DAM FAILURE

Hazard Description

Dams are water storage, control or diversion structures that impound water upstream in reservoirs. Dam failure can take several forms, including a collapse of, or breach in, the structure. While most dams have storage volumes small enough that failures have few or no repercussions, dams storing large amounts can cause significant flooding downstream. Dam failures can result from any one, or a combination, of the following causes:

- Prolonged periods of rainfall and flooding, which cause most failures;
- Inadequate spillway capacity, resulting in excess overtopping of the embankment;
- Internal erosion caused by embankment or foundation leakage or piping;
- Improper maintenance, including failure to remove trees, repair internal seepage problems, or maintain gates, valves, and other operational components;
- Improper design or use of improper construction materials;
- Failure of upstream dams in the same drainage basin;
- Landslides into reservoirs, which cause surges that result in overtopping;
- High winds, which can cause significant wave action and result in substantial erosion;
- Destructive acts of terrorists; and
- Earthquakes, which typically cause longitudinal cracks at the tops of the embankments, leading to structural failure.

Benefits provided by dams include water supplies for drinking, irrigation and industrial uses; flood control; hydroelectric power; recreation; and navigation. At the same time, dams also represent a risk to public safety. Dams require ongoing maintenance, monitoring, safety inspections, and sometimes even rehabilitation to continue safe service.

In the event of a dam failure, the energy of the water stored behind the dam is capable of causing rapid and unexpected flooding downstream, resulting in loss of life and great property damage. A devastating

effect on water supply and power generation could be expected as well. The terrorist attacks of September 11, 2001, generated increased focus on protecting the country's infrastructure, including ensuring the safety of dams.

One major issue with the safety of dams is their age, and the average age of America's 80,000 dams is 51 years. More than 2,000 dams near population centers are in need of repair, according to statistics released in 2009 by the Association of State Dam Safety Officials[1]. In addition to the continual aging of dams there have not been significant increases in the number of safety inspectors resulting in haphazard maintenance and inspection.

The Association of State Dam Safety Officials estimate that $16 billion will be needed to fix all high-hazard dams, but the total for all state dam-safety budgets is less than $60 million[2]. The current maintenance budget does not match the scale of America's long-term modifications of its watersheds. Worse still, more people are moving into risky areas. As the American population grows, dams that once could have failed without major repercussions are now upstream of cities and development.

Location

The State of Texas has 7,413 dams, all regulated by the Texas Commission on Environmental Quality (TCEQ). Of these, 854 are considered "high-hazard," 779 are considered "significant-hazard," and 5,780 are considered "low-hazard." According to the American Society of Civil Engineers' "Report Card," the Association of State Dam Safety Officials reports that there are 403 unsafe dams in Texas.[3]

The maps displayed at Figures 14-1 through Figure 14-9 illustrate the general location of dams for each participating jurisdiction in the GBRA area as recorded by the U.S. Army Corps of Engineers (USACE) in the National Inventory of Dams. Locations have been provided for a total of 115 dams through regional and county level maps, overlaid with census population density to graphically illustrate areas at risk. Further specific locations are provided through latitude and longitude, along with storage capacity, and height of each dam in Table 14-1. Three buffer areas were used based on the storage capacities. In lieu of dam failure inundation maps, total exposure was estimated by using 2000 census population and

[1] Association of State Dam Safety Officials, Journal of Dam Safety

[2] Ibid

[3] http://www.asce.org/reportcard/pdf/tx.pdf

building inventory data from HAZUS-MH MR4, in combination with the location and maximum storage capacity of high and significant hazard dams.

Figure 14-1. Dam Locations – GBRA

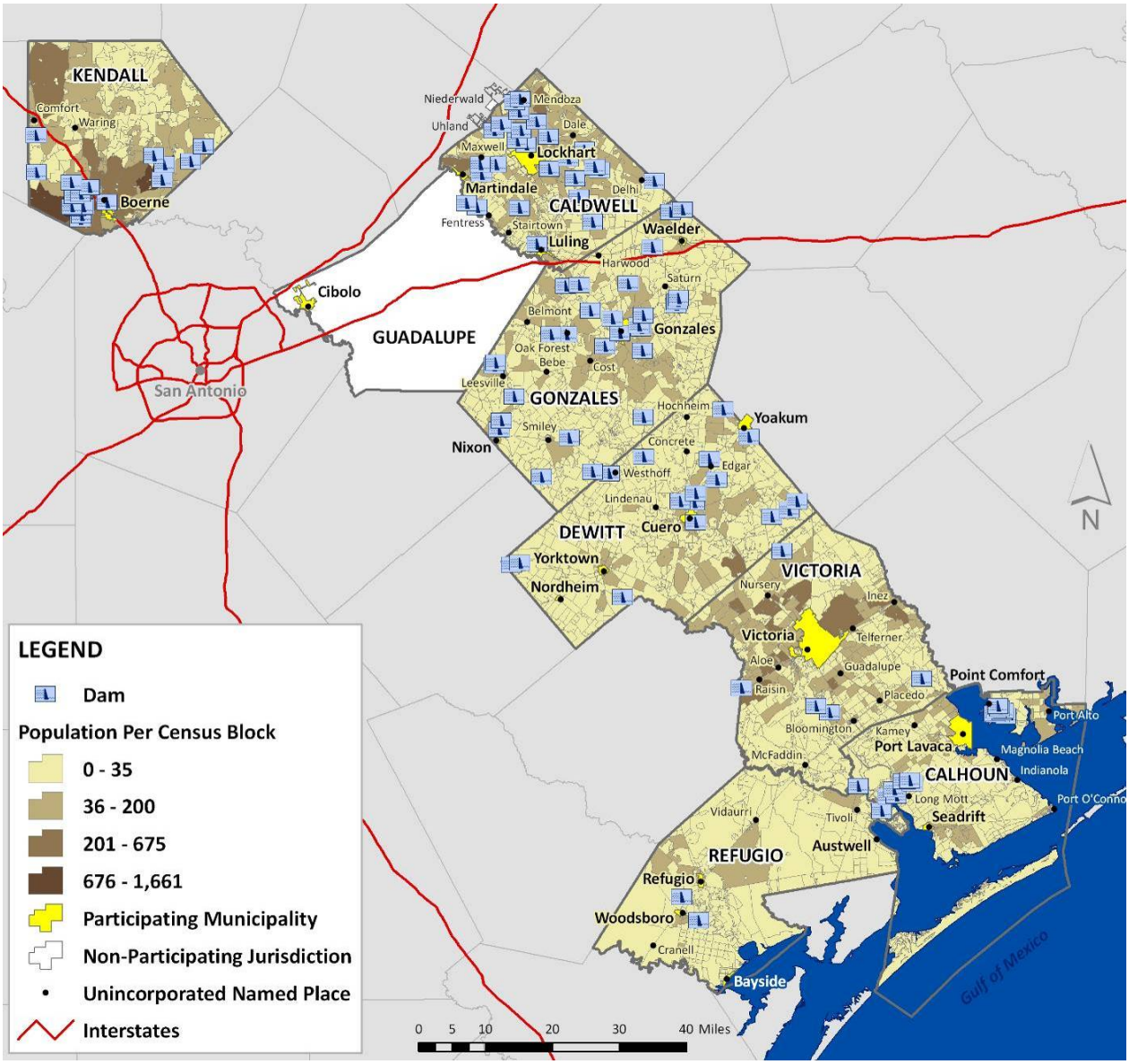


Figure 14-2. Estimated Dam Locations in Caldwell County

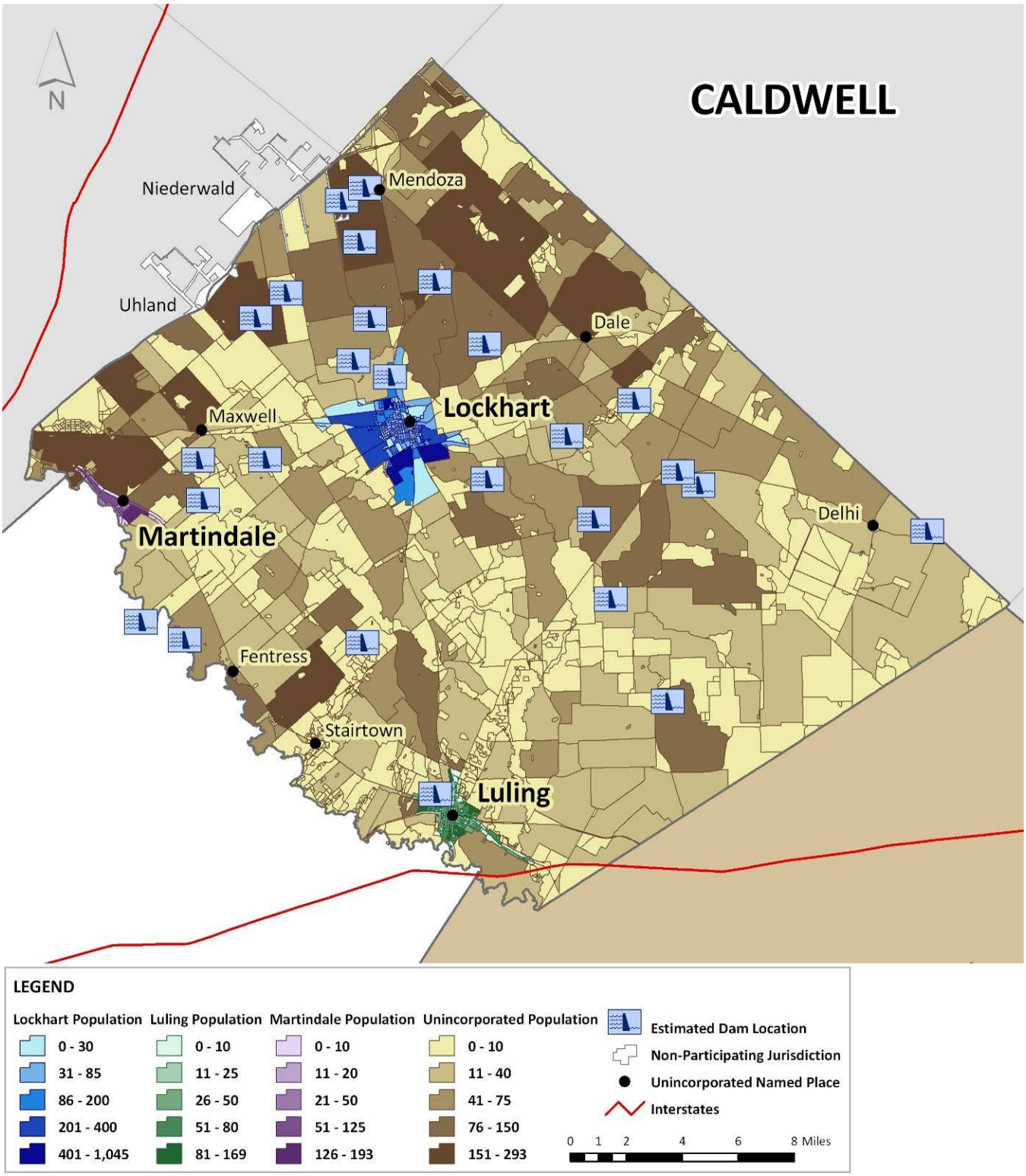


Figure 14-3. Estimated Dam Locations in Calhoun County

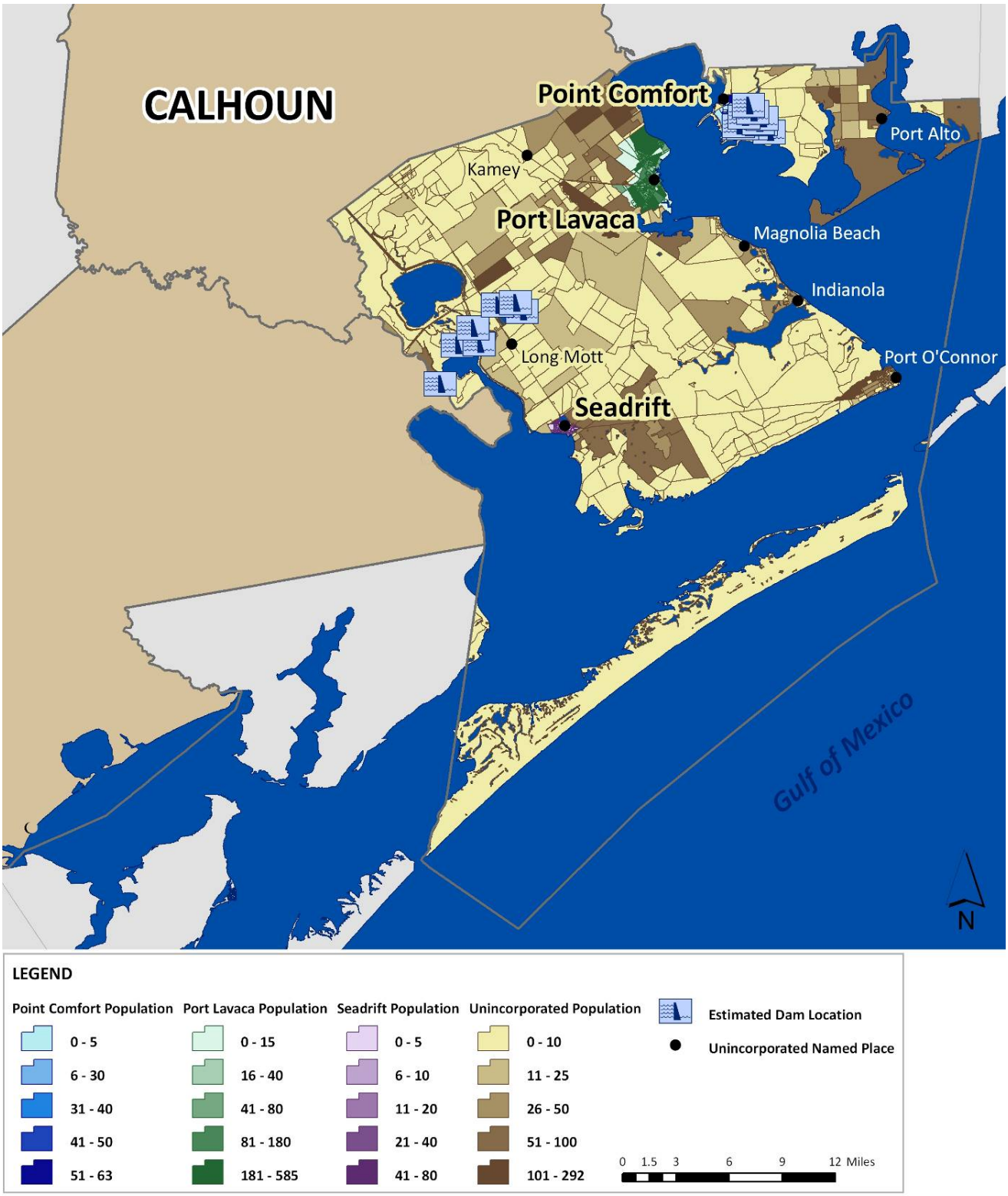


Figure 14-4. Estimated Dam Locations in DeWitt County

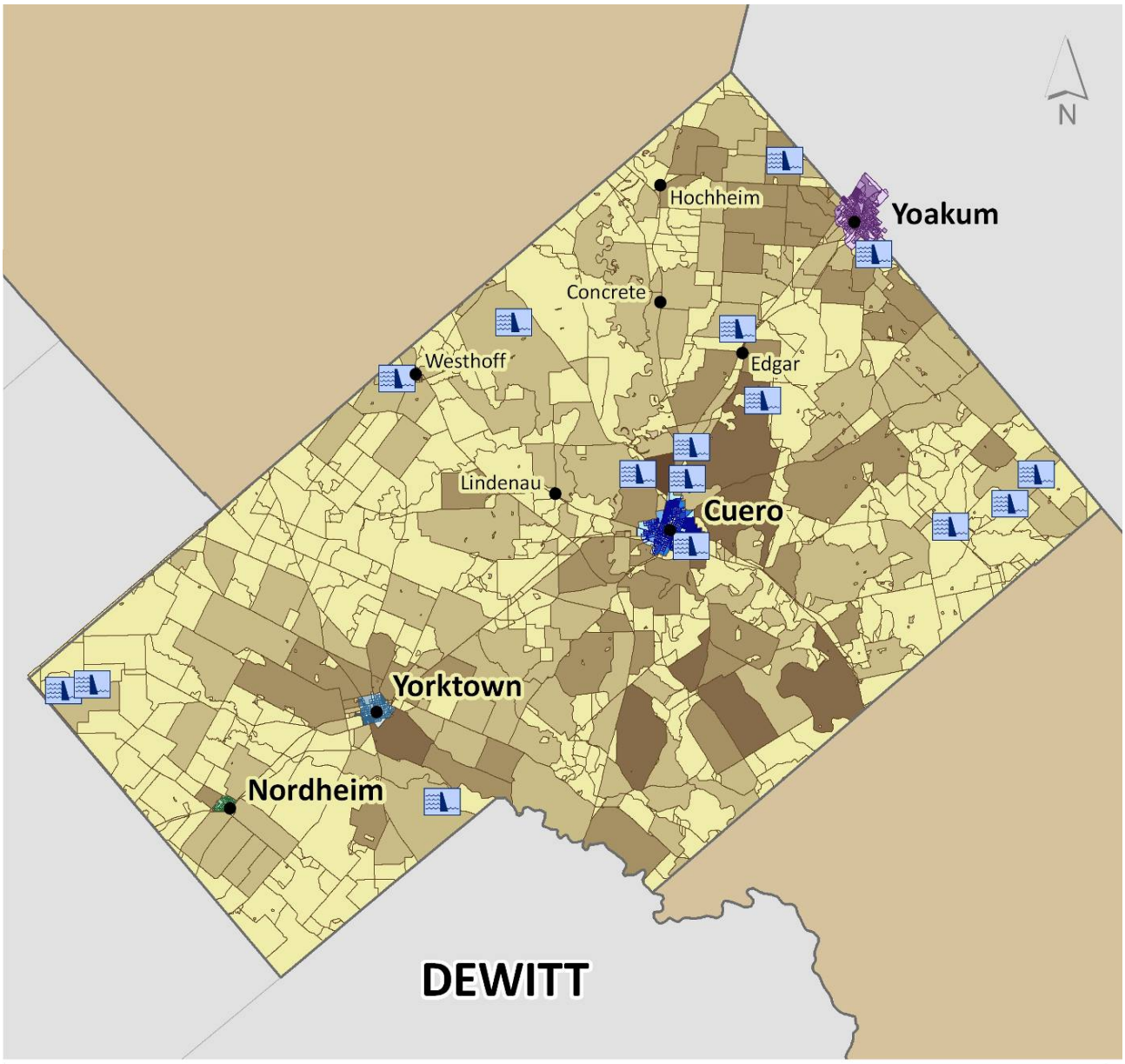


Figure 14-5. Estimated Dam Locations in Gonzales County

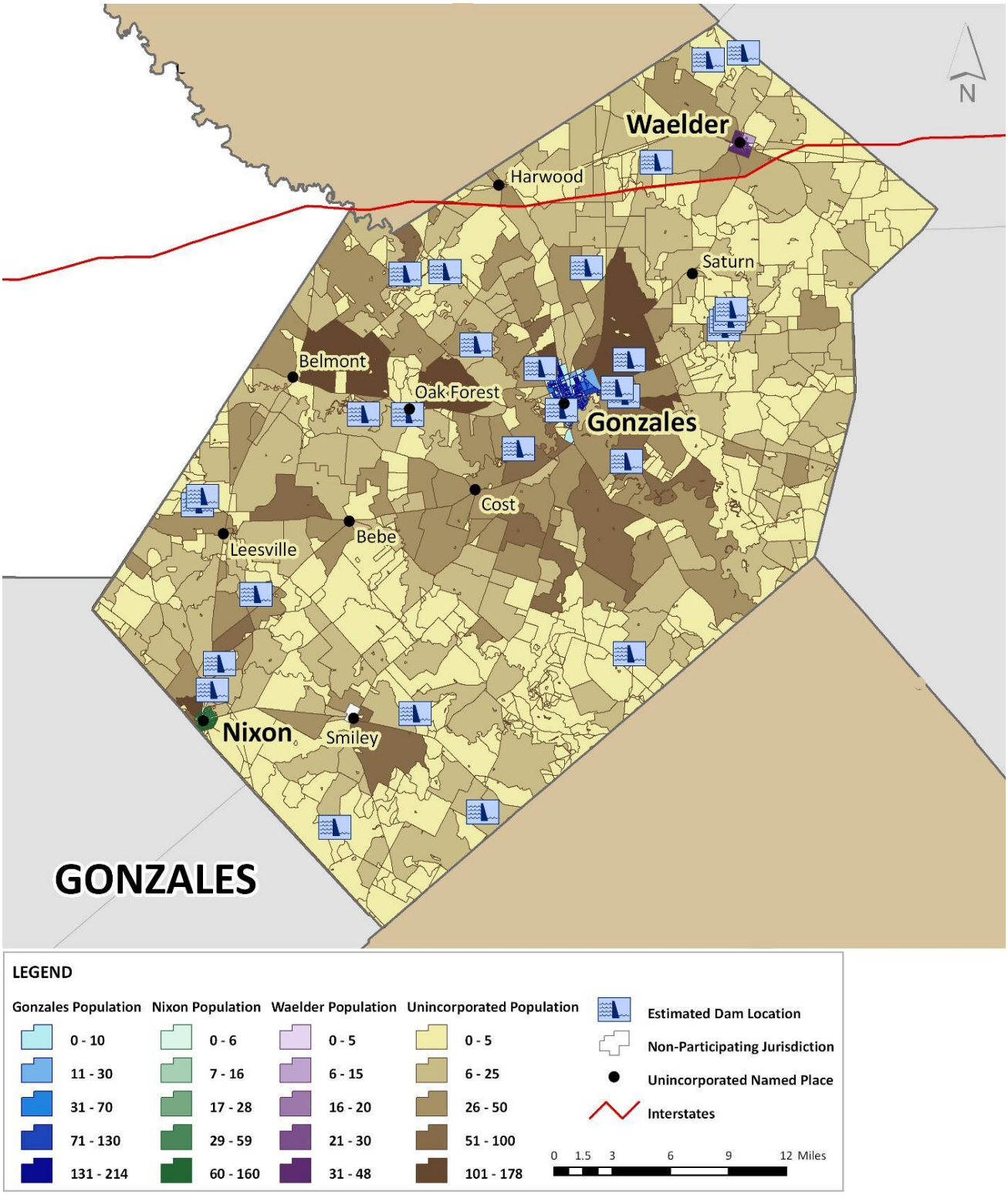


Figure 14-6. Estimated Dam Locations in Kendall County

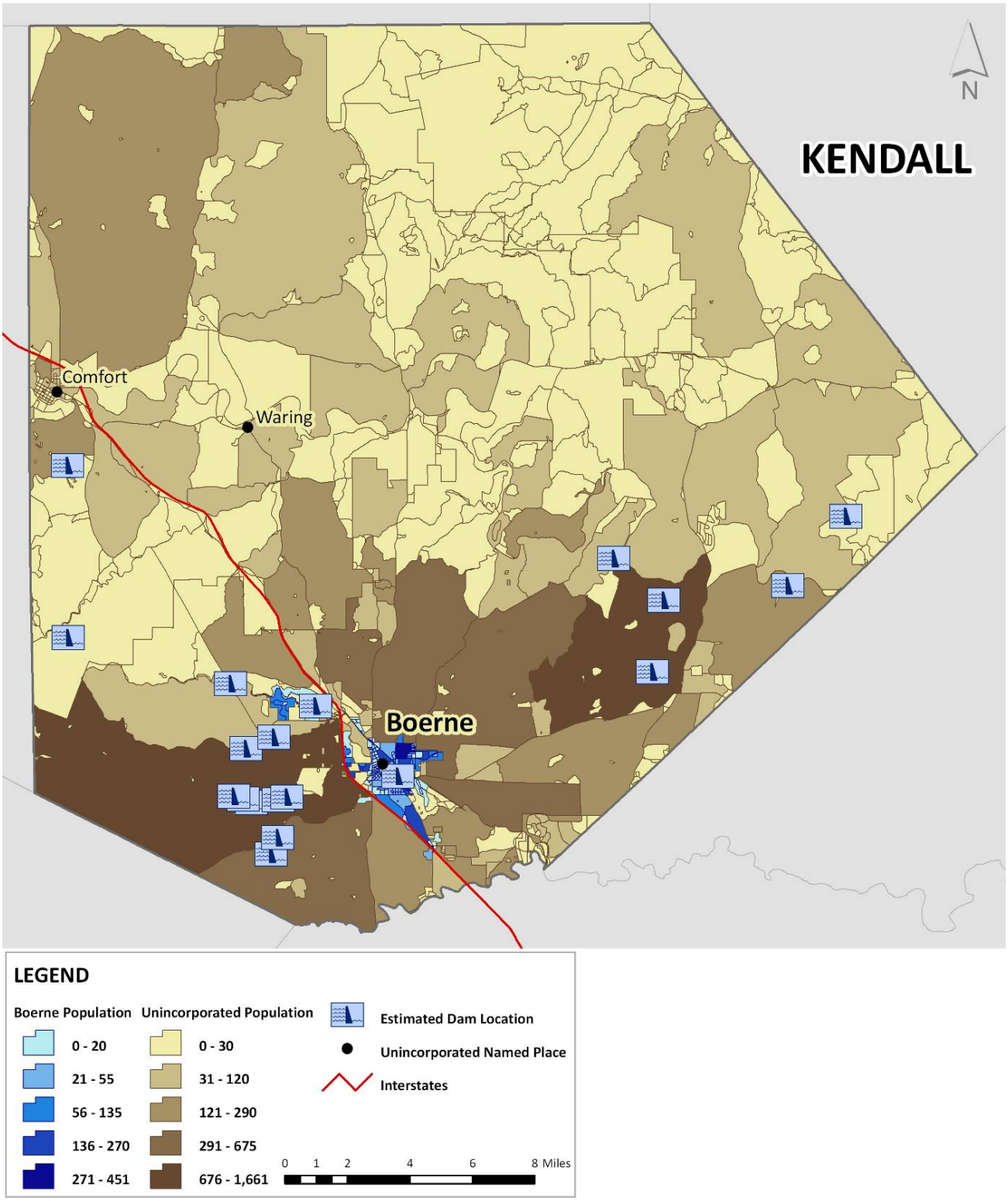


Figure 14-7. Estimated Dam Locations in Refugio County

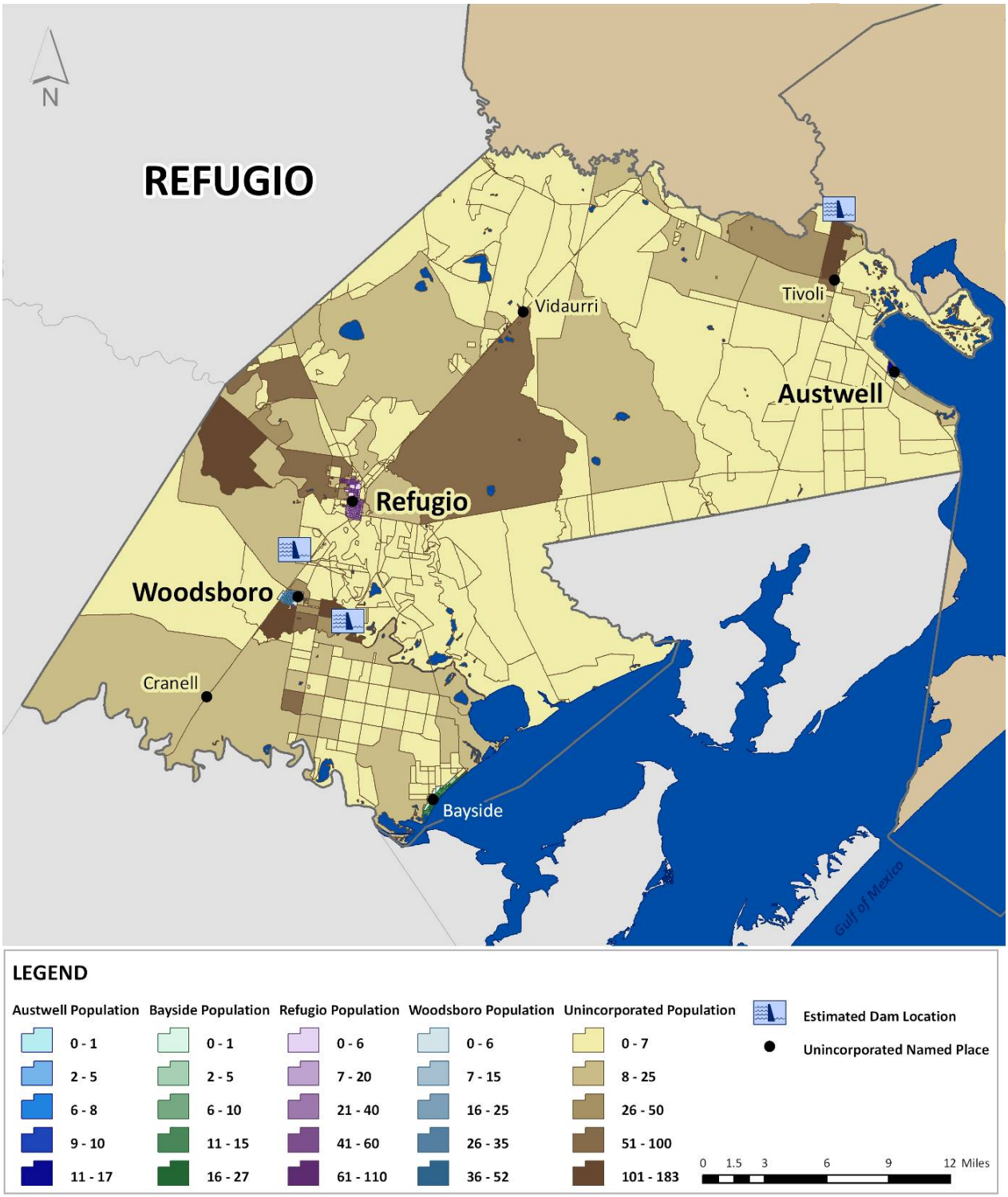


Figure 14-8. Estimated Dam Locations in Victoria County

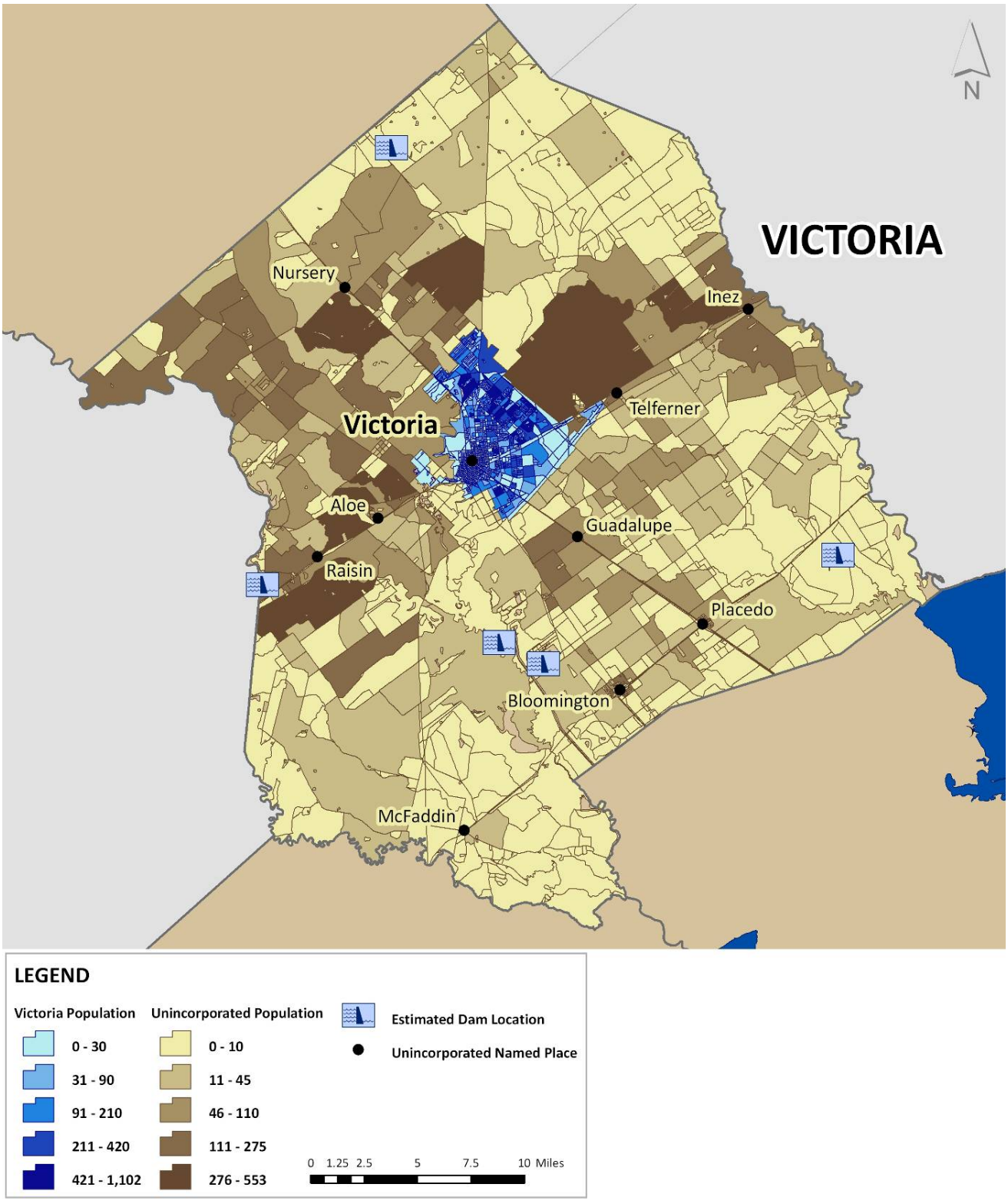
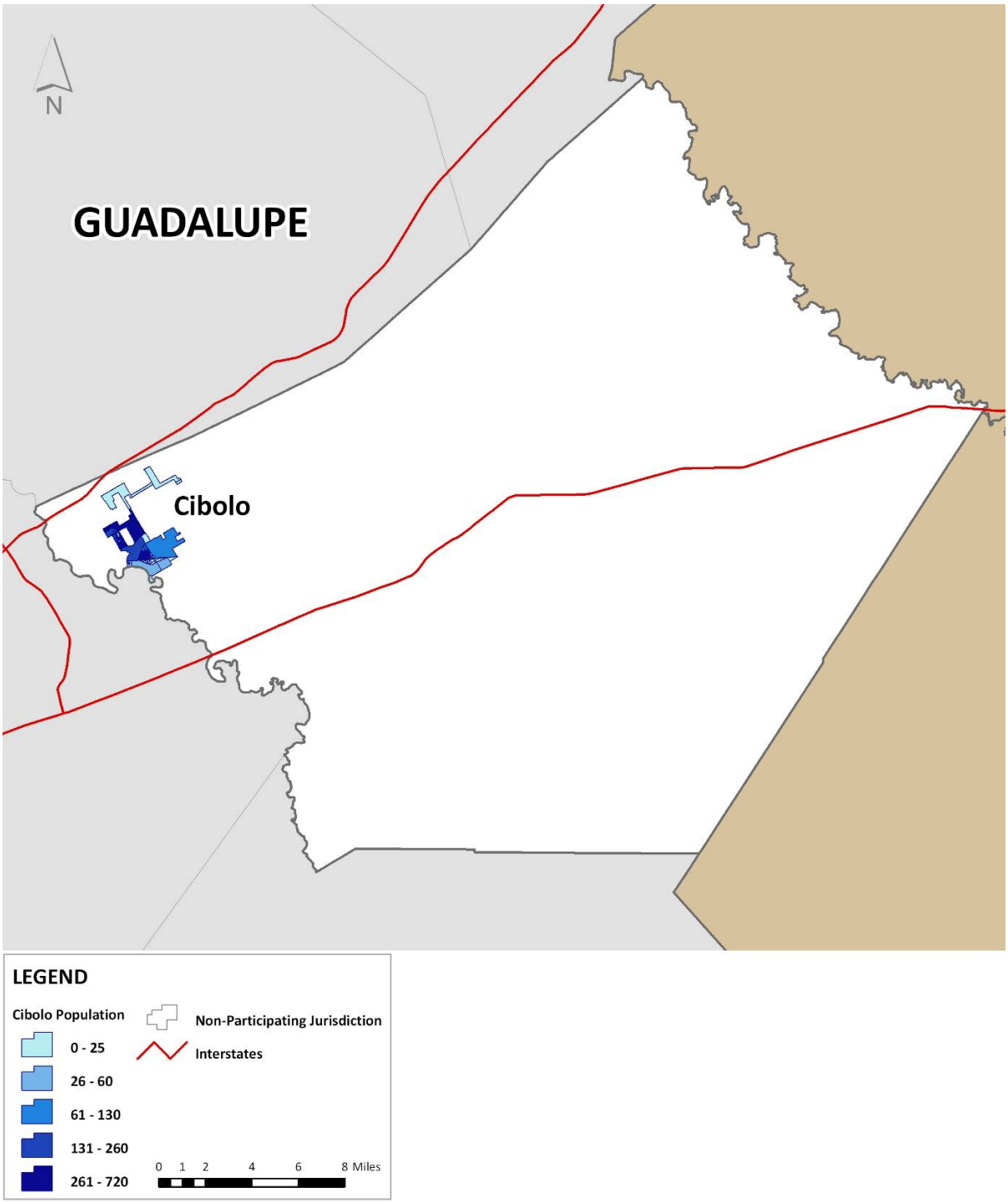


Figure 14-9. Estimated Dam Locations in Cibolo[4] (in Guadalupe County)



[4] Data provided shows no dams relevant to the Cibolo area.

SECTION 14: DAM FAILURE

Table 14-1 details the location information in terms of latitude and longitude, in addition to height, storage, and primary purpose of each dam by county.

Table 14-1. Dam Location and Storage Capacity

County	Latitude	Longitude	NID [5]Height (Ft.)	NID Storage (acre feet)*	Primary Purpose
CALDWELL	29.866136	-97.796179	22	220	Recreation
CALDWELL	29.865917	-97.756478	41	4741	Flood Control and Storm Water Management
CALDWELL	29.939354	-97.761005	49	1137	Flood Control and Storm Water Management
CALDWELL	29.857142	-97.411270	34	5404	Flood Control and Storm Water Management
CALDWELL	29.791633	-97.552164	25	1823	Flood Control and Storm Water Management
CALDWELL	29.854526	-97.624484	42	1527	Flood Control and Storm Water Management
CALDWELL	29.952436	-97.742953	46	8715	Flood Control and Storm Water Management
CALDWELL	29.16616	-97.703318	49	802	Flood Control and Storm Water Management
CALDWELL	29.999893	-97.709044	35	5312	Flood Control and Storm Water Management
CALDWELL	29.978354	-97.698776	35	1700	Flood Control and Storm Water Management
CALDWELL	29.938354	-97.693249	38	1178	Flood Control and Storm Water Management
CALDWELL	29.957187	-97.654322	41	5318	Flood Control and Storm Water Management
CALDWELL	29.894523	-97.536684	28	1066	Flood Control and Storm Water Management
CALDWELL	29.876357	-97.577177	24	2314	Flood Control and Storm Water Management
CALDWELL	29.824774	-97.363997	23	184	Recreation
CALDWELL	29.850007	-97.499341	33	2337	Flood Control and Storm Water Management
CALDWELL	29.691585	-97.657731	30	1993	Flood Control and Storm Water Management
CALDWELL	29.833115	-97.561535	28	3170	Flood Control and Storm Water Management
CALDWELL	29.770436	-97.699917	28	2160	Flood Control and Storm Water Management
CALDWELL	29.738197	-97.519208	12	106	Fire Protection, Stock, Or Small Farm Pond
CALDWELL	29.845180	-97.793618	17	131	Other
CALDWELL	29.772902	-97.805377	8	92	Recreation
CALDWELL	29.908214	-97.681744	19	144	Fire Protection, Stock, Or Small Farm Pond
CALDWELL	29.924744	-97.625220	13	52	Fire Protection, Stock, Or Small Farm Pond
CALDWELL	30.006503	-97.695307	18	211	Fire Protection, Stock, Or Small Farm Pond
CALDWELL	29.782410	-97.831111	10	150	Hydroelectric
CALDWELL	28.482625	-96.81229	10	60	Hydroelectric
CALHOUN	28.496566	-96.797136	12	0	Other
CALHOUN	28.505822	-96.884176	11	600	Irrigation
CALHOUN	28.663330	-96.525000	20	3250	Flood Control and Storm Water Management
CALHOUN	28.657711	-97.547207	40	4100	Flood Control and Storm Water Management
CALHOUN	28.515011	-96.774176	11	1312	Flood Control and Storm Water Management
CALHOUN	28.483333	-96.791667	13	3155	Flood Control and Storm Water Management
CALHOUN	28.509436	-96.751462	12	1964	Other
CALHOUN	28.515011	-97.774176	11	1312	Other
CALHOUN	28.516635	-96.757300	11	1304	Flood Control and Storm Water Management
CALHOUN	28.659483	-96.528648	45	1320	Flood Control and Storm Water Management

[5] National Inventory of Dams (NID)

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County	Latitude	Longitude	NID [5]Height (Ft.)	NID Storage (acre feet)*	Primary Purpose
CALHOUN	28.658861	-96.525771	44	3542	Flood Control and Storm Water Management
CALHOUN	28.664628	-96.541770	53	3722	Flood Control and Storm Water Management
CALHOUN	28.674137	-96.537480	34	7524	Flood Control and Storm Water Management
CALHOUN	28.656008	-96.543462	8	152	Flood Control and Storm Water Management
CALHOUN	28.668218	-96.533789	8	112	Flood Control and Storm Water Management
CALHOUN	28.655967	-96.547484	10	400	Flood Control and Storm Water Management
CALHOUN	28.65194	-96.518755	40	2949	Flood Control and Storm Water Management
CALHOUN	28.655760	-96.534557	15	1174	Irrigation
CALHOUN	28.451256	-96.828352	11	462	Other
DEWITT	29.125864	-97.023361	10	144	Flood Control and Storm Water Management
DEWITT	29.107282	-97.042673	18	173	Flood Control and Storm Water Management
DEWITT	29.129974	-97.311509	37	808	Hydroelectric
DEWITT	29.093580	-97.085915	20	280	Flood Control and Storm Water Management
DEWITT	29.227400	-97.400100	22	182	Fire Protection, Stock, Or Small Farm Pond
DEWITT	29.175393	-97.220488	14	146	Recreation
DEWITT	29.083875	-97.274049	9	125	Recreation
DEWITT	29.146476	-97.272531	22	454	Flood Control and Storm Water Management
DEWITT	29.126418	-97.275994	26	1285	Flood Control and Storm Water Management
DEWITT	29.267190	-97.138501	8	144	Recreation
DEWITT	29.192779	-97.485268	16	128	Fire Protection, Stock, Or Small Farm Pond
DEWITT	29.327597	-97.202018	15	146	Fire Protection, Stock, Or Small Farm Pond
DEWITT	29.221018	-97.237763	20	88	Fire Protection, Stock, Or Small Farm Pond
DEWITT	28.923633	-97.456294	25	140	Recreation
DEWITT	29.000833	-97.708333	45	4100	Flood Control and Storm Water Management
DEWITT	28.997163	-97.728828	29	1908	Flood Control and Storm Water Management
GONZALES	29.496667	-97.455000	14	650	Flood Control and Storm Water Management
GONZALES	29.546475	-97.527311	8	0	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.435541	-97.763173	16	576	Flood Control and Storm Water Management
GONZALES	29.429270	-97.767488	7	70	Flood Control and Storm Water Management
GONZALES	29.495000	-97.58667	11	1058	Hydroelectric
GONZALES	29.495815	-97.624491	42	23520	Hydroelectric
GONZALES	29.468355	-97.492068	42	8120	Hydroelectric
GONZALES	29.570470	-97.308029	20	304	Recreation
GONZALES	29.555740	-97.315137	22	123	Recreation
GONZALES	29.528309	-97.472729	14	106	Recreation
GONZALES	29.601667	-97.553333	6	54	Flood Control and Storm Water Management
GONZALES	29.600277	-97.587339	12	120	Recreation
GONZALES	29.757703	-97.325087	17	164	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.762418	-97.294933	20	106	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.681632	-97.370901	15	120	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.533707	-97.396589	18	80	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.512743	-97.406880	18	158	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.506815	-97.401631	18	144	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.561667	-97.313333	21	92	Fire Protection, Stock, Or Small Farm Pond

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County	Latitude	Longitude	NID [5]Height (Ft.)	NID Storage (acre feet)*	Primary Purpose
GONZALES	29.563333	-97.310000	21	74	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.186307	-97.653114	20	70	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.313519	-97.399529	15	104	Fire Protection, Stock, Or Small Farm Pond
GONZALES	29.290235	-97.756511	15	88	Recreation
GONZALES	29.310000	-97.750000	18	230	Recreation
GONZALES	29.361667	-97.718333	22	117	Recreation
GONZALES	29.603333	-97.431667	13	111	Recreation
GONZALES	29.270833	-97.58333	23	147	Other
GONZALES	29.196667	-97.526667	18	170	Recreation
KENDALL	29.752800	-98.791700	18	30	Irrigation
KENDALL	29.778120	-98.787817	12	50	Recreation
KENDALL	29.832145	-9813113	10	20	Flood Control and Storm Water Management
KENDALL	29.837220	-98.587780	16	35	Irrigation
KENDALL	29.853687	-98.899897	15	16	Fire Protection, Stock, Or Small Farm Pond
KENDALL	29.870560	-98.581670	12	21	Irrigation
KENDALL	29.909199	-98.484048	11	0	Fire Protection, Stock, Or Small Farm Pond
KENDALL	29.801979	-98.805072	31	212	Recreation
KENDALL	29.889950	-98.608305	12	50	Irrigation
KENDALL	29.789052	-98.724035	12	55	Recreation
KENDALL	29.877092	-98.515463	39	1170	Recreation
KENDALL	29.821722	-98.767675	89	15668	Recreation
KENDALL	29.779341	-98.783158	76	4732	Recreation
KENDALL	29.807244	-98.790158	54	1060	Flood Control and Storm Water Management
KENDALL	29.760548	-98.788132	56	1278	Flood Control and Storm Water Management
KENDALL	29.779810	-98.811632	17	120	Recreation
KENDALL	29.778581	-98.806401	18	55	Recreation
KENDALL	29.776850	-98.802176	24	83	Recreation
KENDALL	29.933870	-98.89970	50	92	Irrigation
REFUGIO	28.271572	-97.322085	8	115	Fire Protection, Stock, Or Small Farm Pond
REFUGIO	28.220844	-97.280612	11	88	Recreation
VICTORIA	29.018333	-97.061667	16	128	Flood Control and Storm Water Management
VICTORIA	28.681667	-96.985000	6	155	Irrigation
VICTORIA	28.666667	-96.951667	11	1056	Other
VICTORIA	28.723333	-97.16667	65	169000	Flood Control and Storm Water Management
VICTORIA	28.736667	-96.723333	18	286	Recreation

* Total exposure was estimated by using 2000 census population and building inventory data from HAZUS-MH MR4, in combination with the location and maximum storage capacity of high and significant hazard dams. For dams with a maximum storage capacity of 100,000 acre-feet or more, all census blocks within five miles were considered to be at risk to potential dam failure hazards. For dams with a maximum storage capacity between 10,000 and 100,000 acre-feet, all census blocks within three miles were considered to be at risk to potential dam failure hazards. For dams with a maximum storage

capacity of less than 10,000 acre-feet, all census blocks within one mile were considered to be at risk to potential dam failure hazards.

Extent

The extent or magnitude of a dam failure event can be measured in terms of the classification of the dam. The National Interagency Committee on Dam Safety defines high hazard dams as those where failure or mis-operation will cause loss of human life. Prior to 2009, high hazard dams were defined as those at which failure or mis-operation would probably cause loss of human life. Dams classified as "significant" are those at which failure or mis-operation probably would not result in loss of human life but could cause economic loss, environmental damage, disruption of lifeline facilities, or other significant damage. Low hazard potential dams are those at which failure or mis-operation probably would not result in loss of human life but would cause limited economic and/or environmental losses. Losses would be limited mainly to the owner's property.

The magnitude or extent for the GBRA area can be measured by the storage capacity. Table 14-2 details the hazard potential and extent by capacity.

Table 14-2. Extent Classifications

HAZARD POTENTIAL CLASSIFICATION	LOSS OF HUMAN LIFE	DAM STORAGE CAPACITY
Low	None Expected	Less than 10,000 acre-feet
Significant	Probable (1 to 6)	Between 10,000 and 100,000 acre-feet
High	Loss of Life Expected (7 or More)	100,000 acre-feet or more

Based on the classification and storage capacity for dams in the GBRA area, all significant and high hazard dams were profiled. Table 14-1 includes specific information by County. For dams with a maximum storage capacity of 100,000 acre-feet or more or "high" hazard dams, all census blocks within five miles were considered to be at risk to potential dam failure hazards. For dams with a maximum storage capacity between 10,000 and 100,000 acre-feet or "significant" hazard dams, all census blocks within three miles were considered to be at risk to potential dam failure hazards. For dams with a maximum storage capacity of less than 10,000 acre-feet, all census blocks within one mile were considered to be at risk to potential dam failure hazards.

Of the dams located for the planning area only one is considered a high hazard dam in Victoria County. Therefore people and property within five miles are considered to be at risk. A potential dam failure could result in major economic damage and the loss of seven or more lives. Although this is the only

high hazard dams, two other dams are considered to be significant hazard dams. These dams are located in Kendall and Gonzales counties. People and property within three miles of these dams are considered at risk, with a potential for loss of life of one to six people.

Historical Occurrences

There are about 80,000 dams in the United States today.[6] Catastrophic dam failures have occurred frequently throughout the past century. Between 1918 and 1958, 33 major U.S. dam failures caused 1,680 deaths. From 1959 to 1965, nine major dams failed worldwide. Some of the largest disasters in the U.S. have resulted from dam failures. More than 520 dam incidents, including 21 dam failures, were reported in the past two years to the National Performance of Dams Program, which collects and archives information on dam performance from state and federal regulatory agencies and dam owners.

The State of Texas has not experienced loss of life or extensive economic damage due to a dam failure since the first half of the twentieth century. However, due to limited state staff, many incidents are not reported and, therefore, the actual number of incidents is likely to be greater. There has not been a recorded dam failure event for any of the participating jurisdictions in the basin.

Probability of Future Events

No historical events of dam failure have been recorded in the GBRA area, though the risk of dam failure is monitored closely. Due the lack of historical occurrences, the probability of a future event is unlikely, meaning an event is possible in the next ten years.

Impact and Vulnerability

Table 14-3 lists the number of high and significant hazard dams for each participating jurisdiction in the region, and the total estimated exposure of people and buildings to potential dam failure hazards. Due to homeland security concerns, the analysis was performed for all high and significant hazard dams as a single group per NID classification based on storage capacity, as opposed to separate analyses being conducted for high-hazard dams and significant-hazard dams separately. In lieu of dam failure inundation maps, total exposure was estimated by using 2000 census population and building inventory data from HAZUS-MH MR4, in combination with the location and maximum storage capacity of high and significant hazard dams. For dams with a maximum storage capacity of 100,000 acre-feet or more, all census blocks within five miles were considered to be at risk to potential dam failure hazards. For dams with a maximum storage capacity between 10,000 and 100,000 acre-feet, all census blocks within three

[6] Federal Emergency Management Agency, Dam Safety Program, http://www.fema.gov/hazards/damsafety/.

miles were considered to be at risk to potential dam failure hazards. For dams with a maximum storage capacity of less than 10,000 acre-feet, all census blocks within one mile were considered to be at risk to potential dam failure hazards.

Table 14-3. Total Exposure to High-Hazard Dams by Jurisdiction

JURISDICTION	TOTAL NUMBER OF HIGH AND SIGNIFICANT HAZARD DAMS	TOTAL POPULATION IN JURISDICTION	NUMBER OF PEOPLE AT RISK TO HAZARD	NUMBER OF BUILDINGS AT RISK TO HAZARD	VALUE OF BUILDINGS AT RISK ($) TO HAZARD
Gonzales County	1	8,343	2,534	1,397	$119,302,000
Kendall County	1	17,618	7,804	3,402	$533,117,000
Victoria County	1	23,482	2,883	1,096	$152,499,000
TOTALS FOR STUDY AREA[7]	**3**	**49,443**	**13,221**	**5,895**	**$804,918,000**

Source: USACE; HAZUS-MH MR4

Although there has never been a dam failure in the GBRA area, since there are three dams classified as "high" or "significant", the potential severity of impact of dam failure is substantial. A dam breach could result in multiple deaths with facilities shut down for 30 days or more, and more than 50 percent of property destroyed or damaged. For these reasons, creating mitigations actions to remove or protect people and structures from the path of destruction is necessary in order to minimize impact from dam failure.

[7] Totals for the study area may include values less than $5,000 for dollar amounts and less than 50 for populations that are classified as "negligible" in the table.