quality changes resulting through the implementation of nutrient reduction practices.
- Adaptability to allow for the modification of programs, practices and policy as new information is obtained and changes occur.
- Accountability to ensure compliance with rules and laws, establish clear areas of responsibilities, and that the commitment is made and kept toward achieving the goals.

HYDRAULIC FRACTURING

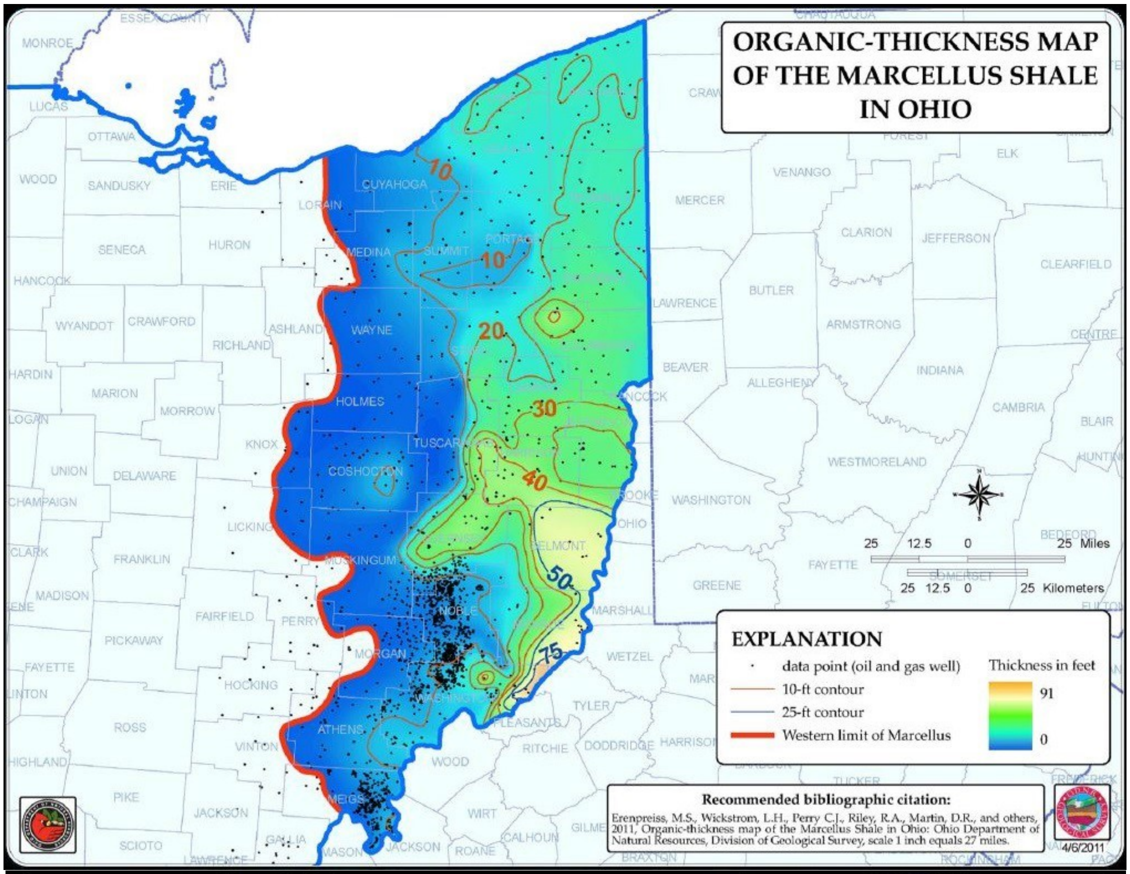
Together, the Marcellus and Utica Shale regions extend across New York, Pennsylvania, Maryland, West Virginia, Ohio and portions of Kentucky and these deposits sit between 7,000 and 12,000 feet below ground. Both the Marcellus and the Utica shale regions are important geologic formations because they hold large reserves of natural gas. Researchers estimate the Marcellus Shale alone could contain as much as 363 trillion cubic feet of natural gas. Ohio is experiencing far less Marcellus Shale drilling than several of the neighboring states because the Marcellus Shale is much thinner on its western edge.

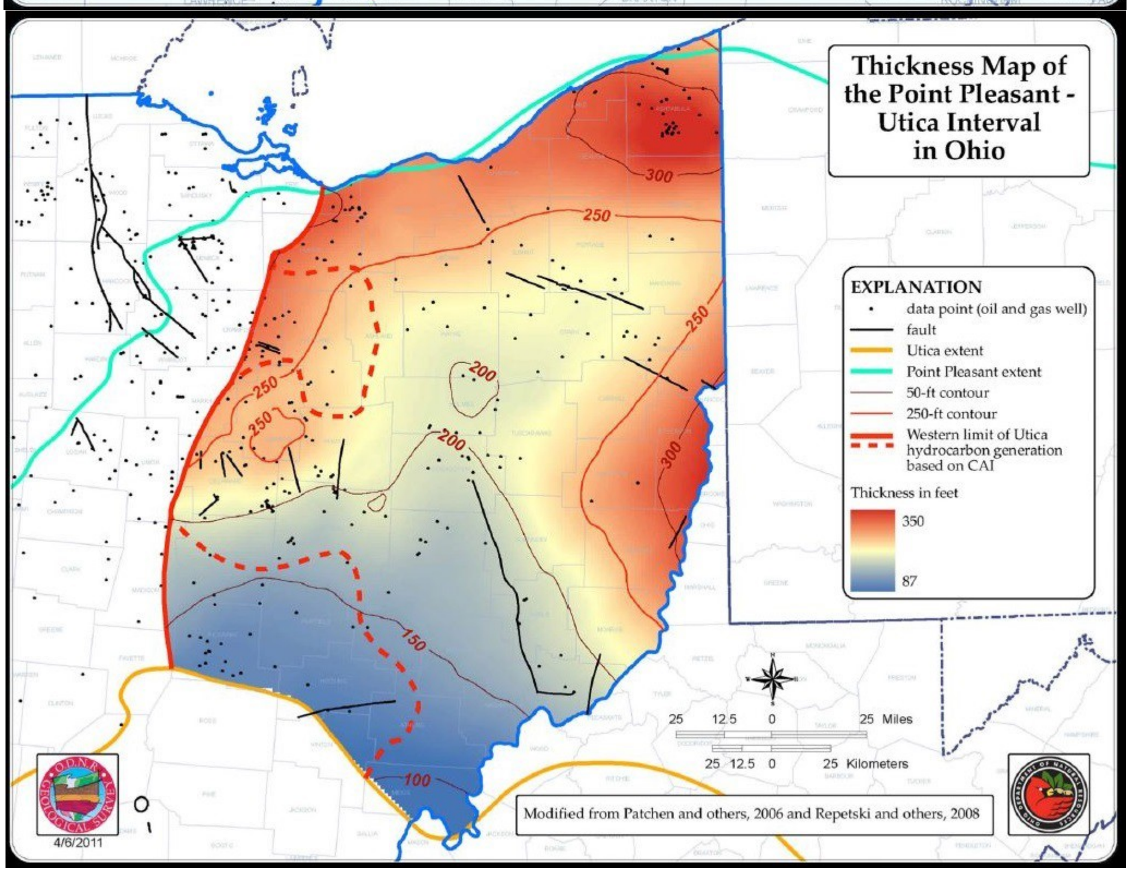




However, Ohio has and will continue to see a significant increase in drilling as much of the state sits over the Utica Shale Formation. The extraction of natural gas from the shale is a two-step process of horizontal drilling and hydraulic fracturing. The process starts with a production well, which is drilled thousands of feet downward and then gradually angled out horizontally through the shale deposit. After the well is drilled, a mixture of water, sand and chemical additives is injected at very high pressure to fracture the shale. This part of the process called hydraulic fracturing or fracing, is a technique used in the oil and gas industry since the 1950's.

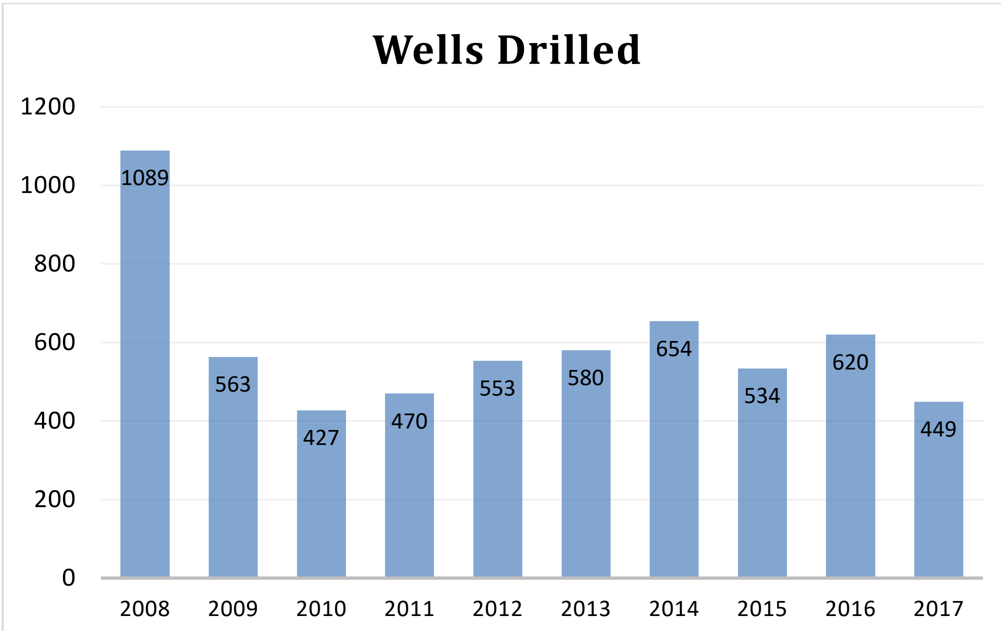
Per the ONDR Division of Geological Survey, resource estimates indicate the Devonian-age Marcellus Shale is the largest exploration play in the eastern United States. Recently, the application of horizontal drilling combined with multi-staged hydraulic fracturing to create permeable flow paths from wellbores into shale units has resulted in a drilling boom for the Marcellus in the Appalachian Basin states of Pennsylvania, West Virginia, southern New York, and eastern Ohio. Fracturing technology also may have application in other shale units, such as the Ordovician-age Utica Shale, which extends across much of the Appalachian Basin region. While limited production has occurred in the Utica up to this point, thickness and widespread geographical extent indicate it may also have great oil-and-gas potential.


ORGANIC-THICKNESS MAP OF THE MARCELLUS SHALE IN OHIO
EXPLANATION
data point (oil and gas well)
10-ft contour
25-ft contour
Western limit of Marcellus
Thickness in feet
91
0
25 12.5 0 25 Miles
25 12.5 0 25 Kilometers
Recommended bibliographic citation:
Erenpreiss, M.S., Wickstrom, L.H., Perry C.J., Riley, R.A., Martin, D.R., and others, 2011, Organic-thickness map of the Marcellus Shale in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, scale 1 inch equals 27 miles.
4/6/2011


Thickness Map of the Point Pleasant - Utica Interval in Ohio
EXPLANATION
data point (oil and gas well)
fault
Utica extent
Point Pleasant extent
50-ft contour
250-ft contour
Western limit of Utica hydrocarbon generation based on CAI
Thickness in feet
350
87
25 12.5 0 25 Miles
25 12.5 0 25 Kilometers
Modified from Patchen and others, 2006 and Repetski and others, 2008
4/6/2011

CURRENT STATE OF NATURAL GAS AND OIL DRILLING IN OHIO

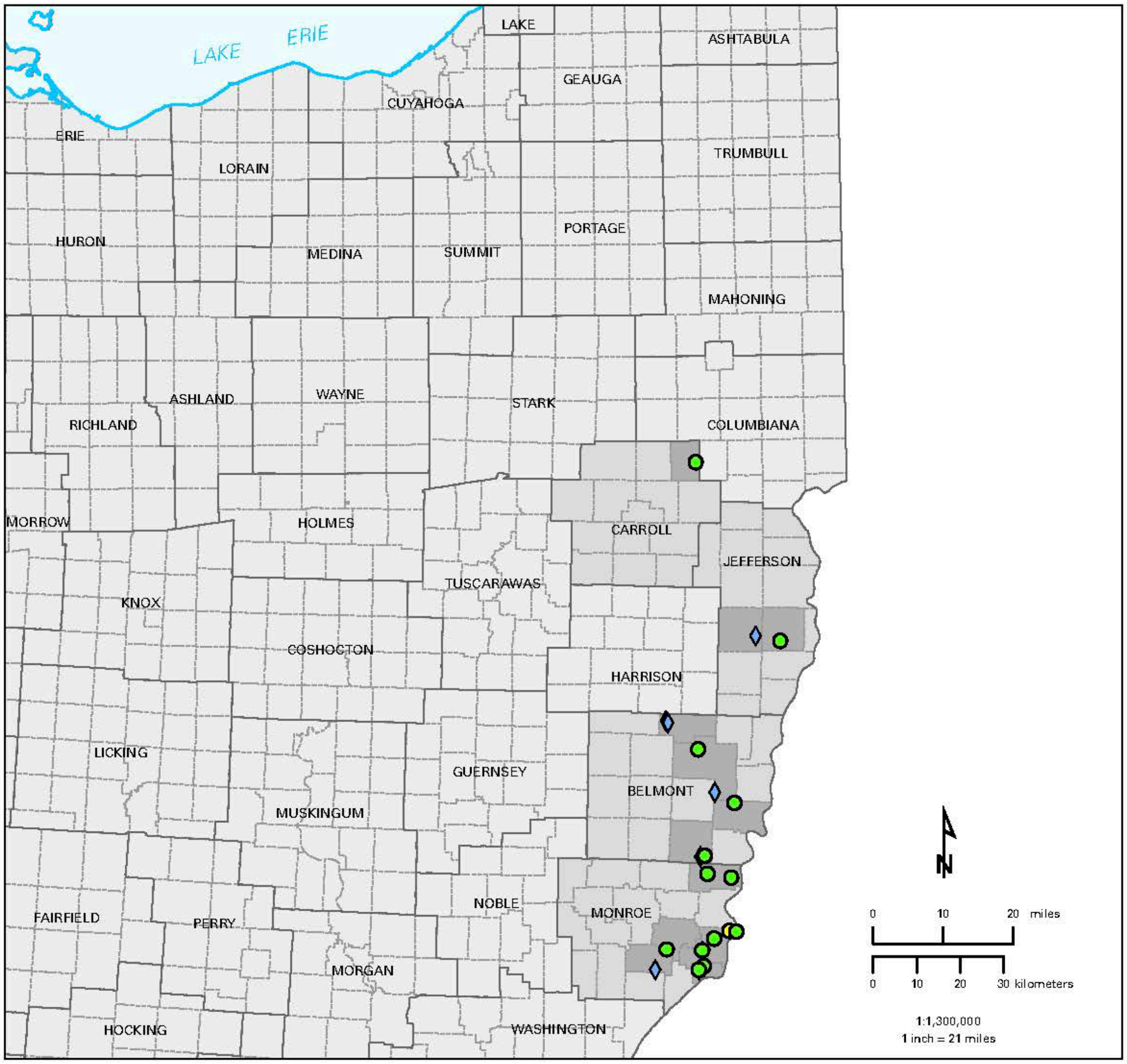
The Ohio Oil & Gas Summary issued each year reflects the most up to date information and trends effecting Ohio's oil and gas industries. The 48th edition of this Summary noted that 449 oil and gas wells were drilled in the state is 2017 and this is down from a peak of 1089 new wells drilled in 2008. The spike of wells drilled from 2005-2008 was related to the exploration of the Devonian Shale.



The ONDR Division of Oil and Gas Resources Management indicates the activity of horizontal well drilling in the Marcellus and Utica-Point Pleasant Shale in the State. As this map indicates the current and future activity will occur in the eastern and southeastern portions of the State.

OHIO DEPARTMENT OF NATURAL RESOURCES

HORIZONTAL MARCELLUS WELL ACTIVITY IN OHIO



EXPLANATION

Horizontal well status as of 12/1/2018

- PERMITTED-(Permitted; Not Drilled; Canceled) (24)
- DRILLED-(Drilling; Well Drilled) (12)
- PRODUCING-(Producing; Plugged Back) (23)
- INACTIVE-(Drilled Inactive; Shut in) (1)

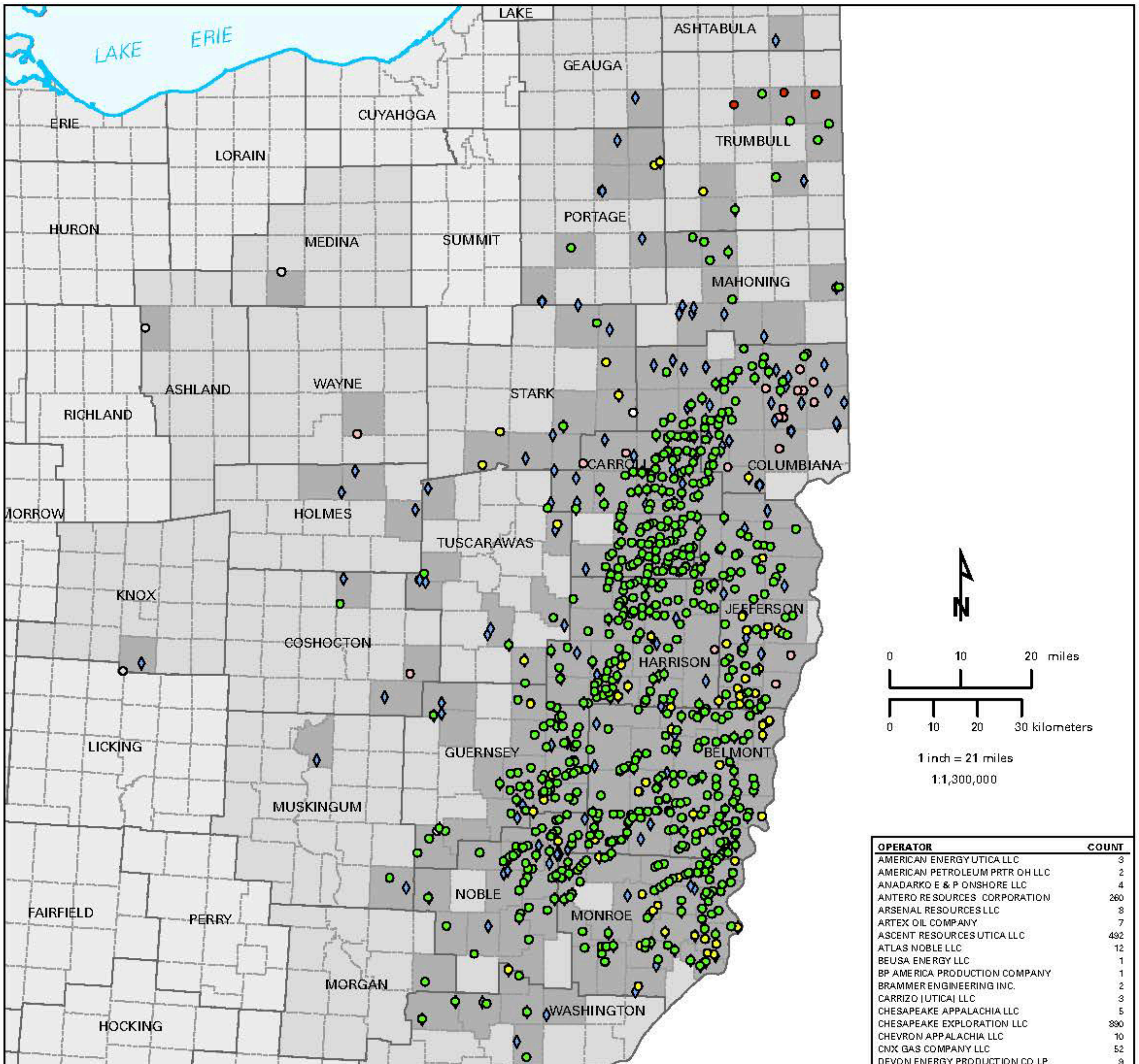
OPERATOR	COUNT
ALLIANCE PETROLEUM CORPORATION	1
ASCENT RESOURCES UTICA LLC	3
CHESAPEAKE EXPLORATION LLC	1
CNX GAS COMPANY LLC	1
ECLIPSE RESOURCES I LP	13
EM ENERGY OHIO LLC	1
EQUINOR USA ONSHORE PROPERTIES INC.	15
HESS OHIO RESOURCES LLC	3
PHILLIPS EXPLORATION INC	1
PROTEGE ENERGY II LLC	1
TRIAD HUNTER LLC	17
XTO ENERGY INC.	3
TOTAL	**60**

Well permit information from the ODNR Division of Oil and Gas Resources Management

Recommended citation:
Ohio Department of Natural Resources, 2018, Horizontal Marcellus Well Activity in Ohio: Columbus, scale 1:1,300,000, revised 12/3/2018.

OHIO DEPARTMENT OF NATURAL RESOURCES

HORIZONTAL UTICA - PT PLEASANT WELL ACTIVITY IN OHIO



OPERATOR	COUNT
AMERICAN ENERGY UTICA LLC	3
AMERICAN PETROLEUM PRTR OH LLC	2
ANADARKO E & P ONSHORE LLC	4
ANTERO RESOURCES CORPORATION	260
ARSENAL RESOURCES LLC	8
ARTEX OIL COMPANY	7
ASCENT RESOURCES UTICA LLC	492
ATLAS NOBLE LLC	12
BEUSA ENERGY LLC	1
BP AMERICA PRODUCTION COMPANY	1
BRAMMER ENGINEERING INC.	2
CARRIZO (UTICA) LLC	3
CHESAPEAKE APPALACHIA LLC	5
CHESAPEAKE EXPLORATION LLC	890
CHEVRON APPALACHIA LLC	10
CNX GAS COMPANY LLC	52
DEVON ENERGY PRODUCTION CO LP	9
ECLIPSE RESOURCES I LP	197
EM ENERGY OHIO LLC	23
ENERVEST OPERATING LLC	26
EQT PRODUCTION COMPANY	4
EQUINOR USA ONSHORE PROPERTIES INC.	32
GEOPETRO LLC	5
GULFPORT APPALACHIA LLC	21
GULFPORT ENERGY CORPORATION	406
HALCON OPERATING COMPANY INC.	4
HESS OHIO DEVELOPMENTS LLC	24
HESS OHIO RESOURCES LLC	1
HG ENERGY LLC	7
HILCORP ENERGY COMPANY	59
M & R INVESTMENTS OHIO LLC	1
NORTHWOOD ENERGY CORP	6
PDC ENERGY INC.	9
PENNENERGY RESOURCES LLC	40
PIN OAK ENERGY PARTNERS LLC	13
PROTEGE ENERGY III LLC	2
R E GAS DEVELOPMENT LLC	10
RICE DRILLING D LLC	128
SIERRA RESOURCES LLC	3
STATOIL USA ONSHORE PROPERTIES INC.	10
SWEPI LP	1
TRIAD HUNTER LLC	32
UTICA RESOURCE OPERATING LLC	35
XTO ENERGY INC.	75
TOTAL	**2,935**

EXPLANATION

Horizontal well status as of 12/1/2018

- PERMITTED-(Permitted; Not Drilled; Canceled) (473)
- DRILLED-(Drilling; Well Drilled) (295)
- PRODUCING-(Producing; Plugged Back) (2,090)
- INACTIVE-(Drilled Inactive; Shut in) (27)
- Lost Hole or Final Restoration (28)
- Dry and Abandoned (3)
- Plugged and Abandoned (19)

Well permit information from the ODNR Division of Oil and Gas Resources Management

Recommended citation:
Ohio Department of Natural Resources, 2018, Horizontal Utica-Point Pleasant Well Activity in Ohio: Columbus, scale 1:1,300,000, revised 12/3/2018.

ENVIRONMENTAL CONCERNS

Some citizens and local governments are becoming aware and concerned about the potential environmental and societal impacts of drilling activity in their communities. The primary concerns noted in “Drilling for Natural Gas in the Marcellus and Utica Shales: Environmental Regulatory Basics” by ODNR & OEPA dated January 2014 are:

- The possible impacts of brine or flowback water on ground water resources
- The hydraulic fracturing fluid compositions and there possible health effects
- Increased road traffic and higher road maintenance costs
- Method of disposal for the brine, hydraulic fracturing fluid and other substances related to the drilling
- Possible increase in seismic activity from injection wells
- Possible increase in air pollution from the drilling related activities

REGULATION OF NATURAL GAS DRILLING IN THE MARCELLUS AND UTICA SHALE

The regulation of Natural Gas Drilling in the Marcellus and Utica Shale lies with primarily two bodies in the State of Ohio: the Ohio Department of Natural Resources (ODNR) and the Ohio Environmental Protection Agency (OEPA). The table below is a summary of ODNR and OEPA regulatory authorities over oil/gas drilling and production activities.

Summary of ODNR and Ohio EPA regulatory authority over oil/gas drilling and production activities

	Ohio Department of Natural Resources	Ohio Environmental Protection Agency
Drilling in the shale deposits	✓ Issues permits for drilling oil/gas wells in Ohio. ✓ Sets requirements for proper location, design and construction requirements for wells. ✓ Inspects and oversees drilling activity. ✓ Requires controls and procedures to prevent discharges and releases. ✓ Requires that wells no longer used for production are properly plugged. ✓ Requires registration for facility owners with the capacity to withdraw water at a quantity greater than 100,000 gallons per day.	✓ Requires drillers obtain authorization for construction activity where there is an impact to a wetland, stream, river or other water of the state. ✓ Requires drillers obtain an air permit to install and operate (PTIO) for units or activities that have emissions of air pollutants.
Wastewater and drill cutting management at drill sites	✓ Sets design requirements for on-site pits/lagoons used to store drill cuttings and brine/flowback water. ✓ Requires proper closure of on-site pits/lagoons after drilling is completed. ✓ Sets standards for managing drill cuttings and sediments left on-site.	✓ Requires proper management of solid wastes shipped off-site for disposal.
Brine/flowback water disposal	✓ Regulates the disposal of brine and oversees operation of Class II wells used to inject oil/gas-related waste fluids. ✓ Reviews specifications and issues permits for Class II wells. ✓ Sets design/construction requirements for Class II underground injection wells. ✓ Responds to questions/concerns from citizens regard safety of drinking water from private wells from oil/natural gas drilling.	
Brine/flowback water hauling	✓ Registers transporters hauling brine and oil/gas drilling-related wastewater in Ohio.	
Pumping water to the drill site from a public water supply system		✓ Requires proper containment devices at the point of connection to protect the public water system.

The ODNR Division of Oil and Gas summarizes below the impacts and effects of the two primary legislative acts that created the current framework for have regulating the oil and gas industry in the State of Ohio.

SENATE BILL 165

On March 31, 2010 Governor Ted Strickland signed Substitute SB 165, the first major revision to Ohio oil and gas law in twenty-five years. Many significant changes were implemented as a result of passage of this new legislation which became effective on June 30, 2010. The bill provided for enhanced permitting authority in urban areas, strengthened funding for operations and orphan well plugging, added additional notification requirements by the industry and expanded enforcement provisions.

SENATE BILL 315

On June 11, 2012, Governor John Kasich signed landmark oil and gas regulatory legislation, which established one of the nation's toughest regulatory frameworks for overseeing the new technologies that allow for the exploration of natural gas in deep shale rock formations. Among other things, SB 315 creates the nation's first combined well construction and hydraulic fracturing chemical disclosure requirement, requires the sharing of all chemical information with doctors, allows appeals to the Ohio Oil & Gas Commission for certain permitting concerns prior to pursuing court action, and requires operators to take pre-drilling water samples and to disclose the proposed source of water used in wet drilling and hydraulic fracturing.

LOCAL LAND USE, ZONING REGULATION, AND HOME RULE

In the state, municipal corporations (cities and villages) have certain powers granted to them in Article XVIII of the state Constitution that exist outside their authority found in the Revised Code. Because these powers originate in the Constitution, laws passed by the General Assembly that interfere with them are invalid as applied to municipal corporations unless those laws otherwise are sanctioned by the Constitution. These constitutionally granted powers, known as "home rule" power include the power of local self-government, the exercise of certain police powers, and the ownership and operation of public utilities. "Police power" has been defined as the authority to make regulations for the public health, safety, and morals and the general welfare of society. Keep in mind any Municipal laws for the exercise of municipal police powers cannot be in conflict with general laws. Included in these "Police power" regulations are local land use and zoning regulation. http://www.lsc.state.oh.us/membersonly/128municipalhomerule.pdf

Per the American Bar Association, on February 17, 2015, the Ohio Supreme Court ruled that a city ordinance aimed at limiting fracing operations cannot be used to circumvent the state's authority over oil and gas drilling. Specifically, the court held in State ex rel. Morrison v. Beck Energy Corp., No. 2015-Ohio-485, that because the state had granted a permit to a drilling company under a state regulatory scheme governing oil and gas operations, the municipality could not pass ordinances setting forth additional restrictions.

The case arises out of a dispute over a permit that Beck Energy Corp. obtained from the state of Ohio to drill an oil and gas well within the Munroe Falls city limits. Beck Energy obtained its permit pursuant to an Ohio statute that (1) provided uniform statewide regulation of oil and gas production; (2) gave a state agency the sole and exclusive authority to regulate the permitting, location, and spacing of oil and gas wells; and (3) required parties seeking to drill a new well to obtain a state permit.

Soon after Beck Energy began drilling, however, Munroe Falls filed a lawsuit seeking an injunction to prohibit the drilling. The city argued that Beck Energy violated city ordinances requiring the company to meet certain conditions before it began drilling. The trial court granted the city's request for injunctive relief and prohibited Beck Energy from drilling until it complied with the city's ordinances. The court of appeals reversed, holding that the state statute governing drilling operations prohibited the city from enforcing its ordinances. Munroe Falls sought relief from the Ohio Supreme Court.

The main issue before the Ohio Supreme Court was whether the state's Home Rule Amendment allowed Munroe Falls to enforce its own permitting scheme on top of the state's permitting system. The Ohio constitution's Home Rule Amendment gives local municipalities the broadest possible powers of self-government in connection with all matters that are strictly local and do not infringe on matters that are of a statewide nature. But the amendment provides that a municipal ordinance must yield to a state law if (1) the municipality's ordinance represents an exercise of police power, rather than of local self-government; (2) the statute is a general law; and (3) the ordinance conflicts with the state statute.

After analyzing these three factors, the Ohio Supreme Court concluded that Munroe Falls' ordinances had to yield to the state statute. The city did not dispute—and the court agreed—that its ordinances amounted to an exercise of police power. Likewise, the court determined that the Ohio statute constituted a general law, as the law operated uniformly throughout the state.

THE NORTHSTAR 1 CLASS II INJECTION WELL AND SEISMIC EVENTS IN YOUNGSTOWN

A preliminary report was released by ODNR in March 2012 on the Northstar 1 Class II Injection Well and the Seismic Events in the Youngstown, Ohio Area. The reports show that since March 2011, the Youngstown area has experienced 12 low-magnitude seismic events along a previously unknown fault line. These events ranged from 2.1- to 4.0-magnitude and were recorded by the ODNR Ohio Seismic Network (OhioSeis). The OhioSeis network works closely with the U.S. Geological Survey to monitor and study all seismic activity within the state. Prior to the network's establishment in 1999, monitoring earthquakes in Ohio was sporadic at best. In fact, before the network was operational, the Ohio Geological Survey was unable to accurately determine any seismic events below an approximate magnitude of 3.1. A station at Youngstown State University joined the network in 2003.

Before 2011, OhioSeis had not recorded earthquake activity with epicenters located in the Youngstown area. Also, no fault line had been previously mapped within the boundaries of Youngstown or Mahoning County. However, the broad geographical area does have a history of seismic activity, and Mahoning Valley residents have felt earthquakes from nearby faults. In fact, the area has experienced at least three prior earthquakes in the past 25 years.

The 2011 earthquakes are distinct from previous seismic activity in the region because of their proximity to a Class II deep injection well, known as the Northstar 1 well. In fact, all of the events were clustered less than a mile around the well. Northstar 1 is one of 177 operational Class II deep injection wells primarily used for oil and gas fluid waste disposal (Ohio Disposal Wells). The well is drilled 200' into the rock formation known as the Precambrian layer at a depth of 9,184' and began injection in December 2010.

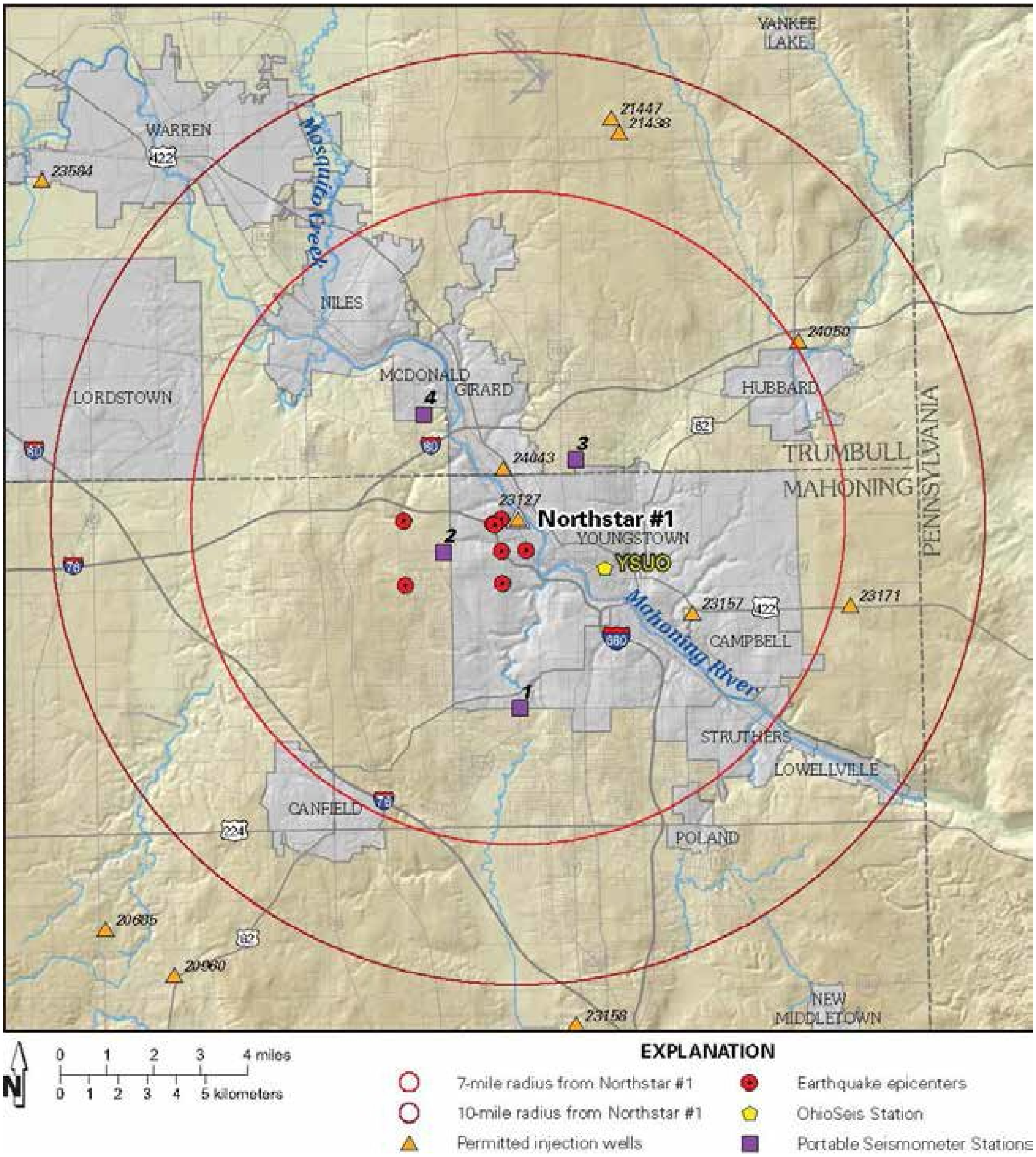
The below table, provide by the US EPA, describes the six categories or "classes" of injection wells, along with the estimated national inventory for each class. The six classes are based on similarity in the fluids injected, activities, construction, injection depth, design, and operating techniques.

This categorization ensures that wells with common design and operating techniques are required to meet appropriate performance criteria for protecting underground sources of drinking water.

Classes	Use	Inventory
Class I	Inject hazardous wastes, industrial non-hazardous liquids, or municipal wastewater beneath the lowermost Underground Sources of Drinking Water (USDW).	680 wells
Class II	Inject brines and other fluids associated with oil and gas production, and hydrocarbons for storage.	172, 068 wells
Class III	Inject fluids associated with solution mining of minerals beneath the lowermost USDW.	22,131 wells
Class IV	Inject hazardous or radioactive wastes into or above USDWs. These wells are banned unless authorized under a federal or state ground water remediation project.	33 sites
Class V	All injection wells not included in Classes I-IV. In general, Class V wells inject non-hazardous fluids into or above USDWs and are typically shallow, on-site disposal systems. However, there are some deep Class V wells that inject below USDWs.	400,000 to 650,000 wells Note: an inventory range is presented because a complete inventory is not available.
Class VI	Inject Carbon Dioxide (CO_2) for long term storage, also known as Geologic Sequestration of CO_2.	6-10 commercial wells expected to come online by 2016. (Interagency Task Force on Carbon Capture and Storage)

Ohio runs its Class II deep injection program on behalf of the U.S. EPA. As a result, the state meets and in many instances far exceeds U.S. EPA standards and regulations for the program. Since the program's inception in 1983, more than 202 million barrels of oilfield fluids have been disposed of, with no reports of subsurface ground water contamination incidents. In addition, no seismic event had been previously linked to operations at any of the state's Class II wells.

The earthquakes and their potential link to the Northstar 1 deep injection well were closely scrutinized by state geologists and regulators, who performed 35 separate inspections of the well from April 26 to Dec. 15, 2011. Each inspection indicated the well was operating within its permitted injection pressure and volume. In addition, ODNR regulators conducted additional testing of the well to determine if injection fluids were entering permitted injection zones. Tracer tests showed injections were reaching appropriate zones and were within permitted injection intervals. However, the tests proved inconclusive with regard to the volume of fluid entering the Precambrian layer. As a result, state regulators requested the well owner plug the Precambrian section of the Northstar 1 borehole, and the well operator voluntarily agreed to the procedure, albeit on a delayed timetable. With only one seismometer deployed in the Youngstown area, state geologists lacked the necessary data on the earthquakes' depth and exact location to draw a direct correlation between the seismic events and the deep injection well.



LAMONT-DOHERTY EARTH OBSERVATORY AT COLUMBIA UNIVERSITY

In November 2011, the ODNR Director ordered the Ohio Geological Survey to seek an outside research partner and deploy the needed portable seismometers around the Youngstown area. The Lamont-Doherty Earth Observatory at Columbia University had the available equipment and was willing to assist the state. The seismometers were deployed on Dec. 1, 2011. On Dec. 24, the newly deployed equipment recorded a 2.7-magnitude earthquake in the area. Data from the portable seismometers was downloaded and analyzed by experts at Lamont- Doherty. On Dec. 29, Lamont-Doherty presented ODNR with their preliminary findings, which indicated the seismic event depth was 2,454’ below the injection well.

Based on the Lamont-Doherty data, ODNR regulators ordered the immediate halt of injections at

Northstar 1, either voluntarily by the operator or by agency order. The next day, the Youngstown area experienced a 4.0-magnitude seismic event. Gov. John Kasich immediately placed an indefinite moratorium on three drilled deep injection wells and one well with a permit pending in the vicinity of the Northstar 1 well.

INDUCED SEISMICITY

Geologists believe it is very difficult for all conditions to be met to induce seismic events. In fact, all the evidence indicates that properly located Class II injection wells will not cause earthquakes. To induce an earthquake a number of circumstances must be met:

- A fault must already exist within the crystalline basement rock and that fault must already be in a near-failure state of stress.
- An injection well must be drilled deep enough and near enough to the fault and have a path of communication to the fault.
- The injection well must inject a sufficient quantity of fluids at a high enough pressure and for an adequate period of time to cause failure, or movement, along that fault (or system of faults).

A number of coincidental circumstances appear to make a compelling argument for the recent Youngstown-area seismic events to have been induced:

- The Northstar 1 well began injection operations in December 2010. Roughly three months later, the first seismic events were noted and were fairly close to the well.
- Subsequent seismic events were clustered around the vicinity of the wellbore.
- Evidence of permeability zones within the Precambrian basement rock is interpreted in some of the geophysical logs obtained from within the Northstar 1 well; and (Logs A, B, C, and D).
- Once sufficient monitoring equipment was in place, the focal depths of events were found to be about 4,000' laterally and 2,500' vertically from the wellbore terminus.

It appears there are observed permeability zones within the Precambrian basement rock in the drill coring logs recorded by the Battelle Memorial Institute during the drilling of Northstar 1. These logs were not available to inform regulators of possible issues in geological formations prior to well operation. Instead, Battelle produced and made the logs available to provide geologists with additional information on the region's geological formations. In the future, ODNR will require the Class II well owner to provide a suite of geophysical logs germane to the respective injection well.

To establish a better understanding of what may have happened, further analysis and detailed modeling of all factors must be completed on the Northstar 1 well and the surrounding geology. This work is already underway through ODNR and cooperating agencies and institutions.

FUTURE EVENTS

As the number of oil, gas, and injection wells in the state increases, so does the potential for environmental impacts. The state is mitigating this risk by enhancing regulatory and monitoring programs for well drilling and waste disposal operations. Additional information on these efforts can be found at the ODNR Division of Oil and Gas website: http://oilandgas.ohiodnr.gov/. The state's direction will be to continue to take steps to ensure that oil and natural gas development benefits the citizens of the state and does not adversely impact human health and the environment.

CLIMATE CHANGE

The Intergovernmental Panel on Climate Change defines climate change as "a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings, or to persistent anthropogenic changes in the composition of the atmosphere or in land use." The National Oceanic Atmospheric Administration defines climate change as "a non-random change in climate that is measured over several decades or longer. The change may be due to natural or human-induced causes."

The Ohio State University's climate outreach notes that, "Climate change, two words that are already synonymous with changes in weather patterns across the world, from global warming to increased rainfall and severe storms. But climate change affects different areas in different ways – while some regions will see increased precipitation in the form of snow or rain, others will dry out because of reduced rainfall. And while overall temperatures across the globe are likely to increase, climate change can also be related to an increase in freezing temperatures and severe winter storms. Ohio is likely to be affected by a number of these phenomena, and adapting to different weather conditions will be important to maintain quality of life in the area."

Climate change acts as an amplifier of existing natural hazards. The fact that climate change is occurring is not disputed and over the past several decades there has been a marked increase in the frequency and severity of weather-related disasters, both nationally and in the state. This trend is being driven in part by changing global and regional climate conditions. The preponderance of available scientific evidence for anthropogenic forcing of climate change is overwhelming, or simply stated climate change is, in part, being caused by human actions, rather than natural factors alone. It is important that all levels of government and all sectors of society have at least a basic understanding of the potential impacts of climate change. The best available scientific data and modeling suggest that climate change has and will continue to impact natural hazards in the state. While the impacts of climate change may vary by regions and jurisdictions throughout the state, it is clear that the potential consequences of climate change will have significant impacts on all the citizens of the state.

OHIO EMERGENCY MANAGEMENT AGENCY SUMMARY ANALYSIS

The scientific studies and data referenced within this section come to one cohesive conclusion, climate change will have an impact on the natural hazards in the state through 2100. The greatest impact to the natural hazards in the state from climate change will be from the changes in precipitation rate and variability. To put it simply, these changes will lead to increased flooding in the spring and fall and increased periods of drought in the summer. Another impact on the state from the effects of climate change is a warming trend that will enhance the possibility of extended and increased extreme heat wave events. This climate change related warming trend will likely lead to an increased evaporation /transpiration feedback cycle, which will lead to reduced availability of water resources.

Since many of the anticipated effects of climate change exacerbate or accelerate existing natural hazards, many of the possible mitigation and adaptation strategies already exist. Based upon the best available scientific data and studies, Ohio EMA would make the following general mitigation and adaption strategy recommendations:

1. Develop greater built environment resilience
2. Improve stormwater infrastructure

3. Increase water quality and resource protection
4. Enhance essential utility resilience

These recommendations will be useful and positive actions regardless of the long term impacts of the climate change on the state. Each of these recommendations will be addressed in greater detail later in this section.

LITERATURE AND STUDIES REVIEW

While there is a considerable amount of climate change data and related studies available, there are still challenges in synthesizing the data from the available scientific sources into both the state and local hazard mitigation plans, due to the spatial context of the data in the Midwest. The majority of these studies use a spatial resolution of the entire United States or a regional approach such as focusing on the Great Lakes or Midwest Regions. There is a limited amount of data available that specifically address the impacts and effects of climate change at the state, watershed or local level for Ohio.

The fact that climate change is occurring is not disputed. The current scientific data and modeling suggest that climate change has and will impact the state. The challenges in determining the probability and severity of future impacts can make it difficult to determine with an absolute degree of certainty the full degree of impact climate change may have on the state. This is also further complicated by the fact that information gathered is continually evolving. Therefore, this section will not attempt to estimate potential losses. This section will only provide information on the potential impacts climate change may have on some of our already existing hazards profiled within the SOHMP.

This section incorporates basic scientific findings and the most current projections for global climate change as they have the potential to impact the state and the Great Lakes Region. This section will not address any one specific jurisdiction or region in an attempt to determine risk as has been completed for natural hazards within this plan update. In some instances, examples of potential impacts to specific areas are incorporated. It is important to note that in such instances, the analysis has been conducted by scientists and subject matter experts as referenced, and not by Ohio EMA Staff. As climate science evolves and improves, future updates to this plan will incorporate any new or improved relevant climate change data.

Several new or updated climate resiliency or related studies have been completed since the 2014 SOHMP, but the underlying issues with the availability of downscaled climate change data continues to be a challenge. The new or updated studies include:

- Ohio River Basin - Formulating Climate Change Mitigation/Adaptation Strategies through Regional Collaboration with the ORB Alliance
- NOAA National Centers for Environmental Information State Summary for Ohio
- Climate Resilience in Ohio, A Public Health Approach to Preparedness and Planning – Ohio Public Health Association
- Fourth National Climate Assessment
- Smart Growth Fixes for Climate Adaptation and Resilience – EPA
- ODOT Infrastructure Resiliency Plan
- Climate Change, Extreme Precipitation and Flooding: The Latest Science - Union of Concerned Scientist

- Local Jurisdiction Climate, Sustainability or Resiliency Plans

OHIO RIVER BASIN– Formulating Climate Change Mitigation/Adaptation Strategies through Regional Collaboration with the ORB Alliance

https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/5108/

The Huntington District of the USACE, in collaboration with the Ohio River Basin Alliance, the Institute for Water Resources, the Great Lakes and Ohio River Division, and numerous other Federal agencies, non-governmental organizations, research & academic institutions, prepared the Ohio River Basin Climate Change Pilot Report.

The report provides downscaled climate modeling information for the entire basin with forecasts of future precipitation and temperature changes as well as forecasts of future streamflow at numerous gaging points throughout the basin. These forecasts are presented at the Hydrologic Unit Code-4 sub-basin level through three 30-year time periods between 2011 and 2099 developed as part of the response to climate change pilot study of the Ohio River basin.

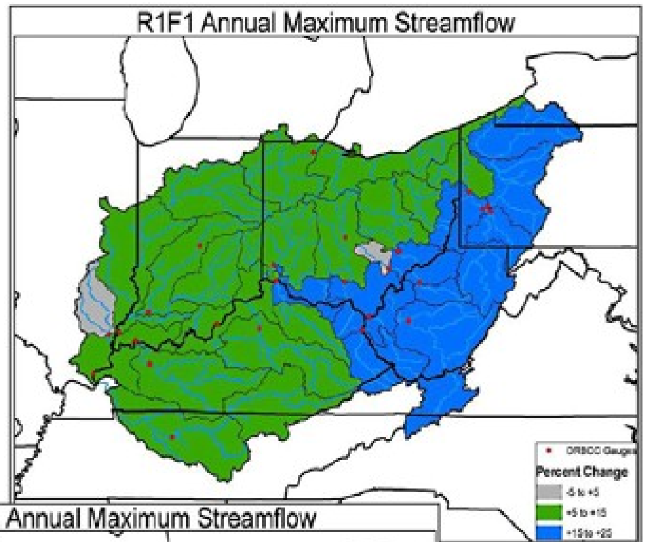
This pilot study was one of the first studies that has developed a downscaled model using current climate change data. This model was developed using archived CMIP3 and CMIP5 Climate and Hydrology Projections, which were in turn downscaled to the river basin level. The downscaled modeling results included both observed data for the 1951-2001(R1) and three 30 year forecast periods; 2011-2040(F1), 2041- 2070(F2) and 2071-2099(F3). The pilot study produced stream flow outputs for the following nine measures:

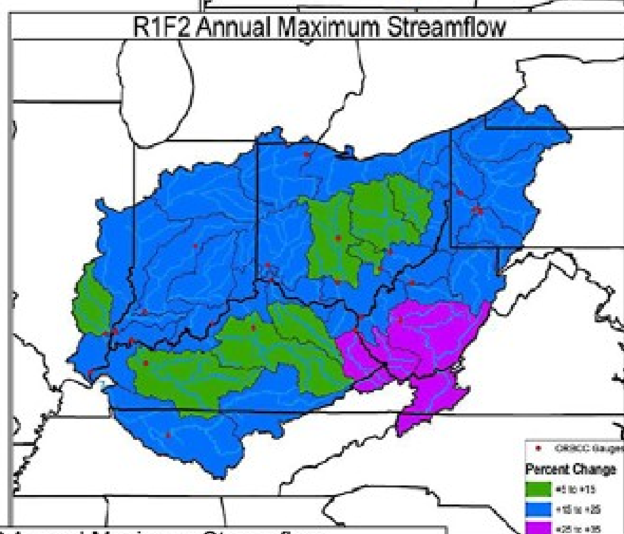
1. Annual % change mean flow
2. Annual % change maximum flow
3. Annual % change minimum flow
4. March % change mean flow
5. March % change maximum flow
6. March % change minimum flow
7. October % change mean flow
8. October % change maximum flow
9. October % change minimum flow

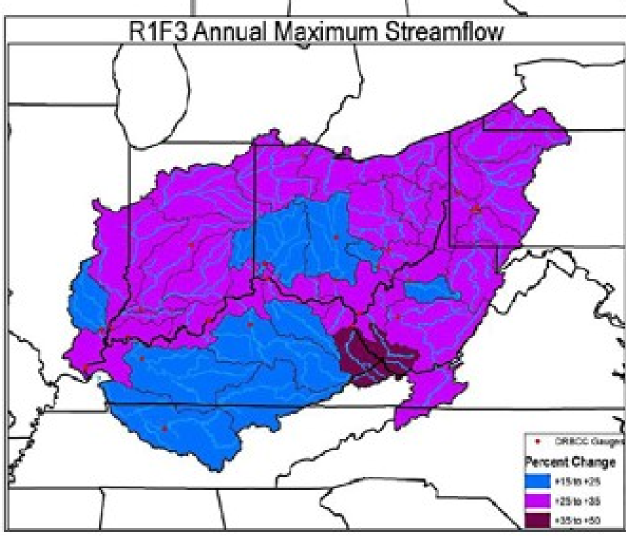
Thematic basin maps have been created to represent the above noted data, these maps highlight the percent changes for the three 30-year periods which are referenced in the maps below as F1 (2011-2040), F2 (2041-2070) and F3 (2071- 2099). The thematic basin maps for the percent change in annual maximum stream flow and percent change in October maximum stream flow have been included for reference. The remainder of the thematic basin maps are available in the draft study.

The downscaling of these ensemble climate models suggest the overall mean, maximum and minimum flows will generally be within range of recent history through the year 2040. After the year 2040, the increases occur in the mean and maximum flows in the 10% to 40% range. There are some watersheds in northern and eastern Ohio that appear to experience greater than 40% increases in mean and maximum flows. This appears to occur primarily from later summer until early winter. The autumn increases in maximum flows may enhance early cool season flood events in late autumn and early winter. These increases could lead to worsening spring flooding beyond 2040. The models suggest that droughts could lengthen or shift more between spring, summer and autumn beyond 2040. The models also suggest that the overall variability is also likely to increase with time as well.

Percent Change in Annual Maximum Stream Flow: In terms of the annual % change in the annual max flows; F1 shows an increase in the max flows across portions of PA and WV within the basin. In F2, this higher max discharge trend continues, but spreads into OH and IN and the Cumberland River watershed.

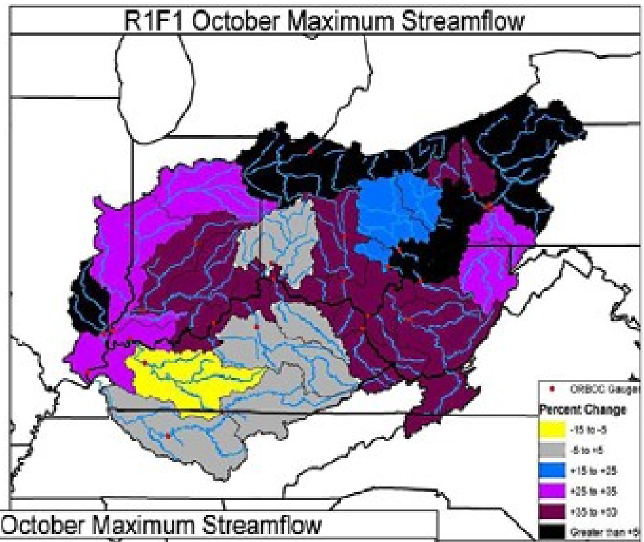


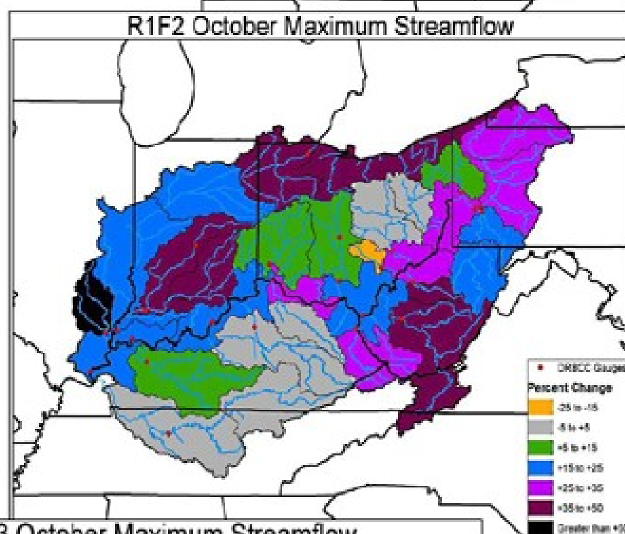


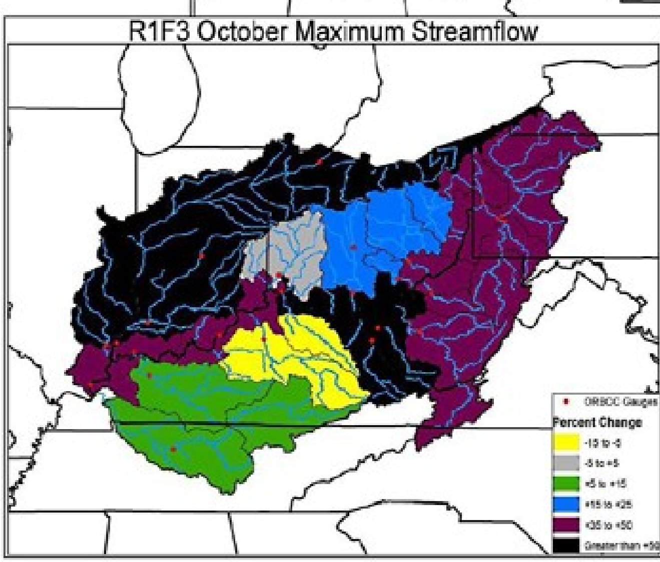


The % change in max flow increases markedly in the Kanawha and Big Sandy River sub-basins. In F3, the annual % change in max flows increases substantially across PA, WV, OH, IN and IL. The increase in annual % change in max flows appears significant in the Big Sandy River watershed during this third period. The progression of these flow changes is shown below in the three figures.

Percent Change in October Maximum Stream Flow: Period F1 shows increases in % change of max flow over much of the basin and substantially higher October flows in the Allegheny River and Little Wabash River watersheds and significant increases in the Kanawha, Scioto, Big Sandy and White River watersheds over the base condition.







Period F2 shows some relaxing of the wetter October conditions but the Kanawha, White River and Little Wabash remain higher than the base condition flows. Period F3 shows a return to higher October flows across the basin with the exception of central OH and KY. Substantial increases during this period are seen in the Big Sandy River, White River and Wabash River watersheds.

The report also included the results of preliminary investigations into the various impacts that forecasted climate change may have on ecosystems and infrastructure, and recommends mitigation and adaptation strategies. The mitigation and adaptation strategies in the pilot study can be deployed at all levels of government, private or corporate ownership to address the anticipated climate change impacts identified in the report and other effects cited in the research literature. Strategies for addressing unavoidable, residual impacts of climate change were also developed, along with objective assessments of the likelihood of success. These strategies include:

- Restoring Wetlands
- Reconnecting Floodplains
- Reducing Consumptive Uses of Water
- Harvesting Precipitation and Flood Flows
- Drought Contingency Planning
- Increasing Nutrient and Abandoned Mine Drainage Management
- Modifying Thermoelectric Power Plant Cooling Systems
- Reducing Flood Damages Through Nonstructural Measures
- Increasing Water Quality and Flow Discharge Monitoring
- Promoting Wise Land Use Management
- Modifying Reservoir Operations, Policies and Structures
- Managing Ecosystem Stress
- Temporal Staging

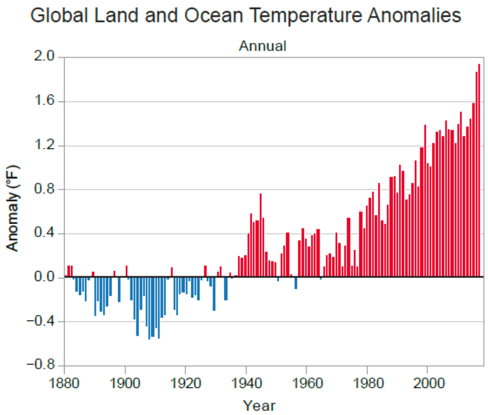
The report then recommends "next-steps", which include filling in numerous data gaps identified during the study process. Many gaps in knowledge, understanding, and modeling need to be filled and much more investment will be required to assure ourselves that (1) the downscaled modeling results displayed in this pilot study are updated on a regular basis (at least decadal), (2) the mitigation and adaptation measures identified remain current based on new strategies and the documented successes or failures of applied strategies by others, and (3) the USACE accept an Army Strong role in leading basin water managers toward a comprehensive plan for basin water planning that can offset the potential effects of climate change on infrastructure and the ecosystems that are dependent upon operation of those facilities.

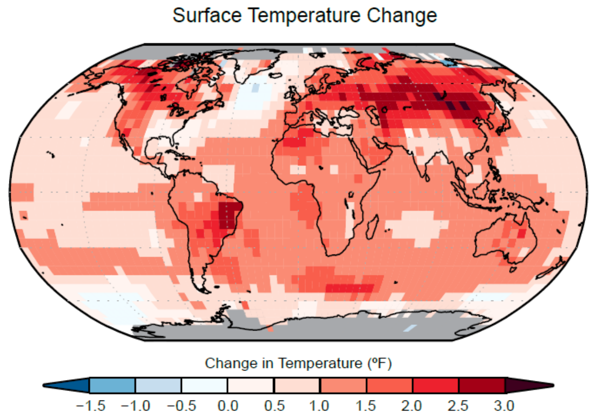
FOURTH NATIONAL CLIMATE ASSESSMENT VOLUME 1 & 2

Fourth National Climate Assessment | Volume 1

The National Climate Assessment is the authoritative assessment of the science of climate change, with a focus on the United States, and serves as the foundation for efforts to assess climate-related risks and inform decision-making. The climate of the United States is strongly connected to the changing global climate and this assessment highlights past, current, and projected climate changes for the United States and the globe.

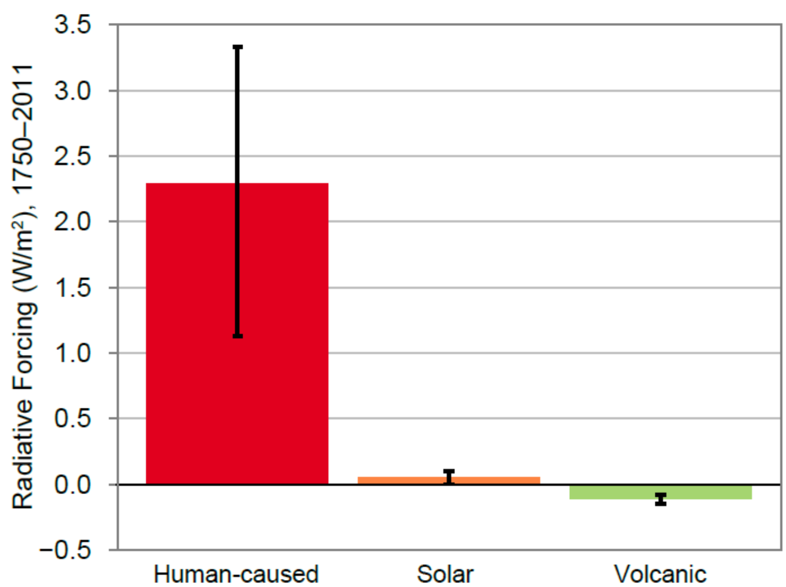
Global annually averaged surface air temperature has increased by about 1.8°F (1.0°C) over the last 115 years (1901–2016). This period is now the warmest in the history of modern civilization, with the last three years being the warmest years on record for the globe. These trends are expected to continue over climate timescales.





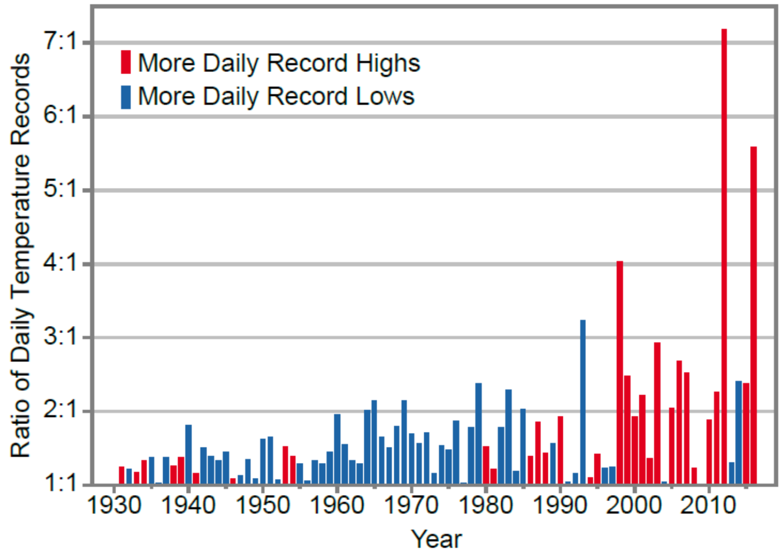
This assessment concludes, based on extensive evidence, that it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century. For the warming over the last century, there is no convincing alternative explanation supported by the extent of the observational evidence.

In addition to warming, many other aspects of global climate are changing, primarily in response to human activities. Thousands of studies conducted by researchers around the world have documented changes in surface, atmospheric, and oceanic temperatures; melting glaciers; diminishing snow cover; shrinking sea ice; rising sea levels; ocean acidification; and increasing atmospheric water vapor.



Changes in the characteristics of extreme events are particularly important for human safety, infrastructure, agriculture, water quality and quantity, and natural ecosystems. Heavy rainfall is increasing in intensity and frequency across the United States and globally, and is expected to continue to increase.

Additionally, heatwaves have become more frequent in the United States since the 1960s, while extreme cold temperatures and cold waves are less frequent. Recent record-setting hot years are projected to become common in the near future for the United States, as annual average temperatures continue to rise. Annual average temperature over the contiguous United States has increased by 1.8°F (1.0°C) for the period 1901–2016; over the next few decades (2021–2050), annual average temperatures are expected to rise by about 2.5°F for the United States, relative to the recent past (average from 1976–2005), under all plausible future climate scenarios.



The magnitude of climate change beyond the next few decades will depend primarily on the amount of greenhouse gases (especially carbon dioxide) emitted globally. Without major reductions in emissions, the increase in annual average global temperature relative to preindustrial times could reach 9°F (5°C) or more by the end of this century. With significant reductions in emissions, the increase in annual average global temperature could be limited to 3.6°F (2°C) or less.

The global atmospheric carbon dioxide (CO2) concentration has now passed 400 parts per million (ppm), a level that last occurred about 3 million years ago, when both global average temperature and sea level were significantly higher than today. Continued growth in CO2 emissions over this century and beyond would lead to an atmospheric concentration not experienced in tens to hundreds of millions of years. There is broad consensus that the further and the faster the Earth system is pushed towards warming, the greater the risk of unanticipated changes and impacts, some of which are potentially large and irreversible.

Fourth National Climate Assessment | Volume 2- Summary Findings

Volume 2 of the Fourth National Climate Assessment (NCA4) focused on consolidating the findings into twelve broad Key Messages:

1. Communities
2. Economy
3. Interconnected Impacts
4. Actions to Reduce Risks
5. Water
6. Health
7. Indigenous Peoples
8. Ecosystems and Ecosystem Services
9. Agriculture and Food
10. Infrastructure
11. Oceans and Coasts
12. Tourism and Recreation

These Key Messages broadly apply across the nation and generally echo other climate change studies in stating that climate change will like have broad impacts in many sectors of American life. For communities across the country, climate change creates new risks and exacerbates existing vulnerabilities, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth.

Volume 2 of the Fourth National Climate Assessment further delineates the impacts of climate change by breaking down the nations into 10 Regions. The State of Ohio is located within the Midwest region, so that is the region we will focus on.

Midwest Chapter

NCA4 identifies 6 key messages in the Midwest Chapter: Agriculture, Forestry, Biodiversity & Ecosystems, Human Health, Transportation & Infrastructure, and Vulnerability & Adaptation. Biodiversity & Ecosystems and Vulnerability & Adaptation are newly introduced key messages for this report. A summary of the overall findings in each key message area of the NCA4 report follows:

Agriculture

The Midwest is a major producer of a wide range of food and animal feed for national consumption and international trade. Increases in warm-season absolute humidity and precipitation have eroded soils, created favorable conditions for pests and pathogens, and degraded the quality of stored grain. Projected changes in precipitation, coupled with rising extreme temperatures before mid-century, will reduce Midwest agricultural productivity to levels of the 1980s without major technological advances.

Forestry

Midwest forests provide numerous economic and ecological benefits, yet threats from a changing climate are interacting with existing stressors such as invasive species and pests to increase tree mortality and reduce forest productivity. Without adaptive actions, these interactions will result in the loss of economically and culturally important tree species, such as paper birch and black ash, and are expected to lead to the conversion of some forests to other forest types or even to non-forested ecosystems by the end of the century. Land managers are beginning to manage risk in forests by increasing diversity and selecting for tree species adapted to a range of projected conditions.

Biodiversity and Ecosystems

The ecosystems of the Midwest support a diverse array of native species and provide people with essential services such as water purification, flood control, resource provision, crop pollination, and recreational opportunities. Species and ecosystems, including the important freshwater resources of the Great Lakes, are typically most at risk when climate stressors, like temperature increases, interact with land-use change, habitat loss, pollution, nutrient inputs, and nonnative invasive species. Restoration of natural systems, increases in the use of green infrastructure, and targeted conservation efforts, especially of wetland systems, can help protect people and nature from climate change impacts.

Human Health

Climate change is expected to worsen existing health conditions and introduce new health threats by increasing the frequency and intensity of poor air quality days, extreme high temperature events, and heavy rainfalls, extending pollen seasons, and modifying the distribution of disease-carrying pests and insects. By mid-century, the region is projected to experience substantial, yet avoidable, loss of life, worsened health conditions, and economic impacts estimated in the billions of dollars as a result of these changes. Improved basic health services and increased public health measures—including surveillance and monitoring—can prevent or reduce these impacts.

Transportation and Infrastructure

Storm water management systems, transportation networks, and other critical infrastructure are already experiencing impacts from changing precipitation patterns and elevated flood risks. Green infrastructure is reducing some of the negative impacts by using plants and open space to absorb storm water. The annual cost of adapting urban storm water systems to more frequent and severe storms is projected to exceed $500 million for the Midwest by the end of the century.

Community Vulnerability and Adaptation

At-risk communities in the Midwest are becoming more vulnerable to climate change impacts such as flooding, drought, and increases in urban heat islands. Integrating climate adaptation into planning processes offers an opportunity to better manage climate risks now. Developing knowledge for decision-making in cooperation with vulnerable communities will help to build adaptive capacity and increase resilience.

Adaption actions could have a positive impact on the effects of climate change in the Midwest. The Community Vulnerability and Adaptation Key Messages of NCA4 follow:

- Expanding the use of green infrastructure and locating it properly may mitigate the negative impact of heat islands in urban settings.

- Documented implementation of climate change planning and action in Midwest cities and rural communities remains low.
- In-depth interviews with local decision-makers on water management across scales have suggested that a lack of political and financial support at the state and federal levels is a barrier to adaptation action in cities and counties.
- While initiatives are underway in the Midwest to mainstream adaptation action (such as the Great Lakes Climate Adaptation Network), there are few examples in published literature that document failure or success.

Factors that shape or contribute to the successful adoption and implementation of adaptation by public-sector organizations include:

- Plans written by a professional staff and approved by elected officials;
- Community engagement, including the participatory development of plans; the formation of action teams or regional collaborations across jurisdictions, sectors, and scales; and public- and private-sector leaders who champion and support the process;
- Adaptation actions that address multiple community goals, not just climate change;
- Well-structured implementation, including the identification of parties responsible for each step, explicit timelines, explicit and measurable goals, and explicit provisions and timelines for monitoring and updating the plan; and
- Adequate funding for the adaptation actions and for sustained community outreach and deliberation.

ODOT INFRASTRUCTURE RESILIENCY PLAN

The plan's executive summary states that the key objective of the study was to identify the vulnerability of the Ohio Department of Transportation's (ODOT's) infrastructure to climate change effects and extreme weather events. The analysis includes a discussion and analysis of the type of transportation assets vulnerable, the degree of exposure, sensitivity, adaptive capacity, and the potential approaches to adapt to these changes. The study includes:

- Understanding the vulnerability of ODOT's overall transportation system to climate change;
- Determining potential consequences from a broad range of potential climate impacts;
- Identifying facilities at risk to climate change impacts within Ohio by type;
- Identify range of adaptation and/or sustainability options (activities) that ODOT should consider in detail in future adaptation studies
- Providing the foundation for ODOT to integrate the results of this vulnerability assessment into future decision making processes and future adaptation/resiliency studies.

Utilizing ODOT's existing GIS systems, the project team developed additional GIS mapping and analytics to evaluate the vulnerability of ODOT's infrastructure to climate change effects. This effort determined that the primary climate change effect of concern is the increased incidence of heavy precipitation events, which will impair the functioning of core assets -- highways, bridges, and culverts.

A summary of this study's recommendations are below:

- Identify a lead office within ODOT- Office of Planning.
- Completion of Annual Tasks by the Resiliency Lead
- Ongoing refinement of VAST model for the 3 asset types (highways, bridges, culverts):

- Interagency Coordination

THE IMPACT OF CLIMATE CHANGE AND POPULATION GROWTH ON THE NFIP THROUGH 2100

http://www.aecom.com/deployedfiles/Internet/News/Sustainability/FEMA%20Climate%20Change%20Report/Climate_Change_Report_AECOM_2013-06-11.pdf

This study was funded by FEMA at the request of the Government Accountability Office. The goal of the study is to gain a better understanding of the potential impacts of climate change on the National Flood Insurance Program. This study focused on both riverine and coastal flooding throughout the U.S. with estimates at 20-year intervals through the year 2100. The study relied on existing data, studies, reports, and research. Although no new climate modeling was performed for this study, the methods used to evaluate the data were innovative. The study found that in riverine environments the typical 1% annual change of floodplain nationwide is projected to grow by about 45%, with areas in the northwest and the Great Lakes region experiencing growth that may exceed 100%. Nationally, 30% of that 45% increase in floodplain is due solely to population growth and would occur without the effects of climate change. The study suggests that 70% of that 45% increase in floodplain riverine areas is due solely to climate change and would occur even if there was no population growth. For reference, the below maps indicate the projected increases in both the percent change in 1% annual flood discharge through 2100 and the median projected percent change in special flood hazard areas through 2100. These results reflect national averages only and are not intended to be interpreted locally.

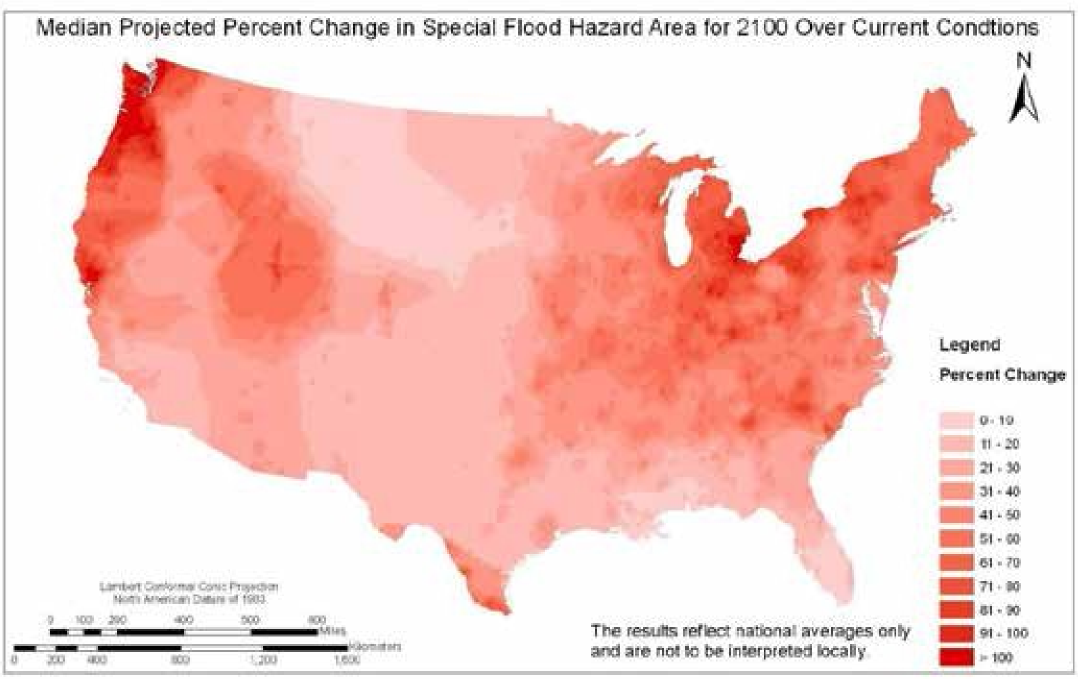


Figure 4-10. The median (50th percentile) relative change of the SFHA at epoch 5 (2100). Changes are with respect to current conditions.

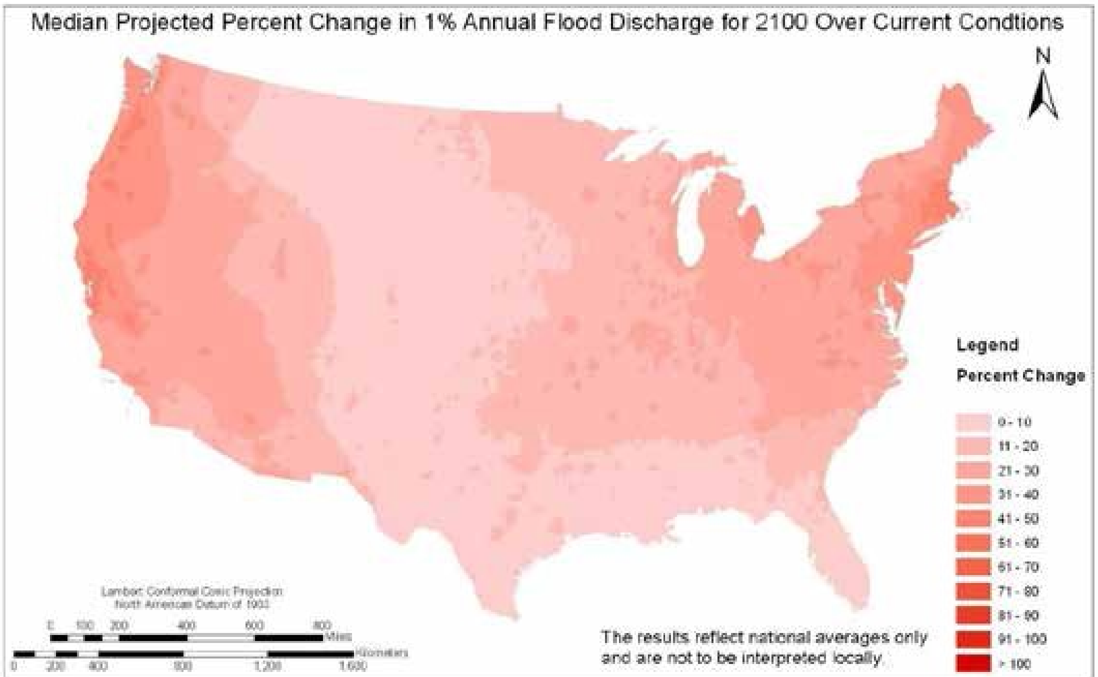


Figure 4-5. The median (50th percentile) relative change of the 1%-annual flood discharge at epoch 5 (2100). Changes are with respect to current conditions.

CLIMATE CHANGE, EXTREME PRECIPITATION AND FLOODING: THE LATEST SCIENCE – UNION OF CONCERNED SCIENTISTS

https://www.ucsusa.org/sites/default/files/attach/2018/07/gw-fact-sheet-epif.pdf

This report is a synopsis by Union of Concerned Scientist of the latest scientific findings on how and why precipitation and flooding patterns have changed in the United States, a summary of the possible future scenarios, and recommendations. While coastal flooding and sea level rise are important parts of the complete picture of flood risk, this synopsis focuses on flooding of inland areas.

According to the 2017 Climate Science Special Report, flooding across the United States is changing, though not uniformly across the country. The data shows that flood frequency has increased in the Mississippi Valley and the Midwest over the last century, including an increase in moderate and major flood frequency in the Midwest. Across the country, increasingly frequent heavy rain is one of the most obvious weather changes. The regions experiencing increases in extreme precipitation generally align well with those experiencing increases in flood frequency. Increases in extreme precipitation frequency and intensity are projected to continue across much of the United States over the 21st century, particularly in the northern and Midwestern regions.

The reports cites several current Federal flood risk reductions programs that may help to mitigate future flood risk such as the Hazard Mitigation Assistance suite of grant programs, HUD CDBG Disaster Recovery grants, and several others. The report also recommends several possible reforms to the NFIP that would establish risk-based insurance rates, fund mapping that factors for future conditions and provide incentives for investment in flood risk reduction measures. Additionally the report suggests several policies that could be implemented at all levels of government, not just at the federal level. The possible policies include:

- Plan, design, build, retrofit and maintain infrastructure to withstand the reality of climate change.

- Incentivize regional flood risk planning to help consolidate funding and resources and implement flood resilience measures on a larger scale.
- Design and implement policies that incentivize good behavior.
- Ensure targeted funding and resources for disadvantaged populations.

The report concludes by stating our current climate no longer replicates many past patterns. Our future climate will only stray farther from what we have come to expect and have developed our societies to withstand. To adapt, we must understand these unfolding precipitation and flooding trends, prepare for changes, and learn to be more resilient amidst them. But, vitally, we are only adaptable to a point, beyond which the damages, costs, and strain will create deep harm. We must recognize the climate risks to the U.S. landscape that we simply cannot cope with, and we must strive to reduce changes to our climate and thus slow, and where we can, outright avoid these dangerous risks.

CLIMATE CHANGE IN THE MIDWEST: IMPACTS, RISKS, VULNERABILITY, AND ADAPTATION

S.C. Pryor, Provost's Professor of Atmospheric Science at Indiana University Bloomington and editor of the Journal of Geophysical Research Atmospheres edited and released Climate Change in the Midwest: Impacts, Risks, Vulnerability, and Adaptation in 2013. This book presents research that focuses on identifying and quantifying the major vulnerabilities to climate change in the Midwest. The book addresses the key sectors that may have vulnerabilities amplified by the effects of climate change, including agriculture, human health, water, energy and infrastructure.

The climate vulnerability assessment performed in the book came to the following conclusions for the Midwest:

1. The average temperature may increase 1 to 3 degrees Celsius over the next several decades. Projected change in the climate models indicate a clear tendency towards increased frequency of heat waves. Further cold- air outbreaks and other extreme cold spells will still occur but with reduced likelihood.
2. That rainfall will increase variably across the Midwest over the next several decades. The rainfall potential will increase 20-30% in the spring and winter months and there will be a significant increase in variability of precipitation events in the summer and fall months. There is evidence to suggest a split in future rainfall events, leading to a greater likelihood of droughts in the summer months and floods in the fall months.
3. Some other affects include the likelihood of warmer nights and possibly warmer days leading to an increased susceptibly to pests. The warming will likely cause a reduction in crop yields and the evaporation / transpiration feedback will lead to less available water resources.
4. The projected soil loss through erosion is expected to be significant and greater than anything that has occurred in the previous century.
5. The most direct impact of climate on human health is heat-related morbidity and mortality. The climate models indicate an increase in heat stress across all models over the course of the 21st century.
6. Using the concepts of stream flow elasticity, projected increases in precipitation over much of the Midwest are estimated to increase by 16- 20%

DROUGHT, EXTREME SUMMER WEATHER AND INVASIVE SPECIES

The studies and reports referenced above indicate that a warming trend will increase over the next several decades up to the extent of the studies/reports which is 2100. This warming trend will increase the possibility of extended and increased extreme heat wave events. The average temperature may increase 1 to 3 degrees Celsius over the next several decades throughout the Midwest. The projected change in the climate models indicate a clear tendency towards increased frequency of heat waves. Further cold-air outbreaks and other extreme cold spells will still occur, but with reduced likelihood. The studies suggest that a warming trend combined with increased variability of rainfall events in the summer months will lead to increasing periods of drought in the state and the Great Lakes region. The models suggest that droughts could lengthen or shift more between spring, summer and autumn beyond 2040. The warming trend will likely cause a reduction in crop yields and the evaporation / transpiration feedback will lead to less available water resources for human consumption, recreation and agricultural purposes. The changes in precipitation, drought and heat patterns will also create more heat related stress on crops and livestock. The changing weather patterns may also lead to a greater amount of crop pests and pathogens ranging farther northward.

FLOODING, SEVERE THUNDERSTORMS, SEVERE WINTER/ICE STORMS

The studies and reports referenced above indicate that one of the primary impacts on the state from climate change will be the changes in precipitation rates and variability. The studies also indicated that rainfall will increase variably across the Midwest over the next several decades. The increased variability of precipitation events will mostly occur in the summer and fall months. There is evidence to suggest a split in future rainfall events, leading to a greater likelihood of droughts in the summer months and floods in the fall months.

The studies also indicated that after the year 2040, the increases occurring in the mean and maximum stream flows will be in the 10% to 40% range with the north and northeast parts of that state experiencing greater than 40% increases. These increases appear to occur primarily from later summer until early winter, with the autumn increases in maximum stream flows enhancing early cool season flood events in late autumn/early winter. These increases also indicated the possibility of worsening spring flooding beyond 2040.

MITIGATION AND ADAPTION STRATEGIES

As the climate change data specific to the state becomes more readily available, mitigation and adaptation will be one of the focuses of dealing with the impacts of climate change. Ohio EMA has recommended four mitigation and adaption strategies that will help alleviate the future impacts of climate change on the natural hazards within the state. These strategies are recommended because they will have positive impacts regardless of climate change and its predicted long term impacts.

DEVELOP GREATER BUILT ENVIRONMENT RESILIENCE

The built environment refers to the any buildings or structures which are manmade as opposed to the natural environment. Developing resilience in the built environment is an important mitigation action, especially when you factor for the probability of increasing precipitation rates and variability. Examples of actions that increase resilience of the built environment include:

- Reduce the number of pre-FIRM flood prone, repetitive loss and severe repetitive loss structures through FEMA mitigation grant programs.

- Adopting building, zoning and floodplain regulations that include higher standards than the minimum regulatory requirements.
- Encourage resilient local land use regulation through the Ohio Balanced Growth Initiative.

IMPROVE STORMWATER INFRASTRUCTURE

Stormwater infrastructure is normally designed to convey or capture flows associated with a designed storm event; the scale of which is based on a probability distribution of observed rainfall events. One of the underlying assumptions of the atypical design approach is that the rainfall probability distribution is static. The best available climate change models indicate that future larger precipitation events will occur with an increasing frequency. The existing stormwater infrastructure, which was designed with current storm approach, cannot be expected to provide the intended level of protection throughout its lifetime service. Examples of actions that improve stormwater infrastructure are:

- Encourage increased green infrastructure and the use of low impact development strategies to reduce stormwater.
- Seek to minimize impervious surfaces such as parking lots, roads, and rooftops in sensitive areas.
- Encourage riparian buffers along streams, rivers, and waterways to maintain natural floodplains.
- Protect and reestablish wetlands to hold runoff and recharge groundwater.
- Implement the separation of combined storm and sanitary sewer overflows to reduce pollution from sewage, bacteria, and E. Coli entering waters during storm event

INCREASE WATER QUALITY AND RESOURCE PROTECTION

The current climate change models indicate that its effects will have a variety of impacts on ground water resources and water quality. The higher water and air temperatures and changes in the timing, intensity, and duration of precipitation will impact water quality and ground water resources. Examples of actions that can be pursued to increase water quality and provide ground and surface water resources protection include:

- Encourage effective water-conservation strategies during summer months, and consider year-round water-conservation strategies for water-intensive users.
- Implement the separation of combined storm and sanitary sewer overflows to reduce pollution from sewage, bacteria, and E. Coli entering waters during storm events.
- Recommend sewer and septic systems be upgraded to reduce non-point source pollution from urban areas, farmland, and other sources.
- Ensure that water extractions and diversions are appropriately planned and factor the future impacts of climate change.

ENHANCE UTILITY AND ENERGY RESILIENCE

Water, electricity, and wastewater treatment are three utility services that are essential for modern daily life. These three utilities support business, industry, recreation, housing, hospitals and schools in communities across the state. These essential utility services have been traditionally planned, designed and operated with an assumption that the future environment is mostly static and predictable. The scientific climate change models show that increasingly variable and extreme precipitation patterns and temperature increases crises will intensify the risks faced by these essential utility services. With these risks in mind, essential utilities need to be working to strengthen their resilience to extreme climate events, also seeking ways to mitigate the impacts of climate change. Examples of actions that can be pursued to assist utilities services in increasing their resiliency include:

- Engage and educate stakeholders, having their active engagement will help to build shared a understanding and support for utility initiatives
- Strengthen existing utility transmission generation networks so they are able to cope with the future demand resulting from climate change.
- Encourage the development and construction of green infrastructure to help lessen the impact of the increasing extreme climate events.
- Support the upgrade of neglected infrastructure networks to provide an efficient supply of utilities.

LOCAL CLIMATE CHANGE ADAPTATION AND MITIGATON PLANS

Ohio's largest 6 cities (Columbus, Cleveland, Cincinnati, Toledo, Akron and Dayton) and the City of Athens have all, in varying levels, identified potential climate change impacts for the city and either acknowledge the need for future adaptation planning (Toledo, Dayton) or have already created adaptation/action plans (Athens, Columbus, Cleveland, Cincinnati, Akron).

Commonly identified impacts by the cities include:

- Health implications from deteriorated air quality and increased temperatures, and;
- Increased heavy precipitation and storm events.

Among cities with adaptation plans:

- Energy efficiency, transportation, and water and food supply are commonly reoccurring themes.
- The cities of Akron, Cincinnati and Cleveland have all identified quantitative, city-wide greenhouse gas reduction goals.
- The cities of Columbus, Cincinnati and Cleveland cite lack of federal and/or state level action on climate change as a driver for its city level adaptation and mitigation planning.

Actions/Recommendations:

- Athens has 10 key recommendations (pertaining to sustainability more generally).
- Columbus has 43 recommendations grouped into 8 thematic areas.
- Cincinnati has 80 recommendations (several recommendation per each objective).
- Cleveland has several actions per each of the 28 objectives.
- Akron has "strategies" for consideration but no finalized recommendations or actions.

The subsequent pages summarize the following documents:

- The Greenprint for Akron (2012)
- The Athens Sustainability Action Plan (2017)
- The Green Cincinnati Plan (2018)
- The Cleveland Climate Action Plan (2018)
- Columbus Climate Action Plan (2018)
- The Potential Impacts of Climate Change on Dayton, Ohio (2013)

- The University of Michigan Climate Center's City Fact Sheet: Toledo Ohio (2016)

Akron

The City of Akron has recognized likely impacts of climate change on the city and has laid out 7 guiding principles as part of its sustainability plan for the city. The city has completed a study to identify baseline levels and sources of emissions in order to achieve tangible Green House Gas (GHG) reductions. The City of Akron's Climate Action Plan was completed using the International Council for Local Environmental Initiatives (ICLEI)'s Climate and Air Pollution Planning Assistance software and is intended to identify where policymakers will need to target emissions reduction activities if they are to make significant progress toward adopted targets.

Athens

The Athens Sustainability Action Plan explores 8 topic areas (energy, economy, solid waste, food, housing and development, transportation, water, air and greenhouse gas emissions) and the current status in Athens for each topic as well as an action plan for each. Based on community concerns and additional research, the City of Athens Environment and Sustainability Commission has identified 10 key recommendations as the most important to put the city on a sustainable path and to reduce greenhouse gas emissions.

Columbus

The Columbus Climate Adaptation Plan (CCAP) recommends 43 actions to be taken by the City that fall under 8 thematic chapters (Extreme Heat, Air quality and Energy, Flooding, Water Quality, Water Use, Ecosystems, Emergency Preparedness and Vulnerable Populations). The list of recommended actions are prioritized into necessary and aspirational actions. Necessary actions are considered the most impactful and easiest to implement based on expertise, cost and will. The Plan recommends that various city departments should assume leadership roles in project planning, assigning duties and executing actions. The City could allocate funds related to climate adaption to departments to utilize and the annual sustainability report should include documentation of progress toward completion of each action item.

Cincinnati

Following Cincinnati's 2017 commitment to reach 100% renewable energy in the city by 2035, the 2018 Green Cincinnati Plan outlines 80 high-impact recommendations to reduce carbon emissions by 80% by 2050. The recommendations have been grouped into eight themes: built environment, education & outreach, energy, food, natural systems, resilience, transportation, and waste. It also identifies 26 measureable goals that will be used to measure progress toward a sustainable, equitable and resilient Cincinnati. The report identifies that adoption of autonomous vehicles, encouraging electric vehicle use and infrastructure, and industrial energy efficiency as the top three recommendations in terms of potential impact towards the 2050 GHG goal.

Cleveland

The 2013 Cleveland Climate Action Plan (updated in 2018) established an overarching GHG reduction goal of 80% below 2010 emissions by 2050, with interim goals of 16% reduction by 2020 and 40% reduction by 2030. The plan identified 28 objectives across five focus areas (energy efficiency and green building, clean energy, sustainable transportation, clean water and vibrant green space, more local food, less waste) and cross-cutting priorities as well as goals through numeric targets and time frames for achieving targets. Additionally, it identifies actions, which are specific strategies that will be implemented to meet the goals and objectives.

Dayton

The City of Dayton does not have a designated climate or sustainability plan. The city has, however, identified and analyzed the potential impacts of climate change on the city. It has acknowledged that the next step is deciding which strategies make the most sense for the city's climate efforts. Strategies focus on increasing the amount of green infrastructure, encouraging the use of pervious surfaces, on-site stormwater management through rain gardens and bio-swales, urban forestry, green and white roofs, energy efficiency, renewable energy, land-use planning, updated zoning policies, the use of reflective pavement, strategies to increase adaptive capacity of residents and businesses, and enhancing community engagement and empowerment.

Toledo

The City of Toledo (with the University of Michigan) has created a Climate Fact Sheet on the city. The city recognizes deteriorating water infrastructure as a major issue as the city is built over a wetland area and ground saturation and stormwater overflow pose major threats to health. The city of Toledo is partnering with General Motors and Teledyne to increase green infrastructure in flood-prone neighborhoods.

CLIMATE CHANGE ADAPTATION LITERATURE AND STUDIES REVIEW

There are several current studies that suggest various climate change adaption strategies for the Great Lakes or Midwestern region. Many of these studies do not provide enough downscaled data or go into sufficient detail to warrant full inclusion within this current iteration of the plan update. As climate science evolves and improves, future updates to this plan will incorporate any new or improved relevant climate change adaption strategies.

CLIMATE CHANGE RESEARCH AT THE OHIO STATE UNIVERSITY

http://esn.osu.edu/climate-change

The Ohio State University has long been a leader in global climate change research, from physical drivers to impacts to adaptation and mitigation. Research teams across the university are investigating many aspects of global change, including:

- Glaciers, climate change and sea level, atmospheric sciences, contemporary and paleo climate.
- Ecosystem and biodiversity impacts, greenhouse gas monitoring and mitigation, freshwater quantity and quality, economic modeling, coastal community adaptation and mitigation.
- Changes in ecosystem services, risk and decision science, education and community engagement, agricultural impacts and strategies.

THE OHIO STATE CLIMATE CHANGE OUTREACH TEAM

http://changingclimate.osu.edu/

The Ohio State University Climate Change Outreach Team is a partnership among multiple departments within Ohio State University; the team's goal is to help localize the climate change issue by bringing related research and resources to residents of Ohio and the Great Lakes region. The team is comprised of leading academics from Ohio State Extension, the Department of Agricultural, Environmental, & Development Economics, Byrd Polar Research Center, School of Environment and Natural Resources (SENR), Department of Geography, Department of Evolution, Ecology & Organismal Biology, Ohio Agricultural Research and Development Center (OARDC) and the Ohio Sea Grant College Program & Stone Laboratory.

CLIMATE CHANGE ADAPTATION IN GREAT LAKE CITIES STUDY

http://deepblue.lib.umich.edu/handle/2027.42/97435

This study looks at the anticipated impacts of climate change and how those impacts affected different communities throughout the state. Researchers have identified a variety of resources, assets, and governance structures that increase the ability and likelihood of successful adaptation, even in the face of significant uncertainty. In order to anticipate and successfully respond to these impacts, cities in the state need to better understand the opportunities and constraints within their own organizations.

To evaluate this capacity, an Integrated Assessment was conducted for four cities in the state (Toledo, Dayton, Elyria, and Avon Lake). The study takes a broad view of the political, social, and ecological causes, consequences, and potential solutions to climate vulnerability and impact reduction. The results of the study describe the capacities and constraints each city possesses, as well as identifies best practices cities can implement to take advantage of these capacities and overcome constraints. Each city had specific capacities and constraints based on the analysis, several overarching themes emerged. Decision-makers in each city expressed interest in adapting to climate change. Leaders within city governments are working to connect issues of sustainability and adaptation to the core mission of their departments, as well as forming policy networks across the city. Overall, leadership and the quality of current city employees emerged as key capacities throughout the study, but there are significant constraints to adaptation as well. Two broad trends identified are scarce financial resources and limited access to scientific knowledge. The lessons learned in this study could be applied to future plan updates as additional appropriate climate change data become available statewide.

ADAPTING TO CLIMATE CHANGE: A PLANNING GUIDE FOR STATE COASTAL MANAGER'S – A GREAT LAKES SUPPLEMENT

https://coast.noaa.gov/czm/media/adaptationgreatlakes.pdf

This report for the Great Lakes region is intended to provide additional detail and supplement the Adapting to Climate Change: A Planning Guide for State Coastal Managers, which the National Oceanic and Atmospheric Administration (NOAA) Office of Ocean and Coastal Resources released in 2010. The report included information on climate change and steps to help set up a planning process, assess vulnerability, devise a strategy, and implement a plan to minimize climate change impacts on the Great Lake's coasts. The planning guide also provides an extensive list of resources to help throughout the planning and implementation process.

The report provides updated data and information on the potential climate change impacts and effects for Great Lakes coastal areas. It highlights case examples of adaptive actions taking place in the Great Lakes region today, many of which are still in the planning and policy development stages.

NOAA – NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION STATE SUMMARY OF OHIO

https://statesummaries.ncics.org/oh

The State Climate Summaries were produced to meet a demand for state-level information in the wake of the Third U.S. National Climate Assessment, released in 2014. The summaries cover assessment topics directly related to NOAA's mission, specifically historical climate variations and trends, future climate model projections of climate conditions during the 21st century, and past and future conditions of sea level and coastal flooding.

The three key takeaways from the Ohio Summary are:

- Historically unprecedented warming is projected by the end of the 21st century and increases in extreme heat are of particular concern for Cincinnati, Columbus and other urban areas where urban heat island effect raises summer temperatures.
- Winter and spring precipitation are projected in increase. Extreme precipitation is projected to increase, potentially causing more frequent and intense floods.
- The intensity of future droughts is projected in increase. Future summer droughts are likely to be more intense.

SMART GROWTH FIXES FOR CLIMATE ADAPTATION AND RESILIENCE- EPA
https://www.epa.gov/smartgrowth/smart-growth-fixes-climate-adaptation-and-resilience

The Environmental Protection Agency's (EPA) Smart Growth Fixes for Climate Adaptation and Resilience: Changing Land Use and Building Codes and Policies to Prepare for Climate Change (2017) is intended to help local jurisdictions develop strategies to prepare for climate change impacts through land use, zoning and building code policies. The policy options described in this publication bring multiple short- and long-term environmental, economic, health, and societal benefits that can not only prepare a community and its residents and businesses for the impacts of climate change, but also improve everyday life.

The strategies can be worked into a local community's regular processes, for example, through scheduled updates to zoning and building codes. This approach allows incremental change, which might be easier for some communities because it costs little or nothing extra compared to "business as usual", and gives communities the opportunity to adjust codes based on the most up-to-date climate observations and projections. To help communities determine which policy and code changes might be best for them, the options in each chapter are categorized as modest adjustments, major modifications, and wholesale changes.

The options can address one, some or all of the following hazards: flooding and precipitation, sea level rise, extreme heat, drought, and wildfire. Examples of the options include, but are not limited to:

- Use regional climate change, population demographics, transportation demand, and related projections to understand where community assets could be vulnerable.
- Evaluate development incentives to see if they encourage development in particularly vulnerable areas.
- Design open space in flood plains for multiple amenities.
- Adopt a site plan requirement that requires all new development to retain all stormwater on-site.
- Establish a task force to review building codes, development patterns, and other relevant issues.

CLIMATE RESILIENCE IN OHIO, A PUBLIC HEALTH APPROACH TO PREPAREDNESS AND PLANNING
https://ohiopha.org/download/climate-resiliency-in-ohio/

In 2016, the Ohio Public Health Association (OPHA) formed the Ohio Public Health Resiliency Coalition (OPHCRC) to develop a document for use by local public health professionals in their efforts to address the public health impacts of climate change and climate-related weather events in their jurisdictions.

The result of the OPHCRC's work is the paper titled Climate Resilience in Ohio, a public health approach to preparedness and planning that focuses on the risks and adverse outcomes that the communities served by Ohio's local health departments (LHDs) are likely to face due to climate change effects. It was the Coalition's decision to focus first on adaptation and resilience from a public health perspective and then to build upon this work and address mitigation efforts. In the context of climate change, the term "adaptation" refers to activities, programs and efforts that seek to allow societies to continue functioning in the face of continued temperature increases and fluctuations in local weather patterns.

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

As downscaled climate change data becomes more readily available the state will assess its vulnerability in terms of population, structures and critical facilities at risk. The state will also encourage the inclusion of such data in local hazard mitigation plans once the data is granular enough to support the analysis.