4.3.1 Dam Failure

This section provides a profile and vulnerability assessment of the dam failure hazard in Fulton County. A dam is an artificial barrier allowing storage of water, wastewater, or liquid-borne materials for many reasons (flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, or pollution control). Many dams fulfill a combination of these stated functions (Association of State Dam Safety Officials 2013). They are an important resource in the United States.

Man-made dams can be classified according to type of construction material used; methods applied in construction, slope, or cross-section of the dam; how a dam resists forces of water pressure behind it; means used to control seepage; and occasionally purpose of the dam. Materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, miscellaneous materials (plastic or rubber), and any combination of these materials (Association of State Dam Safety Officials 2013).

More than a third of the country's dams are 50 or more years old. Approximately 14,000 of those dams pose a significant hazard to life and property if failure occurs. About 2,000 unsafe dams are dispersed throughout the United States in almost every state.

Dams typically fail when spillway capacity is inadequate and excess flow overtops the dam or when internal erosion (piping) through the dam or foundation occurs. Complete failure occurs if internal erosion or overtopping results in a complete structural breach, releasing a high-velocity wall of debris-filled water that rushes downstream, damaging or destroying anything in its path (Federal Emergency Management Agency [FEMA] 2015b).

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

- Overtopping caused by floods that exceed capacity of the dam
- Deliberate acts of sabotage
- Structural failure of materials used in dam construction
- Movement or failure of the foundation supporting the dam
- Settling and cracking of concrete or embankment dams
- Piping and internal erosion of soil in embankment dams
- Inadequate maintenance and upkeep (FEMA 2015b)

Regulatory Oversight of Dams

Potential for catastrophic flooding caused by dam failures led to enactment of the National Dam Safety Act (Public Law 92-367), which for 30 years has protected Americans from dam failures. The National Dam Safety Program (NDSP) is a partnership among states, federal agencies, and other stakeholders that encourages individual and community responsibility for dam safety. Under FEMA's leadership, state assistance funds have allowed all participating states to improve their programs through increased inspections, emergency action planning, and purchases of needed equipment. FEMA has also expanded existing and initiated new training programs. Grant assistance from FEMA provides support for improvement of dam safety programs that regulate most dams in the United States (FEMA 2013).

Pennsylvania Department of Environmental Protection

The Pennsylvania Department of Environmental Protection (PA DEP) holds responsibility for dam safety. Hazard Potential Category 1 dams are those "where its failure could result in significant loss of life, excessive economic losses, and significant public inconvenience." Hazard Potential Category 2 dams are those "where its failure could result in the loss of a few lives, appreciable property damage, and short-duration public inconvenience" (PA DEP 2009a). Owners of dams classified as Hazard Categories 1 or 2 ("high-hazard" dams) are required to create an Emergency Action Plan (EAP) that describes the dam, the inundation area if the dam were to catastrophically fail, and procedures for responding to the dam failure (such as notification to

the vulnerable population). Fulton County receives copies of EAPs and inundation maps for high-hazard dams whose failure could impact local residents.

U.S. Army Corps of Engineers Dam Safety Program

The U.S. Army Corps of Engineers (USACE) is responsible for safety inspections of some federal and non-federal dams in the United States that meet the size and storage limitations specified in the National Dam Safety Act. USACE has inventoried dams and has surveyed each state's and federal agency's capabilities, practices, and regulations regarding design, construction, operation, and maintenance of the dams. USACE has also developed guidelines for inspection and evaluation of dam safety (USACE 2017b). The USACE National Inventory of Dams (NID) provides the most recent dates of inspection of the following Fulton County dams:

- Camp Sinoquipe Lake Dam: June 1, 2018
- Cowans Gap Dam: December 18, 2017
- Meadow Grounds Dam: June 22, 2017
- Valley-Hi Eagle Lake Dam: December 18, 2017

Federal Energy Regulatory Commission Dam Safety Program

The Federal Energy Regulatory Commission (FERC) has the largest dam safety program in the United States. FERC cooperates with a large number of federal and state agencies to ensure and promote dam safety and, more recently, homeland security. FERC staff inspect hydroelectric projects on an unscheduled basis to investigate the following:

- Potential dam safety problems
- Complaints about constructing and operating a project
- Safety concerns related to natural disasters
- Issues concerning compliance with terms and conditions of a license (FERC 2017)

Every five years, an independent consulting engineer, approved by FERC, must inspect and evaluate projects with dams higher than 32.8 feet (10 meters) or with total storage capacity of more than 2,000 acre-feet (FERC 2017).

FERC monitors and evaluates seismic research in geographic areas where seismic activity is a concern. This information is applied to investigate and analyze structures of hydroelectric projects within these areas. FERC staff also evaluates effects of potential and actual large floods on safety of dams. FERC staff visit dams and licensed projects during and after floods, assess extents of damage, and direct any studies or remedial measures the licensee must undertake. FERC's *Engineering Guidelines for the Evaluation of Hydropower Projects* guides FERC engineering staff and licensees in evaluations of dam safety. The publication is frequently revised to reflect current information and methodologies (FERC 2017).

FERC requires licensees to prepare EAPs and conducts training sessions on developing and testing these plans. The plans outline an early warning system in the event of an actual or potential sudden release of water from a dam failure. The plans include operational procedures that may be implemented during regulatory measures, such as reducing reservoir levels and downstream flows, as well as procedures for notifying affected residents and agencies responsible for emergency management. These plans are frequently updated and tested to ensure that all applicable parties are informed of the proper procedures in emergencies (FERC 2017).

4.3.1.1 Location and Extent

Seven (7) dams are present throughout Fulton County, as shown on Figure 4.3.1-1. The vast majority of these dams pose little risk; however, nine Hazard Category 1 "high-hazard" dams require EAPs. Table 4.3.1-1 lists dam classification definitions. Table 4.3.1-2 is a complete list of dams in Fulton County with "high-hazard" dams listed first. According to the U.S. Army Corps of Engineers, there are four dams located in Fulton

County, two of which are publicly owned, and two of which are privately owned (USACE 2019, NPDP 2015). Table 4.3.1-2 below reflects the list of dams maintained by PA DEP.

Figure 4.3.1-1. Dams in Fulton County

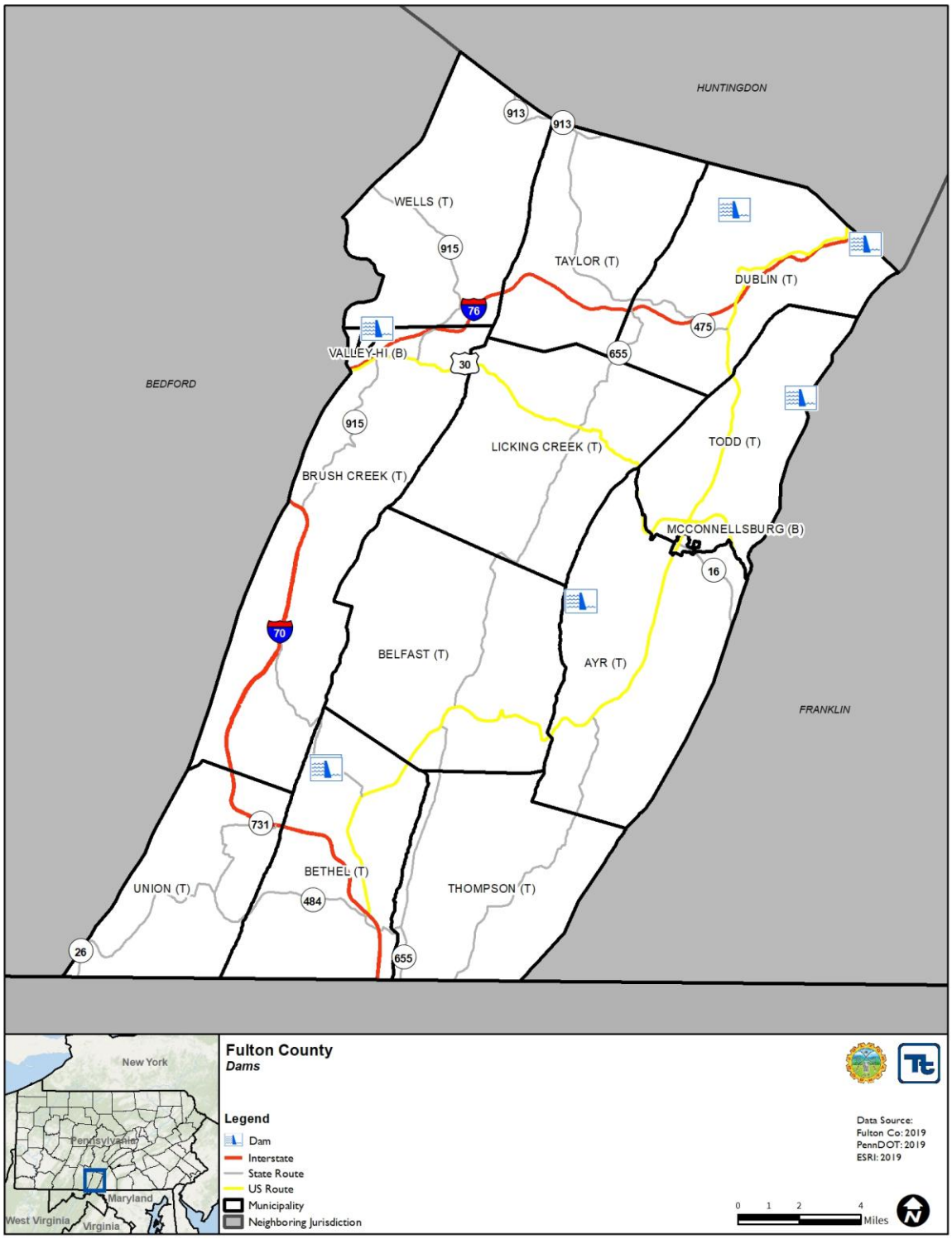

Table 4.3.1-1. Dam Classification Definitions

Size Category		
Category	**Impoundment Storage (Acre-feet)**	**Dam Height (Feet)**
A	Equal to or greater than 50,000	Equal to or greater than 100
B	Less than 50,000 but greater than 1,000	Less than 100 but greater than 40
C	Equal to or less than 1,000	Equal to or less than 40
Hazard Potential Category		
Category	**Population at Risk**	**Economic Loss**
1	Substantial (numerous homes or small businesses or a large business or school)	Excessive, such as extensive residential, commercial, or agricultural damage, or substantial public inconvenience
2	Few (a small number of homes or small businesses)	Appreciable, such as limited residential, commercial, or agricultural damage, or moderate public inconvenience
3	None expected (no permanent structures for human habitation or employment)	Significant damage to private or public property and short-duration public inconvenience such as damage to storage facilities or loss of critical stream crossings
4	None expected (no permanent structures for human habitation or employment)	Minimal damage to private or public property and no significant public inconvenience

Source: Commonwealth of Pennsylvania 2011.

Table 4.3.1-2. Dams in Fulton County

Dam Name	Municipality	Stream	Type	Class	Permittee
High-Hazard Dams					
Meadow Grounds	Ayr Township	Roaring Run	Earth	B-1	PA Fish and Boat Commission
Cowan's Gap	Todd Township	Little Aughwick Creek	Earth	B-1	DNCR – Bureau of State Parks
Valley-Hi Eagle Lake	Valley-Hi Borough	Oregon Creek	Earth	C-1	Valley-Hi Development Association, Inc.
Other Dams					
Camp Sinoquipe Lake	Dublin Township	Plum Run	Earth	C-4	Boy Scouts of America
Grewe Upper	Bethel Township	Mellot Run	Earth	C-4	Josef Grewe
Grewe Lower	Bethel Township	Mellot Run	Earth	C-4	Josef Grewe
Burnt Cabins Mill Pond	Dublin Township	S Br Little Aughwick Creek	Earth	C-4	Greg and Dawn Harnish

Source: PA DEP 2017a

4.3.1.2 Range of Magnitude

Extent or magnitude of a dam failure event can be measured in terms of classification of the dam. FEMA has three classification levels of dam hazard potential: low, significant, and high. The classification levels build on each other. The hazard potential classification system should be used with the understanding that failure of any dam or water-retaining structure could represent a danger to downstream life and property (FEMA 2004). Each FEMA classification level of dam hazard potential is described as follows:

- Low-hazard potential dams are those where failure or misoperation would result in no probable loss of human life and low economic or environmental losses. Losses are principally limited to the owner's property.
- Significant-hazard potential dams are those where failure or misoperation would result in no probable loss of human life but could cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns. Significant-hazard potential dams are often located in predominantly rural or agricultural areas.
- High-hazard potential dams are those where failure or misoperation will probably cause loss of human life.

Table 4.3.1-3 lists USACE-developed classifications of hazard potentials of dam failures based only on potential consequences of a dam failure; this classification does not take into account probability of failure.

Table 4.3.1-3. U.S. Army Corps of Engineers Hazard Potential Classification

Hazard Category[1]	Direct Loss of Life[2]	Lifeline Losses[3]	Property Losses[4]	Environmental Losses[5]
Low	None (rural location, no permanent structures for human habitation)	No disruption of services (cosmetic or rapidly repairable damage)	Private agricultural lands, equipment, and isolated buildings	Minimal incremental damage
Significant	Rural location, only transient or day-use facilities	Disruption of essential facilities and access	Major public and private facilities	Major mitigation required
High	Certain (one or more) extensive residential, commercial, or industrial development	Disruption of essential facilities and access	Extensive public and private facilities	Extensive mitigation cost or impossible to mitigate

[1] Categories are assigned to overall projects, not individual structures at a project.

[2] Loss-of-life potential is based on inundation mapping of area downstream of the project. Analysis of loss-of-life potential should take into account the population at risk, time of flood wave travel, and warning time.

[3] Lifeline losses include indirect threats to life caused by the interruption of lifeline services from project failure or operational disruption; for example, loss of critical medical facilities or access to them.

[4] Property losses include damage to project facilities and downstream property and indirect impact from loss of project services, such as impact from loss of a dam and navigation pool, or impact from loss of water or power supply.

[5] Environmental impact downstream caused by the incremental flood wave produced by the project failure, beyond what would normally be expected for the magnitude flood event under which the failure occurs.

Source: USACE 2016

The worst-case scenario dam failure would be the sudden catastrophic failure of the Cowan's Gap dam, which could threaten the population in the inundation zone as well as any individuals using the lake for recreation. The Meadow Grounds dam has been drained and is currently waiting for structural improvements and repairs.

Once the surrounding waterways have been refilled, the sudden catastrophic failure of the Meadow Grounds dam would also be considered a worst-case scenario. The most likely dam failure would be the failure of a small earthen dam along a minor stream and would not threaten any lives or property.

4.3.1.3 Past Occurrence

There have been two significant dam failures in Pennsylvania. The worst dam failure to occur in the U.S. took place in Johnstown, PA, in 1889 and claimed 2,209 lives. Another dam failure took place in Austin, PA, (Potter County) in 1911 and claimed 78 lives. To date, there have not been any dam failures in Fulton County's recent history.

4.3.1.4 Future Occurrence

Likelihood of a dam failure in Fulton County is difficult to predict. Dam failure events are infrequent and usually coincide with events that cause them, such as earthquakes, landslides, and excessive rainfall and snowmelt. However, the risk of such an event increases for each dam as the dam's age increases or frequency of maintenance decreases.

"Residual risk" to dams is risk that remains after implementation of safeguards. Residual risk to dams is associated with events beyond those that the facility was designed to withstand. However, probability of any type of dam failure is low in today's dam safety regulatory and oversight environment.

Based on Risk Factor Methodology Probability Criteria (further defined in Section 4.4), and assuming regular maintenance and inspections of the dams in Fulton County, dam failures are considered *unlikely* in the county.

4.3.1.5 Vulnerability Assessment

The dam failure hazard is of significance to Fulton County because three of the county's seven dams are classified as high-hazard by PA DEP. Warning time for dam failure is often limited. These events are frequently associated with other natural hazard events such as earthquakes, landslides, or severe weather, limiting their predictability and compounding the hazard. Populations without adequate warning of the event are highly vulnerable to this hazard. Direct and indirect losses associated with dam failures include injury and loss of life, damage to structures and infrastructure, agricultural losses, utility failure (power outages), and stress on community resources.

Impact on Life, Health, and Safety; General Building Stock; Critical Facilities; and the Economy

The entire population residing within a dam failure inundation zone is considered exposed and vulnerable. Of the population exposed, the most vulnerable include the economically disadvantaged and the population over the age of 65. Economically disadvantaged populations are more vulnerable because they are likely to evaluate their risk and make decisions to evacuate based on the net economic impact to their family. The population over the age of 65 is also highly vulnerable because they are more likely to seek or need medical attention that may not be available because of isolation during a flood event, and they may have more difficulty evacuating.

The EAPs associated with the Fulton County high-hazard dams provide information concerning the estimated number of homes and residents vulnerable to a dam failure. Dam failure events are frequently associated with other natural hazard events such as earthquakes, landslides, or severe weather, which limits their predictability and compounds the hazard. Populations without adequate warning of the event are highly vulnerable to this hazard.

Table 4.3.1-4. Fulton County High-Hazard Dam EAP Impacts

Dam Name	Vulnerable Structures/Homes	Vulnerable Residents
Meadow Grounds Dam	65 Homes	163 Residents
Cowans Gap Dam	57 Permanent Inhabited Structures	N/A
Valley-Hi Dam	7 Homes	20 Residents

Source: Meadow Grounds EAP 2012, Cowans Gap EAP 2008, Valley-Hi EAP 2010
Note: The Cowans Gap Dam inundation area does not impact any hospitals, schools, or nursing homes. Fort Littleton Bible Church is located in the inundation area for Fort Littleton.
The Valley-Hi Dam inundation area does not impact any businesses, hospitals, nursing homes, or daycares.

Impact on General Building Stock, Critical Facilities, and the Economy

All buildings and infrastructure located in the dam failure inundation zone are considered exposed and vulnerable. Property located closest to the dam inundation zone has the greatest potential to experience the largest, most destructive surge of water. All transportation infrastructures within the dam failure inundation zone are vulnerable to damage. Damage to these infrastructures could cut off evacuation routes, limit emergency access, and create isolation issues. Utilities such as overhead power, cable, and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation zones.

Impact on the Environment

The environment is vulnerable to several risks in the event of a dam failure. Water releases from dams usually contain very little suspended sediment; this can lead to scouring of river beds and banks. The inundation may introduce foreign elements into local waterways, resulting in destruction of downstream habitat and impacting many animal and plant species, especially endangered species. The subsequent rush of water downstream can rapidly increase flow rate and turbidity of streams and rivers in minor dam failures or overwhelm terrestrial habitat with floodwaters in severe dam failure events.

Dam failures can often result in the release of hazardous materials, either swept up in floodwaters or in sediment that is contained behind the dam as is often the case in areas that have had mining activities take place upstream. After the flood waters subside, contaminated and flood-damaged building materials and contents must be properly disposed. Contaminated sediment must be removed from buildings, yards, and properties.

Dam failures may result in significant water quality and debris disposal issues. Flood waters can back up sanitary sewer systems and inundate wastewater treatment plants, causing raw sewage to contaminate residential and commercial buildings and the flooding waterway. The contents of unsecured containers of oil, fertilizers, pesticides, and other chemicals get added to flood waters. Water supplies and wastewater treatment could be off-line for weeks. After the flood waters subside, contaminated and flood-damaged building materials and contents must be disposed of properly.

Future Growth and Development

As discussed in Section 2.4, areas targeted for future growth and development have been identified across the county. Any areas of growth could be impacted by the dam failure hazard if within the identified hazard areas. The county intends to discourage development within vulnerable areas and to encourage higher regulatory standards on the local level.

While existing floodplain development regulations in place may offer some protection for new development located in these areas, such protections would likely not be sufficient in many instances in the event of a catastrophic dam failure. This results from a number of factors, such as the extent of the dam inundation areas may be larger than the regulated floodplain, and water depths and velocities may be stronger and higher than the 1% annual chance flood event.

Effect of Climate Change on Vulnerability

The climate of Pennsylvania is already changing and will continue to change over the course of this century. Precipitation is expected to increase over the next several decades. Future climate change may impact storm patterns, increasing the probability of more frequent, intense storms with varying duration. Since dam overtopping is often caused by excessive rainfall, it is appropriate to relate the future vulnerability of dams directly with the potential for increased rainfall in Fulton County.

Dams are designed partly based on assumptions about a river's flow behavior, expressed as hydrographs (flow over time). Changes in weather patterns can have significant effects on the hydrograph used for the design of a dam. If the hydrograph changes, it is conceivable that the structure can lose some or all of its designed margin of safety, also known as freeboard. Loss of designed margins of safety may cause floodwaters to more readily overtop the dam or create unintended loads. Such situations could lead to a dam failure.

Climate change may increase the probability of dam failures, as indicated above. Changes in climate may lead to higher intensity rainfall events. As a result, the failure probability of low, significant, and under-designed high-hazard dams may increase.

Additional Data and Next Steps

This vulnerability assessment was based on the most current and best available data, including updated building and critical facilities inventories. For future Hazard Mitigation Plan (HMP updates), additional dam failure inundation areas can be delineated and used to spatially assess the asset exposure. A custom-general building stock could be generated for future plans to assess impacts at the structural level versus the census block level. Depth grids could be generated for the inundation areas and used in HAZUS-MH to estimate potential losses similar to Flood (Section 4.3.5).