4.3 DAM & LEVEE FAILURE

SECTION 4.3 DAM AND LEVEE FAILURE

4.3-1 HAZARD OVERVIEW

Note: Appendix G contains the Enhanced Dam Risk Assessment, completed in 2022, which aligns with the planning requirements for the High Hazard Potential Dam (HHPD) Rehabilitation Program.

Hazard Definitions

Dam Failure

A dam is an artificial barrier that has the ability to store water, wastewater, or liquid-borne materials for many reasons, such as 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 and can be classified according to the type of construction material used, the methods used in construction, the slope or cross-section of the dam, the way the dam resists the forces of the water pressure behind it, the means used for controlling seepage, and, occasionally, according to the purpose of the dam (Association of State Dam Safety Officials, 2023).

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, 1996). 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 (FEMA 2013a)

The extent or magnitude of a dam failure event can be measured in terms of the classification of the dam. According to the NJDEP Dam Safety Program, there are three hazard classifications of dams. The classifications relate to the potential for property damage and/or loss of life in the event of a dam failure. Probable future development of the area downstream from the dam which might be affected by its failure is also considered in determining the hazard classification.

- Class I - High-Hazard Potential: This classification includes those dams, the failure of which may cause the probable loss of life or extensive property damage.
    i. The existence of normally occupied homes in the area that are susceptible to significant damage in the event of a dam failure will be assumed to mean "probable loss of life".
    ii. Extensive property damage means the destructive loss of industrial or commercial facilities, essential public utilities, main highways, railroads or bridges. A dam may be classified as having a high hazard potential based solely on high projected economic loss.
    iii. Recreational facilities below a dam, such as a campground or recreation area, may be sufficient reason to classify a dam as having a high hazard potential.
- Class II - Significant-Hazard Potential: This classification includes those dams, the failure of which may cause significant damage to property and project operation, but loss of human life is not envisioned. This classification applies to predominantly rural, agricultural areas, where dam failure may damage isolated homes, major highways or railroads or cause interruption of service of relatively important public utilities.
- Class III - Low-Hazard Potential: This classification includes those dams, the failure of which would cause loss of the dam itself but little or no additional damage to other property. This classification applies to rural or agricultural areas where failure may damage farm buildings other than residences, agricultural lands, or non-major roads.

Levee Failure

Levees are typically barriers between floodwaters and a nearby municipality. They include a series of culverts, canals, ditches, storm sewers, or pump stations, called "interior drainage" systems. These systems channel water from the land side of a levee over to the water side. When floodwaters exceed the height of a levee, overtopping occurs. As the water passes over the top, it can erode the levee, worsening the flooding and potentially causing an opening or beach in the levee. A levee breach occurs when part of a levee gives way, creating an opening through which floodwaters may pass. A breach can occur gradually or suddenly. The most dangerous breaches happen quickly during periods of high water. The resulting torrent can quickly swamp a large area behind the failed levee with little to no warning (American Society of Civil Engineers, 2010). USACE operates, maintains, and evaluates levees to determine if they meet accreditation requirements. Most levees are owned by local communities and flood control districts that must ensure proper operation and maintenance of the levee system as well (FEMA, 2013c). It should be noted that a designed levee is different from a bulkhead which serves the primary purpose of keeping soil in place and preventing the shoreline from eroding during flooding and wave attack.

Dam Failure Warning Times

Dams can fail with little warning; warning time varies depending on the cause of the failure. Intense storms may produce a flood in a few hours or even minutes for upstream locations. Flash floods can occur within a few minutes of the beginning of heavy rainfall, and dam failure may occur within hours of the first signs of breaching. Other failures and breaches can take much longer to occur, from days to weeks, because of debris jams, the accumulation of melting snow, buildup of water pressure on a dam with deficiencies after days of heavy rain, etc. Flooding can occur when a dam operator releases excess water downstream to relieve pressure from the dam (FEMA, 2013d).

In events of extreme precipitation or massive snowmelt, evacuations can be planned with sufficient time. In the event of a structural failure because of earthquake, there may be no warning time. A dam's structural type also affects warning time. Earthen dams do not tend to fail completely or instantaneously. Once a breach is initiated, discharging water erodes the breach until either the reservoir water is depleted, or the breach resists further erosion. Concrete gravity dams also tend to have a partial breach as one or more monolith sections are forced apart by escaping water. The time of breach formation ranges from a few minutes to a few hours (USACE, 1997).

Levee Failure Warning Times

Like dam failures, warning time depends on the cause of the failure. A levee failure caused by structural failure can be sudden and perhaps with little to no warning. This is despite warnings regarding the structural integrity of the system. If heavy rains are impacting a levee system, communities located in the immediate danger zone can be evacuated before a failure occurs. If the levee failure is caused by overtopping, the community may or may not be able to recognize the impending failure and evacuate. If a levee failure occurs suddenly, evacuation may not be possible.

Secondary Hazards

Dam Failure

Dam failure can cause severe downstream flooding, depending on the magnitude of the failure. Other potential secondary hazards of dam failure are landslides around the reservoir perimeter, bank erosion on the rivers, and destruction of downstream habitat. Dam failures can occur as a result of structural failures, such as progressive erosion of an embankment or overtopping and breaching by a severe flood. Earthquakes may weaken dams. Floods caused by dam failures have caused loss of life and property damage (FEMA, 1996).

Levee Failure

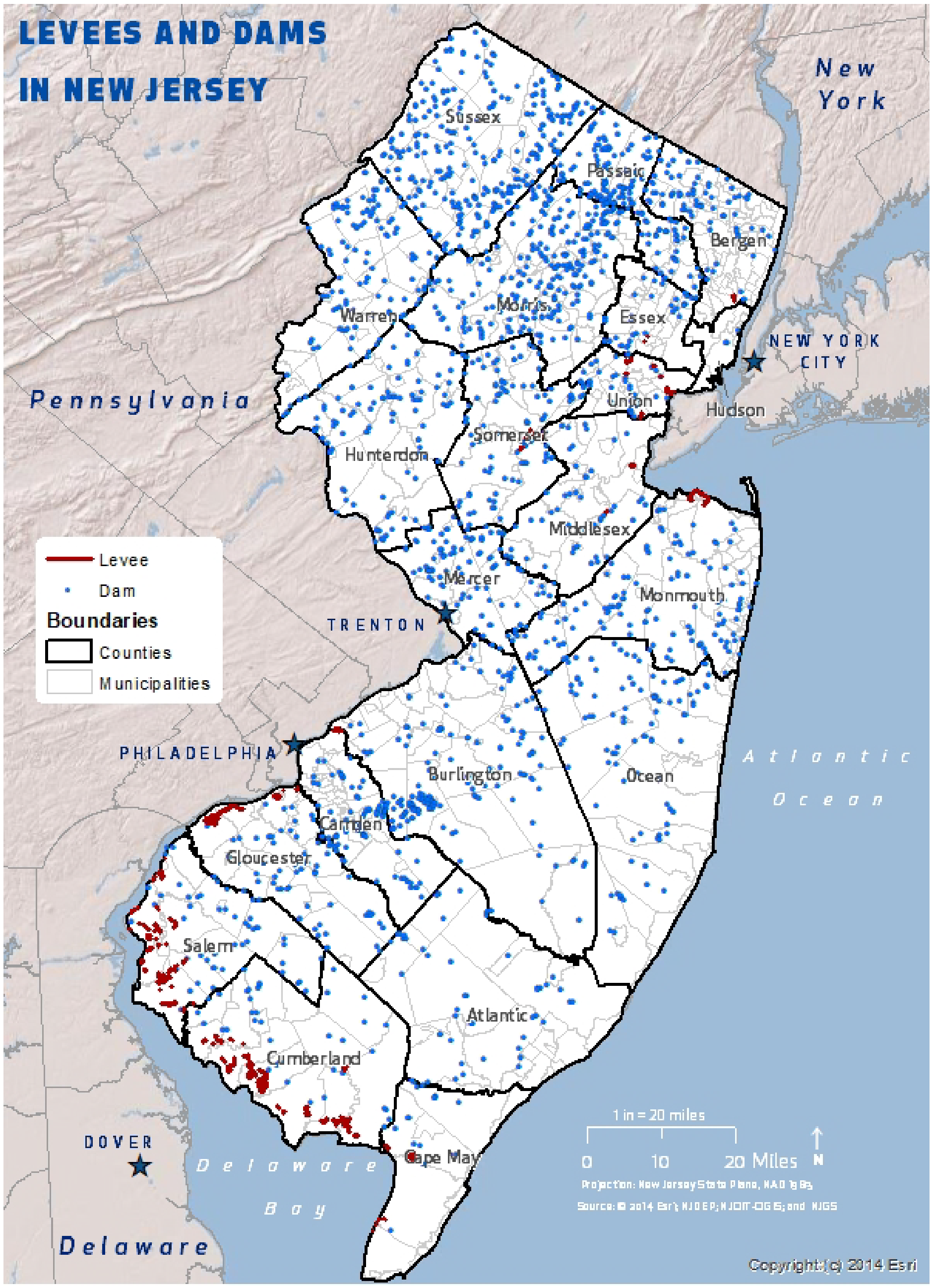
Levee failures can cause severe downstream flooding like that of dam failure. Also similar to dam failure, levee failure can cause landslides, bank erosion, and destruction of habitat as well as loss of life and property damage. Levee failures can also cause environmental incidents due to hazardous materials releases when floodwaters infiltrate facilities that store these types of materials.

4.3-2 LOCATION AND EXTENT

Location

According to the NJDEP Bureau of Dam Safety there are 1,730 regulated dams in New Jersey, many of which are concentrated in the north and center of the State. Nearly half (48%) of the dams in New Jersey are owned by private entities or individuals. A comprehensive listing regarding the types and locations of levees across the State is not available. This is due in part to the lack of oversight at the State level, but more notably because many of the levee systems were not built through formal processes. According to the USACE's National Levee Database (NLD) there are 101 levee systems in New Jersey that span a total of 95 miles and have an average age of 34 years. Figure 4.3-1 displays the location of these dams and levees throughout New Jersey.

Figure 4.3-1 Locations of Dams and Levees in New Jersey



Source: NJDEP, 2013

Table 4.3-1 lists more information on levee systems by county as reported in the NLD. It only includes counties that have levee systems. There are 11 levee systems that are FEMA Accredited, which means that FEMA determined that each meets the requirements of NFIP regulations and Flood Rate Insurance Maps (FIRMs) recognizing that the levee reduces the flood hazard posed by 1-percent-annual-chance flood events (FEMA, 2020). According to USACE, there are 10 levees in New Jersey in Essex, Gloucester, Monmouth, and Union Counties that are a part of its Rehabilitation and Inspection Program (RIP) that provides funding and technical assistance to levees with non-federal public sponsors (USACE, 2023). There are 35 levee systems with state or local sponsors, one with a federal sponsor, 30 systems sponsored by either private individuals or corporations, and 38 systems that have unknown sponsors. These do not add up to 101 as some systems have multiple sponsors.

Table 4.3-1 Levee Locations and Characteristics by County

County	Total Number of Levees	Total Length (Miles)	FEMA Accredited Levees	Levees in USACE Rip Program	Levees with State or Local Sponsors	Levees with Federal Sponsor	Levees with Private Sponsor
Bergen	1	0.81	0	0	1	0	0
Burlington*	1	0.74	0	0	1	0	0
Camden*	3	2.29	0	0	3	0	0
Cape May	6	5.65	0	0	2	0	2
Cumberland	31	32.4	0	0	6	0	11
Essex	2	0.18	2	2	2	0	0
Gloucester	5	11.86	3	0	2**	0	2**
Middlesex*	3	3.65	2	1	3	0	0
Monmouth	1	5.34	0	1	1	0	0
Salem	38	23.50	0	0	8	1	15
Somerset*	3	3.24	2	1	2	0	0
Union	9	6.00	3	6	6	0	0

* Includes systems that span multiple counties
** One levee has multiple sponsors
Source: USACE, 2023

Dam Failure – Extent

Table 4.3-2 summarizes the number of dams and their hazard classifications, by County. Passaic, Morris, and Sussex Counties have the most high-hazard dams, each with over 40. They are the only counties with more than twelve such dams and have 56.4% of all high-hazard dams in New Jersey. Morris and Sussex Counties also have around 40 significant hazard dams.

Table 4.3-2 Number of Dams by County in New Jersey

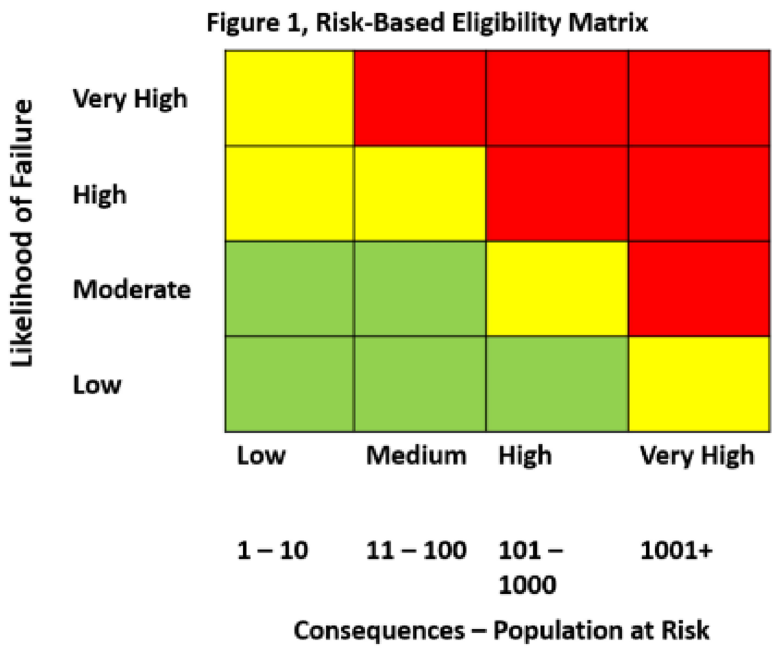
County	High Hazard		Significant Hazard		Low Hazard		Total
	Count	Share	Count	Share	Count	Share	
Atlantic	1	3%	8	20%	31	78%	40
Bergen	7	9%	10	13%	61	78%	78
Burlington	10	14%	40	54%	95	128%	74
Camden	1	1%	19	25%	55	73%	75
Cape May	0	0%	7	64%	4	36%	11
Cumberland	3	13%	11	46%	10	42%	24
Essex	8	27%	5	17%	17	57%	30
Gloucester	3	5%	23	42%	29	53%	55

County	High Hazard		Significant Hazard		Low Hazard		Total
	Count	Share	Count	Share	Count	Share	
Hudson	1	100%	0	0%	0	0%	1
Hunterdon	10	11%	9	10%	73	79%	92
Mercer	8	9%	8	9%	72	82%	88
Middlesex	4	9%	11	26%	28	65%	43
Monmouth	12	11%	15	13%	86	76%	113
Morris	40	18%	45	20%	141	62%	226
Ocean	8	8%	16	16%	76	76%	100
Passaic	50	37%	22	16%	62	46%	134
Salem	1	2%	20	47%	22	51%	43
Somerset	5	6%	12	14%	68	80%	85
Sussex	41	17%	41	17%	157	66%	239
Union	3	12%	8	32%	14	56%	25
Warren	15	18%	6	7%	62	75%	83
Totals	231	13%	336	19%	1163	67%	1730

Source: NJDEP, 2023

FEMA also has a dam classification system. In 2021, the FEMA HHPD Grant Program introduced a new risk-based eligibility matrix, used in combination with assessment data from USACE's National Inventory of Dams (NID), to create a more consistent process for assessing dam risk and prioritizing funding from the program. It was only applicable for Fiscal Year (FY) 2021 but gives insight into how FEMA analyzes the risks associated with dam failures. Figure 4.3-2 below shows this matrix, with the Likelihood of Failure directly tied to the NID Condition Assessment results.

Figure 4.3-2 FEMA FY 2021 Risk Eligibility Matrix



Levee Failure – Extent

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 one-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 un-certified 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).

4.3-3 PREVIOUS OCCURANCES AND LOSSES

FEMA Disaster Declarations

Based on all sources researched, New Jersey has not been included in any FEMA disaster declarations directly related to dam or levee failure events since the first disaster declaration in 1953.

Historic Events Summary for Dam Failure

The following section provides details about several dam failure events that occurred in New Jersey since 2004. Several sources provided historical information regarding previous occurrences and losses associated with dam failure events throughout the State. Loss and impact information for these events could vary depending on the source; therefore, the accuracy of monetary figures and event details is based only on the available information identified during research for this HMP. No data on the history of levee failure events was found.

Burlington County Storm, 2004

On July 12, 2004, parts of Burlington County, New Jersey experienced an unusually heavy rainfall event. The areas hit most severely were Evesham Township, Medford Township, Medford Lakes Borough, Mt. Laurel Township, Pemberton Township, Southampton Township, and Tabernacle Township. Doppler radar estimates of total rainfall for the 24-hour period ending 0700 hours EDT on July 13, 2004 were between 8-12 inches. A total of 18 dams failed as a result of the ensuing floods, and another 28 were damaged. Property damage from the flood was estimated at $50 million. The flooding led to the evacuation of about 760 residents, the complete destruction of seven homes, major flood damage to approximately 200 homes, flood damage to approximately 1,000 homes, the closing of 25 major roads, (including the New Jersey Turnpike and New Jersey State Routes 70 and 73), and serious damage or destruction to 14 bridges (NOAA NCEI 2023).

Southwestern New Jersey Dam Breaks, 2011

Between August 13 and 14, 2011, heavy rains resulted in flooding in southwest New Jersey. The areas hit most severely were eastern Salem, western Cumberland, eastern Gloucester, eastern Camden, and western Atlantic Counties. Rainfall totals in these counties included 10.82 inches in Upper Deerfield Township (Cumberland County), 8.53 inches in Franklin Township (Gloucester County), 8.04 inches in Winslow Township (Camden County) and 7.51 inches at Hammonton (Atlantic County).

In Cumberland, Gloucester, and Salem Counties, more than 181 homes were damaged including 33 homes that received major damage. Overall, this storm resulted in 1 death and over $25 million in property damages in New Jersey (NOAA, NCEI, 2013). A total of 4 dams failed as a result of the ensuing floods, and another 26 were damaged. Inspection teams, consisting of Bureau engineers, performed inspections to assess damages and hazards associated with the area dams. A total of 125 dams were inspected by Bureau engineers in the days following the event (NJDEP, 2023)

Tropical Storm Irene, August 2011

Tropical Storm Irene struck the State of New Jersey between August 27 and 28, 2011. Irene was reclassified from a hurricane to a tropical storm just prior to making landfall in New Jersey. The storm caused the largest coastal evacuation in State history, record flooding on many rivers, hundreds of road closures., power outages to over 700,000 residents, and at least 12 fatalities (New Jersey State Hazard Mitigation Plan, 2014). Overall, Tropical Storm Irene resulted in over $760 million in property damages in New Jersey (NOAA, NCEI, 2013). The statewide rainfall average was approximately 7 inches, making Tropical Storm Irene New Jersey's largest rainstorm in over a century. Portions of Monmouth, Union, Morris, and Passaic Counties received more than 10 inches of rainfall.

The NJDEP Bureau of Dam Safety reported that a total of six dams failed as a result of the ensuing floods, and 51 dams were damaged. Three of the failed dams are located upstream from USGS gaging stations. Saffin Pond Dam failed completely. It is located on Weldon Brook, a tributary to Lake Hopatcong, upstream from the USGS stage-only gage on Lake Hopatcong and the continuous-record streamflow-gaging station on Musconetcong River at the outlet of Lake Hopatcong. The New Jersey No Name # 89 Dam, located on a tributary to Crosswicks Creek in North Hanover Township in Burlington County upstream from the gage on Crosswicks Creek at Extonville, failed completely. The Bureau of Dam Safety also reported damage to the spillway at Cassville Dam, located on a small tributary to the Toms River, upstream from the gage on Toms River near Toms River. (USGS, 2013).

Inspection teams, consisting of Bureau engineers, performed inspections to assess damages and hazards associated with the area dams. A total of 119 dams were inspected by Bureau engineers in the week following the event (NJDEP, 2023)

Glen Lake Dam, January 2015

Uncontrolled seepage through the Glen Lake Dam in Sussex County caused internal erosion and led to a piping failure through the embankment adjacent to the dam's concrete spillway (ASDSO, 2023).

Clement Lake Dam, June 2019

After days of high winds and heavy rains between June 19-21, 2019, the Clement Lake Dam in Camden County breached near the spillway, releasing approximately 240,000 ft^3 of water downstream into the Millard Creek, which flows through the Route 561 Superfund Dump Site. Clement Lake Dam has a low hazard classification.

Porches Mill Dam, August 2020

On August 7, 2020, Woolwich Township in Gloucester County received heavy rainfall over a few hours causing Porches Mill Dam to overtop and breach. The event resulted in loss of the impoundment and a 70-foot section of Oliphant Mill Road which runs atop the dam (New Town Press, 2020).

4.3-4 PROBABILITY OF FUTURE OCCURENCES

Dam Failure

Dam failure events are infrequent and usually coincide with events that cause them, such as earthquakes, landslides, and excessive rainfall and snowmelt. As noted in the Previous Occurrences and Losses section, dam failures typically occur in New Jersey due to heavy rains or other precipitation. There is a "residual risk", or risk that remains after safeguards have been implemented, associated with dams. The residual risk for dams 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.

Despite the overall probability being low, it is still important to identify dams that pose significant risks to prevent future occurrences.

The following guidelines have been established by the NJDEP Bureau of Dam Safety to help meet the requirements of the National Inventory of Dams condition assessment of existing dam structures.

- Satisfactory: No existing or potential dam safety deficiencies are recognized. Acceptable performance is expected under all applicable loading conditions (static, hydrologic, seismic) in accordance with the applicable regulatory criteria. Minor maintenance items may be required.
- Fair: Acceptable performance is expected under all required loading conditions (static, hydrologic, seismic) in accordance with the applicable dam safety regulatory criteria. Minor deficiencies may exist that require remedial action and/or secondary studies or investigations.
- Poor: A dam safety deficiency is recognized for any required loading condition (static, hydrologic, seismic) in accordance with the applicable dam safety regulatory criteria. Remedial action is necessary. POOR also applies when further critical studies or investigations are needed to identify any potential dam safety deficiencies.
- Unsatisfactory: Considered unsafe. A dam safety deficiency is recognized that requires immediate or emergency remedial action for problem resolution. Reservoir restrictions may be necessary.

The risk assessment was based on the few dozen dams that qualified for the HHPD program risk assessment. As part of this plan update, an Enhanced Dam Risk Assessment was completed, both to identify the dams that should be prioritized in mitigation planning and to adhere to the planning requirements for FEMA's HHPD Rehabilitation Grant Program using their update risk-based eligibility matrix. The analysis identified 36 dams that were in poor condition and subjected them to further analysis that resulted in 19 dams falling into FEMA's High-Risk category. **Table 4.3-3 Prioritized HHPD-Poor Dams.** below showcases these dams. These dams represent the greatest risk due to the combination of their probabilities to fail and the expected consequences if they do. More information on the analysis, including the methodology, can be found in Appendix G.

Table 4.3-3 Prioritized HHPD-Poor Dams

Structure Name	DEP File Name
Centennial Lake Dam	31-82
River Wall Dam	22-194
Franklinville Lake Dam	31-26
Hackettstown Reservoir Dam	24-67
High Crest Lake Dam	22-161
Jaqui Mill Pond Dam	25-9
Lake Lenape Dam	36-5
Lefferts Lake Dam	29-025
Lionshead Lake Dam	23-65
Longwood Lake Dam	22-122
Matawan Lake Dam	29-19
Powder Mill Pond Dam	25-48
Round Valley Reservoir - South Dam	24-82
Round Valley Reservoir - North Dam	24-83
Spruce Run Reservoir Dam	24-81
Valhalla Lake Dam	25-167
Warren Mill Dam	24-5
West Branch Reservoir Dam	25-73
West Milford Lake Dam	22-96

Levee Failure

A complete levee failure, like dam failures, is rather infrequent and typically coincides with events that cause them such as heavy rainfall, storm surge, or hurricanes. As previously stated, there have been no major documented levee failures in New Jersey to date; however, the potential does exist given the varied construction and maintenance procedures in place for systems in New Jersey. Aside from unregulated levee systems, some levees that the USACE inspects regularly have not scored well in terms of structural standing. Table 4.3-4 shows the current inspection ratings for levees in New Jersey under the USACE program.

Table 4.3-4 Inspection Status of New Jersey Levees Monitored by the United States Army Corps of Engineers

System Name	Last Inspection	Inspection Rating*
S. Orange, Rahway East Branch, LB North	40,374	Minimally Acceptable
S. Orange, Rahway East Branch, RB South	40,367	Minimally Acceptable
Gibbstown	-	-
Raritan Bay and Sandy Hook Bay, Keansburg	40,318	Unacceptable
Rahway, Rahway River South Branch RB	40,332	Minimally Acceptable
Hillside, Elizabeth River Left Bank	40,065	Minimally Acceptable
Elizabeth, Elizabeth River Right Bank South	40,317	Unacceptable
Elizabeth, Elizabeth River Right Bank North	40,317	Unacceptable
Elizabeth, Elizabeth River Left Bank South	40,315	Unacceptable
Elizabeth, Elizabeth River Left Bank North	40,317	Minimally Acceptable

**Three National Levee Database Inspection Ratings can be given: Acceptable, Minimally Acceptable, and Unacceptable.*

Source: USACE, 2013

Potential Effects of Climate Change

Dam Failure

Procedures for the design, estimation of probability of failure, and risk assessment of infrastructure rely on 10–100 years of past data to create assumptions about a river's flow behavior based on flood and rainfall intensity, frequency, and duration (NCA, 2018). This is expressed as a hydrograph. Changes in weather patterns due to climate change can have significant effects on the hydrograph used for the design of a dam. Annual precipitation in New Jersey is expected to increase by 4% to 11% by 2050 (NJDEP, 2020) which could influence the hydrographs of many dammed rivers in the state. As a result, it is conceivable that a dam could lose some or all 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.

This risk is worsened by the general state of infrastructure across the country including New Jersey. Aging and deteriorating dams and levees represent an increasing hazard when exposed to extreme or, in some cases, even moderate rainfall (NCA, 2018). The 2021 American Society of Civil Engineers infrastructure report card reported 231 high hazard dams in NJ (ASCE, 2021).

Additional climate factors which could negatively influence dam performance include a possible increase in sediment in water flows due to more intense rainfall leading to soil erosion which can affect gate performance and routing capacity. Finally, compound extremes can also increase the risk of cascading infrastructure failure since some infrastructure systems rely on others, and the failure of one system can lead to the failure of interconnected systems, such as water–energy infrastructure (NCA, 2018).

Levee Failure

Levees in New Jersey may be affected by the impacts of climate change. Of particular concern may be the stress that a rising sea level could have on levee systems. Since 1900, sea level along the coast of the state has risen about 12 inches. According to the 2020 New Jersey Scientific Report on Climate Change under current scenarios there is a 50% chance that sea-level rise will meet or exceed 1.4 feet and a 17% chance it will exceed 2.1 feet by 2050. Those levels increase to 3.3 and 5.1 feet by the end of the century (NJDEP, 2020). As sea levels rise there may be additional hydrostatic pressure placed on coastal and tidal river levee systems, thus increasing the potential for failure.

Additionally, climatologists predict an increase in the intensity of precipitation and of coastal storms such as hurricanes and tropical storms in the region which could place added burdens on levee systems, testing their structural integrity. Projections estimate an increase of 4% to 11% in precipitation in the state by 2050; (NJDEP, 2020) as a result, levee systems may have to retain more water further stressing this infrastructure.

Beyond increased rainfall, increases in droughts and warm spells as a result of a changing climate could also compromise earth dams and levees as a result of the ground cracking due to drying, a reduction of soil strength, erosion, and subsidence (sinking of land) (NCA 2018). Adding to this risk, many of the State's levees are structurally deficient, increasing their susceptibility to these factors.

4.3-5 VULNERABILITY ASSESSMENT

Vulnerable Jurisdictions

Dam and levee failure could occur anywhere in the state where dams or levees exist. All but three counties in the state identified dam and levee failure as a hazard of concern within their HMPs. In other sections of Risk Assessment, the Planning Team compared the ranking of the hazard by county HMP to FEMA's National Risk Index (NRI). However, the NRI does not include a hazard category for coastal erosion and therefore is not applicable to this section and therefore only the ranking of hazard by county HMP is included in Table 4.3-5.

Table 4.3-5 Dam and Levee Failure Risk Rankings

County	Ranking of Hazard by County HMP
Atlantic	Low
Bergen	Profiled, Not Ranked
Burlington	Not Profiled
Camden	Low
Cape May	Not Profiled
Cumberland	Low/Medium
Essex	High
Gloucester	Medium
Hudson	TBD
Hunterdon	Low
Mercer	Low
Middlesex	High
Monmouth	Low
Morris	Low
Ocean	Not Profiled
Passaic	Low
Salem	Medium/High
Somerset	High
Sussex	Low
Union	Medium
Warren	Medium

Source: FEMA NRI (accessed June 2023), County HMPs (accessed June 2023)

Built Environment

The NRI does not include a hazard category for dam and levee failure; therefore, estimated annual losses from buildings due to dam and levee failure (and subsequent estimates for estimated annual losses from state-owned facilities) cannot be calculated using NRI data.

Dam Failure

As part of the Risk Assessment that was completed for this plan update and contained in Appendix G, analysis was done to determine how much of the population was at risk for dam failures for the high hazard dams identified, including a look at how risks shifted throughout the day. The dams were analyzed under the three different scenarios: spillway design storm with dam failure, spillway design storm without damfailure, and sunny day failure. This analysis is considered sensitive and is not shared publicly. A spillway design storm (SDS) is a storm event that a dam structure is required to be designed to safely pass. A spillway design storm in New Jersey can range from a 24-hour 100-year frequency storm event for Class III (low hazard) dams to the Probable Maximum Precipitation event for Class I (high hazard) dams.

Spillway design storm with dam failure scenario may occur when a dam is subjected to unprecedented loading. The most common failure from extreme loading usually occurs due to an extreme flood event. Dam failure flood flows can be several times as large as the rain-induced flood. Generally, those downstream are aware that flooding is occurring or likely to occur and may already be taking protective measures. However, those at risk may not be prepared for the magnitude of flooding caused by a dam failure.

Spillway design storm without dam *failure scenario* is when there is no dam break or infrastructure failure, but there is still downstream inundation. An example of this would be a dam overtopping during a precipitation event, but no breaks or cracks in the structure occurring. These events would result in less flooding than failures as the integrity of the structure is not compromised.

A *sunny day failure* occurs during dry weather and may be caused by internal erosion in an earth dam, ice loading, a seismic event, or other conditions such as defects in the dam or foundation. Although the resultant flows are less than during a “rainy day” event, which occurs during a precipitation event that causes extreme loading, the flows can be large enough to flood overbank areas that are heavily developed. Those downstream may be unaware of the failure in progress and less prepared for the resulting flood, creating an increased incremental risk.

Levee Failure

As stated above, residential and commercial buildings located nearest the levee overtopping or breach location will suffer the most damage from the initial embankment failure flood wave and landward buildings will be damaged by inundation (FEMA, 2004). There was not enough data available to properly assess the risks to structures and facilities for each individual levee across the state.

Lifeline Impacts

FEMA created the eight Community Lifelines to contextualize information from incidents, communicate impacts in plain language, and promote a more unified effort across a community that focuses on stabilizing these lifelines during response. More information on these lifelines can be found in Section 4.1.

The impacts that hazards can have on these lifelines can be broken into three categories: causal, compounding, and cascading. Causal impacts are those caused directly by the hazard itself. Compounding impacts are those caused by or made more complex by additional hazards. Cascading impacts are additional impacts caused from disruptions to the lifelines. Table 4.3-7 showcases the most likely lifelines to be impacted by dam or levee failure, including a short description of anticipated impacts.

Table 4.3-6 Lifelines Most Likely Impacted by Dam/Levee Failure

Lifelines	Notes
Safety and Security	Dam or Levee failure could impact Safety and Security lifelines by requiring significant resources in emergency response and other government services. Impairment of transportation infrastructure could further impact the effectiveness of these lifelines.
Food, Hydration, Shelter	Dam or levee failure could result in flooding and other hazards which present significant risk to Food, Hydration, and Water lifelines by damaging physical structures including homes, and causing harm to agricultural operations potentially impacting food supply chains.
Health and Medical	Potential Impacts to the Health and Medical lifeline could be a result of damage to medical structures and transportation infrastructure. Patient movement and medical supply chains can be impacted by damage to roadways and other transportation lifelines.
Energy	Dam or levee failure could result in a disruption to the power grid if it occurs nearby power supply distribution equipment. There are two existing hydropower stations in New Jersey, theoretically power supply could be impacted in the event of this hazard occurring
Communications	In the event of a dam or levee failure affecting the power grid, it could result in additional disruptions to communications infrastructure.
Transportation	Dam or levee failure can result in impairment of transportation infrastructure such as roads and bridges due to physical damage as well as standing water or debris carried by flooding. Damage to the Transportation lifeline has cascading effects among other lifelines which depend on movement of people or goods.
Hazardous Materials	Dam or levee failure could lead to potential contamination from hazardous materials because of flood damage to any nearby facilities or contaminated sites in the affected area.

Population and the Economy

Economic Impacts - Dam Failure

As part of the Risk Assessment that was completed for this plan update and contained in Appendix G, analysis was done to determine the economic loss for high-hazard dams under the three different scenarios described above. Appendix G and the final outputs of the risk analysis are considered sensitive and not shared publicly.

Economic Impacts - Levee Failure

Data was not available to properly assess the economic risk presented by each individual levee across the state. However, it is known that levee failures present significant risks to adjacent properties and structures.

Population Impacts - Dam Failure

As part of the Risk Assessment that was completed for this plan update and contained in Appendix G, analysis was done to determine how much of the population was at risk for dam failures for the high hazard dams identified, including a look at how risks shifted throughout the day. The dams were analyzed under the three different scenarios described above: spillway failure, no failure, and sunny day failure. The final outputs of this analysis were not published for public viewing due to security concerns.

Socially vulnerable populations were not considered during the population aspect of this risk analysis: however, particularly vulnerable populations include older adults and young people who may be unable to get themselves out of the inundation area. 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, which may not be available because of isolation during a flood event and difficulties in evacuating.

Population Impacts - Levee Failure

Data was not available to properly assess the population at risk for each individual levee across the state. The discussion above on socially vulnerable populations may apply to levees as well.

Ecosystems and Natural Assets

Water Resources

Dam and levee failures may cause the release of hazardous materials into the environment when floodwaters infiltrate development and infrastructure. This may lead to widespread contamination of surface and groundwater resulting in costly remediation (FEMA, 1996). Emergency dewatering used to address impacts of this hazard has the potential to cause thermal shock and hypoxia in downstream waters which can be disruptive to aquatic ecosystems, fisheries, and recreational resources.

Freshwater and Coastal Wetlands

Wetlands can be sensitive to excessive water and may be damaged by extreme or long-term flooding caused by dam or levee failure. Flooding caused by dam and levee failure can destroy the functions of wetlands to provide flood storage, water filtration, and wildlife habitat.

Forests and Vegetated Lands

Forests and vegetated lands have the capacity to retain excess water to prevent the damaging effects of floods on communities and infrastructure, but they can also be sensitive to excessive water from dam or levee failure. Excessive quantities of water could permanently damage crops or cause root undermining and disease in trees causing long term impacts on vegetated lands.