

## SECTION 4. RISK ASSESSMENT

### 4.3 Hazards of Concern

This section provides a hazard profile and vulnerability assessment of the dam and levee failure hazard in Camden County.

#### 2022 HMP Changes

- Due to similarities, and their combination in the 2019 NJ HMP, the Dam Failure and Levee Failure hazards are now discussed in the same section.
- The hazard profile has been significantly enhanced to include a detailed hazard description, location, extent, previous occurrences, probability of future occurrence, and potential change in climate and its impacts on the hazard is discussed.
- New and updated figures from federal and state agencies are incorporated.
- Previous occurrences were updated with events that occurred between 1950 and 2020.

#### 4.3.2 Dam and Levee Failure

##### Dam Failure

A dam is an artificial barrier that has the ability to store 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 the stated functions (Association of State Dam Safety Officials 2020).

Dam failures typically occur 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 waters that rush downstream damaging and/or destroying anything in its path (FEMA 1997).

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

- Overtopping caused by floods that exceed the capacity of the dam
- Deliberate acts of sabotage
- Structural failure of materials used in dam construction
- Movement and/or failure of the foundation supporting the dam
- Settlement and cracking of concrete or embankment dams
- Piping and internal erosion of soil in embankment dams
- Inadequate maintenance and upkeep (New Jersey HMP 2019)

##### Levee Failure

A levee is a physical barrier constructed to protect areas from rising floodwaters. Levees typically remove valuable floodplain storage and block the ability of the channel to move water. There are also concerns

with rainfall that falls on the levee itself. Most important is the possibility for catastrophic and sudden failure under extreme flood events, potentially resulting in loss of life and total destruction of property.

A levee breach occurs when part of a levee gives way, creating an opening through which floodwaters may pass. A breach may occur gradually or suddenly. The most dangerous breaches happen quickly during periods of high water. Earthen levees can be damaged in several ways. Strong river currents and waves can erode the surface. Trees growing on a levee can blow over, leaving a hole where the root wad and soil used to be. Burrowing animals can create holes that enable water to pass through a levee. If severe enough, any of these situations can lead to a zone of weakness that could cause a levee breach. In seismically active areas, earthquakes and ground shaking can cause a loss of soil strength, weakening a levee and possibly resulting in failure. Seismic activity can also cause levees to slide or slump, both of which can lead to failure.

#### 4.3.2.1 Location and Extent

##### Dams

The New Jersey Department of Environmental Protection (NJDEP) database identified and classified 77 state-regulated dams in Camden County; refer to Table 4.3.2-1. Of the 77 dams, 1 has been classified as having 'high hazard potential', meaning its failure may cause the probable loss of life or extensive property damage. It is important to note the classification is based on the consequences of dam failure and not the condition, probability or risk of failure itself.

Table 4.3.2-1. Number of Dams in Camden County

High Hazard	Significant Hazard	Low Hazard	Other Structures
1	19	57	7

Source: NJ DEP 2021

In addition, NJDEP identifies seven 'other structures' in Camden County. These structures are not classified as dams within their database but may be similar structures. These include dams that are less than five feet, have been removed, never built, failed, etc.

Camden County considers the location of dams as sensitive information; therefore, a map is not displayed and the number and classification of dams in each municipality is not listed in the plan.

##### Levees

The USACE estimates that there are as many as 100,000 miles of levees across the United States. Levee systems exist throughout the coastal areas of New Jersey, including along the Delaware River. There are 17 levee systems in Camden County, concentrated along the Delaware River and Pennsauken Creek (USACE 2021).

### 4.3.2.2 Range of Magnitude

#### Dam Failure

The extent or magnitude of a dam failure event can be measured in terms of the classification of the dam. Additionally, there are two factors that influence the potential severity of a full or partial dam failure are: (1) the amount of water impounded; and (2) the density, type, and value of development and infrastructure located downstream (Association of State Dam Safety Officials 2020).

FEMA, USACE and NJDEP all have classification systems for dams. Please refer to *Federal Guidelines for Dam Safety: Hazard Potential Classification System for Dams* (2004) and *Safety of Dams – Police and Procedures* (2014) for an explanation of the FEMA and USACE classifications.

The New Jersey Department of Environmental Protection (NJDEP) assigns one of four hazard classifications to state-regulated dams in New Jersey. The classifications relate to the potential property damage and/or loss of life in the event of a dam failure.

- Class I (High-Hazard Potential) - Failure of the dam may result in probable loss of life and/or extensive property damage
- Class II (Significant-Hazard Potential) - Failure of the dam may result in significant property damage; however, loss of life is not envisioned.
- Class III (Low-Hazard Potential) - Failure of the dam is not expected to result in loss of life and/or significant property damage.
- Class IV (Small-Dam Low-Hazard Potential) - Failure of the dam is not expected to result in loss of life or significant property damage. Dam must also meet the requirements of a Class IV dam above (NJDEP 2014).

It is required by the State of New Jersey that all High Hazard and Significant Hazard dams must have NJDEP-approved Emergency Action Plans (EAP) in place. It is the responsibility of the dam owner to review and update the EAP on an annual basis. The State also requires regular dam inspections. Dam Safety Inspections are intended to identify conditions that may adversely affect the safety and functionality of a dam and its appurtenant structures; to note the extent of deterioration as a basis for long term planning, periodic maintenance or immediate repair; to evaluate conformity with current design and construction practices; and to determine the appropriateness of the existing hazard classification. Inspection guidelines are summarized in Table 4.3.2-2. Complete inspection and operating requirements for dams can be found in the New Jersey Dam Safety Standards (N.J.A.C. 7:20-1.11).

Table 4.3.2-2. New Jersey Dam Inspection Requirements

Dam Size/Type	Regular Inspection	Formal Inspection
Class I (High Hazard) Large Dam	Annually	Once every 3 years
Class I (High Hazard) Dam	Once every 2 years	Once every 6 years
Class II (Significant Hazard) Dam	Once every 2 years	Once every 10 years
Class III (Low Hazard) Dam	Once every 4 years	Only as required
Class IV (Zero Hazard) Dam	Once every 4 years	Only as required

Source: N.J.A.C. 7:20-1.11

In New Jersey, every dam in the State as defined in the Safe Dam Act, N.J.S.A. 58:4 is required to meet State dam safety standards. Dam Safety Laws provide the NJDEP with enforcement capabilities to achieve statewide compliance with dam safety standards. This includes issuing orders for compliance to dam owners, and pursuing legal action if the owner does not comply (with the goal of compliance and possible fines levied on a per-day basis for violations) (NJDEP 2017).

### Levee Failure

In the event of a levee failure, floodwaters may ultimately inundate the protected area landward of the levee. The extent of inundation is dependent on the flooding intensity. Failure of a levee during a 1-percent annual chance flood will inundate the approximate 100-year flood plain previously protected by the levee. Residential and commercial buildings located nearest the levee overtopping or breach location will suffer the most damage from the initial embankment failure flood wave. Landward buildings will be damaged by inundation (FEMA 2004).

Levees require maintenance to continue to provide the level of protection they were designed and built to offer. Maintenance responsibility belongs to a variety of entities including local, state, and federal government and private landowners. Well-maintained levees may obtain certification through independent inspections. Levees may not be certified for maintaining flood protection when the levee owner does not maintain the levee or pay for an independent inspection. The impacts of an uncertified levee include higher risk of levee failure. In addition, insurance rates may increase because FEMA identifies on Flood Insurance Rate Maps that the structures are not certified to protect from a one-percent annual chance flood event (FEMA 2004).

#### 4.3.2.3 Past Occurrences

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As stated in the 2019 New Jersey State HMP, dam failures can occur suddenly, without warning, and may occur during normal operating conditions. This is referred to as a “sunny-day” failure. Dam failures may also occur during a large storm event. Significant rainfall can quickly inundate an area and cause floodwaters to overwhelm a reservoir. If the spillway of the dam cannot safely pass the resulting flows, water will begin flowing in areas not designed for such flows, and a failure may occur. New Jersey has seen significant property damage including damage or loss of dams, bridges, roads, and buildings as a result of storm events and dam failures (NJOEM 2019).

Between 1954 and 2020, FEMA has not included New Jersey in any dam or levee failure-related disasters (DR) or emergencies (EM). Camden County has not experienced dam failures in the past. According to the 2019 New Jersey HMP, during the July 12-13, 2004 heavy rains, 17 dams failed, and 28 dams were damaged in nearby Burlington County, which exacerbated flooding in parts of Camden County (Figure 4.3.2-1).



New Jersey as a result of heavy rains or other precipitation. There is a “residual risk” associated with dams. Residual risk is the risk that remains after safeguards have been implemented. For dams, the residual risk is associated with events beyond those that the facility was designed to withstand. However, the probability of any type of dam failure is low in today’s dam safety regulatory and oversight environment (New Jersey State HMP 2019).

In Section 4.4, the identified hazards of concern for Camden County were ranked. The probability of occurrence, or likelihood of the event, is one parameter used for hazard rankings. Based on historical records and input from the Planning Committee, the probability of occurrence for dam failure in the County is considered ‘rare’ (between 1 and 10% annual probability of occurring).

#### 4.3.2.5 Climate Change Impacts

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New Jersey has become wetter over the past century. Northern New Jersey’s 1971-2000 precipitation average was over five inches (12-percent) greater than the average from 1895-1970 (Sustainable Jersey Climate Change Adaptation Task Force [CATF] 2011). The heaviest 1 percent of daily rainfalls have increased by approximately 70 percent between 1958 and 2011 in the Northeast (Horton et al. 2015). Average annual precipitation is projected to increase in the region by 4 to 11-percent by the 2050s and 5 to 13-percent by the 2080s (New York City Panel on Climate Change [NPCC] 2015).

As described in the State HMP, dams are designed partly based on assumptions about a river’s flow behavior, expressed as hydrographs. 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 dam can lose some or its entire designed margin of safety, also known as freeboard. Loss of designed margin of safety may cause floodwaters more readily to overtop the dam or create unintended loads. Such situations could lead to a dam failure (NJOEM 2019).

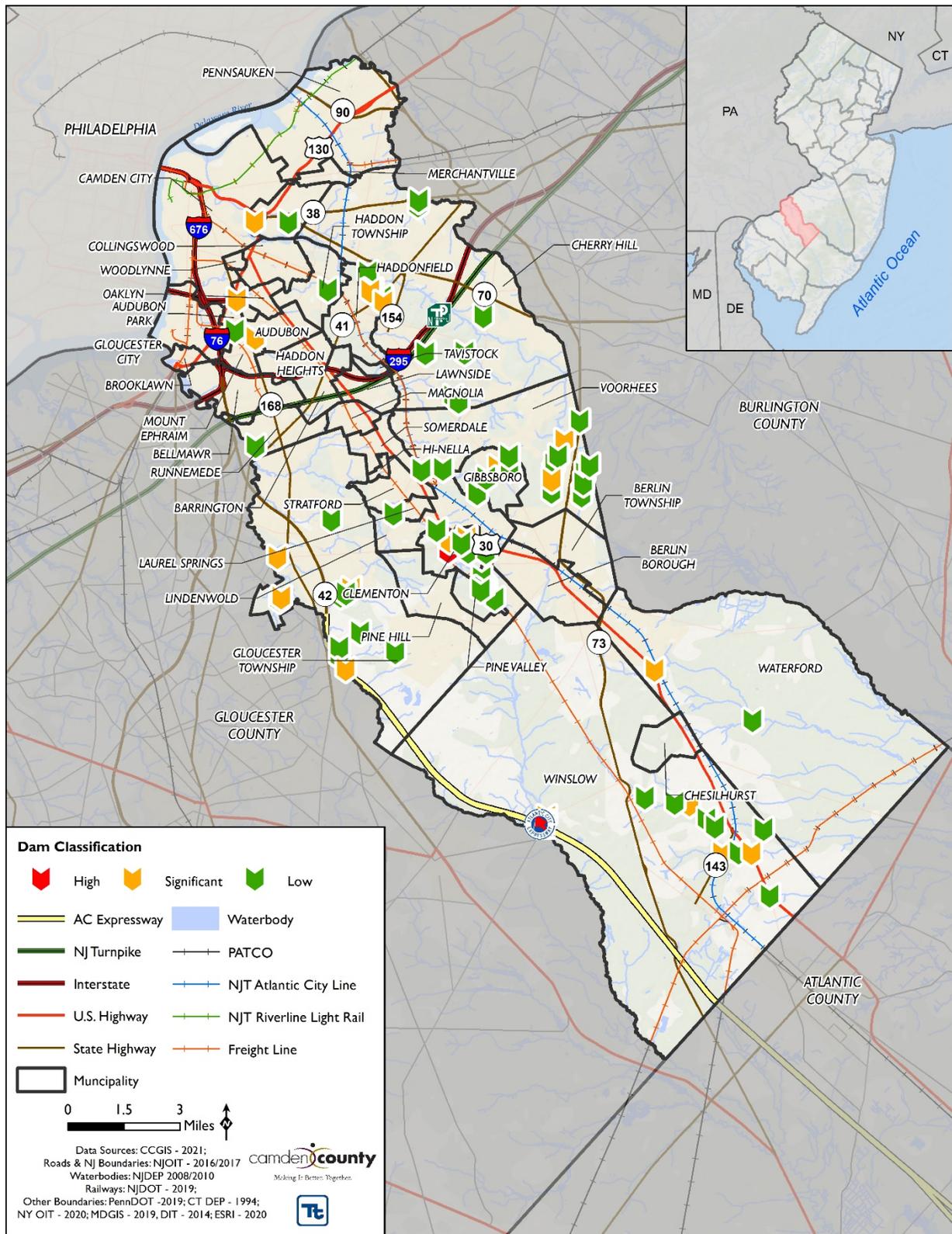
#### 4.3.2.6 Vulnerability Assessment

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The dam failure hazard is of significance to Camden County because 77 dams are present across Camden County, one of which is classified as high hazard by NJ DEP (Figure 4.3.1-2). 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.

Dam failure inundation maps and downstream hazard areas are considered sensitive information and are not made available in the Camden County Hazard Mitigation Plan. To assess Camden County’s risk to dam failure, a qualitative review was implemented.

Figure 4.3.2-2. Classification of Dams Located In Camden County



**Impact on Life, Health and Safety**

The impact of dam and levee failure on life, health, and safety is dependent on several factors such as the class of dam/levee, the area that the dam/levee is protecting, the location of the dam/levee, and the proximity of structures, infrastructure, and critical facilities to the dam or levee structure. According to the State HMP, the level of impact that a failure would have can be predicted based upon the hazard potential classification as rated by the United States Army Corps of Engineers (State of NJ 2019). Table 4.3.2-3 outlines the recommended hazard classifications.

*Table 4.3.2-3 United States Army Corps of Engineers Hazard Potential Classification*

Hazard Category(a)	Direct Loss of Life (b)	Lifeline Losses (c)	Property Losses (d)	Environmental Losses (e)
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

- a. Categories are assigned to overall projects, not individual structures at a project.
- b. Loss-of-life potential is based on inundation mapping of area downstream of the project. Analyses of loss-of-life potential should take into account the population at risk, time of flood wave travel, and warning time.
- c. 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.
- d. 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.
- e. 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: State of NJ 2019

The entire population residing within a dam failure inundation zone is considered exposed and vulnerable to an event. The potential for loss of life is affected by the capacity and number of evacuation routes available to populations living within these areas. Those most at risk include the economically disadvantaged and the population over the age of 65. The 2019 American Community Survey population estimates indicate there were 77,791 persons over 65 years old and 61,187 living below the poverty level in Camden County. These populations are more at risk during a dam failure event because economically disadvantaged populations are likely to evaluate their risk and make the decision to evacuate based upon the net economic impact to their family, while elderly populations are likely to seek or need medical attention. The availability of medical attention may be limited due to isolation during a flood event and other difficulties in evacuating. There is often limited warning time for a dam failure event. Populations without adequate warning of the event are highly vulnerable.

Dam failure can cause persons to become displaced if flooding of structures occurs. Dam failure may mimic flood events, depending on the size of the dam reservoir and breach. Understanding potential outcomes of flooding for each dam in Camden County would require intensive hydraulic modeling.

#### Impact on General Building Stock

Buildings located downstream of a dam are at risk to damages should there be a failure. Downstream inundation areas were not available to quantify any potential losses to structures. Properties located closest to the dam inundation area have the greatest potential to experience the largest, most destructive surge of water. The overall impact of flooding damages caused by dam failure will vary depending on the depth of flooding and velocity of the surge.

#### Impact on Critical Facilities and Lifelines

Dam failures may also impact critical facilities and lifelines located in the downstream inundation zone. Consequentially, dam failure can cut evacuation routes, limit emergency access, and/or create isolation issues. Dam failure can cause severe downstream flooding and may transport large volumes of sediment and debris, depending on the magnitude of the event. Widespread damage to buildings and infrastructure affected by an event would result in large costs to repair these locations. In addition to physical damage costs, businesses can be closed while flood waters retreat and utilities are returned to a functioning state. Further, utilities such as overhead power lines, cable and phone lines could also be vulnerable. Loss of these utilities could create additional isolation issues for the inundation areas.

#### Impact on the Economy

Severe flooding that follows an event like a dam failure can cause extensive structural damage and withhold essential services. The cost to recover from flood damages after a surge will vary depending on the hazard risk of each dam. The State HMP discusses damages from dam failures ranging from \$7 million to \$25 million as a result of previous events in the State. This cost likely varies because of the density of structures and businesses that surround the protected area.

Severe flooding that follows an event like a dam failure can cause extensive damage to public utilities and disruptions to delivery of services. Loss of power and communications may occur and drinking water and wastewater treatment facilities can become temporarily out of operation. Debris from surrounding buildings can accumulate should the dam mimic major flood events, such as the 1-percent annual chance flood event that is discussed in Section 4.3.7 (Flood).

#### Impact on the Environment

The environmental impacts of a dam failure can include significant water-quality and debris-disposal issues or severe erosion that can impact local ecosystems. Flood waters can back up sanitary sewer systems and inundate wastewater treatment plants, causing raw sewage to contaminate residential and commercial buildings and the flooded waterway. The contents of unsecured containers of oil, fertilizers, pesticides, and other chemicals may get added to flood waters. Hazardous materials may be released and distributed widely across the floodplain. Water supply and wastewater treatment facilities could be offline for weeks. After the flood waters subside, contaminated and flood-damaged building materials

and contents must be properly disposed of. Contaminated sediment must be removed from buildings, yards, and properties.

### Future Changes That May Impact Vulnerability

Understanding future changes that affect vulnerability can assist in planning for future development and ensure establishment of appropriate mitigation, planning, and preparedness measures. Several factors are examined in this section to assess hazard vulnerability.

### Projected Development

As discussed and illustrated in Section 3 (County Profile), areas targeted for future growth and development have been identified across the County. The New Jersey Pinelands Commission has identified Pinelands Management Area Boundaries, including regional growth areas and rural development areas that may also provide insight to where development and growth may occur in the County. In addition, each community was requested to provide recent and anticipated new development and infrastructure projects; summarized in Section 9 (Jurisdictional Annexes). According to the data provided by the communities, there are approximately 89 recent and anticipated new development projects for Camden County. While this number of new development projects could be underestimated, this best available data provides insight about future risk of impacts from dam failure for the County.

Any areas of growth could be potentially impacted by a dam or levee failure event if the structures are located within the flood protection area and mitigation measures are not considered. Therefore, it is the intention of the County and all participating municipalities to discourage development in vulnerable areas or to encourage higher regulatory standards at the local level. Due to the sensitive nature of dam locations and downstream inundation zones, an assessment to determine the proximity of these new development sites to potential dam inundation cannot be performed at this time.

### Projected Changes in Population

Camden County has experienced population decline since 2010. According to the U.S. Census Bureau, the County's population has decreased 1.3-percent between 2010 and 2019 (U.S. Census Bureau 2020). Even though the population has decreased, changes in population density should be evaluated as well. High population density can create issues for local residents during an evacuation. Refer to Section 3 (County Profile) for more information about population trends in the County.

### Climate Change

As discussed above, most studies project that the State of New Jersey will see an increase in average annual precipitation. An increase in annual precipitation amounts in the region, primarily in the form of heavy rainfalls, will have the potential to increase the potential for dam failure events. Increases in precipitation may stress the dam wall. Further, existing dams may not be able to retain and manage increases in water flow from more frequent, heavy rainfall events. Heavy rainfalls may result in more frequent overtopping of these dams and flooding of the County's assets in adjacent inundation areas. However, the probable maximum flood used to design each dam may be able to accommodate changes in climate.

**Change of Vulnerability Since 2017 HMP**

Overall, the County’s vulnerability has not changed and the County will continue to be exposed and vulnerable to dam failure events, especially those located within or near downstream inundation zones. Because of the sensitive nature of the dam failure inundation zones, potential losses have not been quantified and presented in this plan. To estimate potential losses to population, buildings, critical facilities and infrastructure, dam inundation areas and depths of flooding may be used to generate depth grids. Hazus may be used to estimate potential losses for the County and participating municipalities.

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