Independent Review of the Tolt Early Warning System and Dam Safety

June 2025

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EXECUTIVE SUMMARY

A. Background and Need

The South Fork Tolt Dam (Tolt Dam) is a large dam owned by the City of Seattle that supplies 30% of the water to the Seattle metropolitan area. The dam is 14 river miles upstream of the City of Carnation, WA (population 2,158). In the remote event that there is a major incident or failure of the dam, the City of Seattle owns and operates a warning system (commonly referred to as the Tolt Early Warning System) that includes seven audible outdoor sirens that would be activated to warn and trigger evacuation of the downstream inundation area, including much of the City of Carnation. If a failure occurred, there would be at least 1.5 hours until the leading edge of the flood wave arrived at the City of Carnation.

Over the past several decades, the sirens have been tested weekly on Wednesdays at noon. However, over the past five years, the sirens have also broadcast several unplanned soundings and false alarms. This began on July 28, 2020, when the siren system activated announcing that the dam had failed and that everyone needed to evacuate. Chaos resulted as people tried to evacuate, and roads became clogged. Many people had feelings of fear and doom. As the sirens continued to blare, City of Carnation officials were not able to verify whether the dam was failing or not. Once verified as a false alarm, operators were still unable to turn the sirens off. The siren system issued this false alarm continuously for 38 minutes. The event traumatized many in the community and has had lasting emotional impacts on some residents.

In response to this 2020 false alarm event, the City of Seattle accelerated a siren replacement project that was initiated in 2016 and was already well underway. The construction, installation, and testing of the new siren system resulted in additional unplanned soundings of both the old and new systems. This continued until March 27, 2024, when the new system experienced an unplanned sounding. At this point, the old siren system had already been permanently decommissioned. Following this March 27 incident, the City of Seattle temporarily deactivated and isolated the new siren system, requiring manual activation by a human operator to sound the sirens.

On March 29, 2024, the regulator for the safety of Tolt Dam, the Federal Energy Regulatory Commission (FERC), instructed the City of Seattle to evaluate and implement alternatives to the existing siren system. In its letter, FERC noted that from all indications Tolt Dam was safe for continued operation. It was also noted that the siren system component of the Tolt Early Warning System both predated the project's FERC license as well as the prevalence of cell phones and reverse 911 alert systems. To quote FERC, "The current siren warning system does not appear to be consistent with standard of practice at other FERC regulated projects with similar public alert requirements and circumstances. The combination of the siren testing frequency and series of false alarm events has clearly become detrimental instead of beneficial to public safety." The numerous unplanned soundings and false alarms reduced trust in the Tolt Early Warning System and may have, by extension, reduced trust in the safety of Tolt Dam.

In response to this letter, the siren system was turned off. In the absence of the siren system, alternative methods (such as ALERT King County, Wireless Emergency Alerts, the Emergency Alert System, text messaging, TV/radio broadcast, reverse 911, and others) would be used by emergency managers to warn and evacuate the public in the remote chance of a major incident or failure of Tolt Dam.

On May 20, 2024, the City of Seattle committed to FERC to engage reputable industry experts to perform an independent assessment of the Tolt Early Warning System by June 2025. The independent team's collective experience and expertise would encompass:

- dam safety and risk,
- emergency management,
- public alerting and warning systems,
- human, organizational and operational performance, and
- public communication.

The Review Team consisted of a senior dam safety engineer, a warning specialist, a risk communication expert, and an engineer project manager with significant experience in dam failure consequence analysis.

This report is the result of the independent Review Team's work over a five-month review period. The team reviewed pertinent documentation and conducted interviews with representatives of the City of Seattle, the City of Carnation, King County Office of Emergency Management (OEM), King County Sheriff's Office, Eastside Fire and Rescue, NORCOM, FERC, the National Weather Service, the City of Duvall, Riverview School District, Carnation-Duvall Citizen Corps, Sno-Valley Senior Center, and Remlinger Farms.

B. Summary Findings

1. Tolt Dam

1.1 – The dam is continuously monitored, well-maintained, and safe.

- The City of Seattle is operating a sound dam safety program.
- According to recent dam safety assessments performed by independent consultants, Tolt Dam is well monitored and maintained. It is in good condition.
- The dam safety regulator (FERC) has standard of practice regulations for dam safety and is requiring the City of Seattle to follow those regulations for Tolt Dam.
- A recent dam safety comprehensive assessment estimated that the dam has an extremely small chance of failing (a 1 in 10,000 or 0.01% chance of happening in any given year) and assigned the dam a "moderate" risk classification. The risk assessment of the dam found it to be in satisfactory condition with no significant adverse conditions observed. Based on the findings of the assessment, the City of Seattle is performing studies to further understand or reduce risks for extreme seismic events.

- While continued monitoring of the dam and studies of potential vulnerabilities are warranted, the risk assessment concluded that the dam can continue to be operated normally. If higher risks were to be identified in future assessments, the City of Seattle would be required to take additional actions (e.g., investigations, repairs, changes in operation, or emergency planning efforts) to reduce risk within acceptable limits (FERC, 2015).
- The Emergency Action Plan for Tolt Dam was found to meet industry standards and federal requirements. It is being regularly updated, tested, and exercised.

2. Tolt Early Warning System

2.1 – There is a loss of confidence in the early warning system.

- Over-warning due to frequent tests, unplanned soundings, and/or multiple false alarms reduce the credibility of warning systems. In the case of the Tolt Early Warning System, some residents, public officials, and City of Seattle staff have expressed a loss of confidence in the associated siren system.
- This loss of confidence may hinder communication and timely response of the public during an actual emergency event. There is a need for continued community engagement, public outreach, and other efforts to rebuild trust.

2.2 – The early warning system is complex. High reliability cannot be guaranteed.

- The Tolt Early Warning System is inherently complex with multiple indoor and outdoor sirens, computer and manual remote activation options, multiple communication technologies, power supplies, dam monitoring equipment, and complex and frequently exercised testing protocols.
- The past unplanned soundings were caused by many different things including computer problems, water infiltration, maintenance (short circuit), confusion with a separate nearby siren system, human error, and operator ergonomics (unreadable display panel).
- Sound problems including too loud/too soft and garbled words have also plagued the system.
- The system complexity, commissioning problems, multiple unplanned soundings, and false alarms lead the Review Team to believe that it would be nearly impossible to prevent new mis-soundings and false alarms were the system to be put back in operation without significant simplifying modifications.

2.3 – Given modern warning technologies that are currently in place, the need for the siren system is questionable.

- The sirens associated with the Tolt Early Warning System are currently turned off. Other warning methods that are currently in place (such as ALERT King County) would be used in an actual event. These methods include wireless emergency alerts (text messages), radio and television broadcast, tone alert and weather radio, reverse 911 phone calls,

social media, and potential route alerting and loudspeakers by King County deputies or other first responders.

- These non-siren warning methods are considered to be a diverse and effective collection of warning channels, though special efforts need to be made to ensure residents who live the furthest upstream in the inundation zone where cell coverage is limited can be contacted.
- There are no federal regulations regarding early warning systems for dams. In a few instances, FERC has required a warning system to be installed where residences or other facilities are near the dam and response time is limited. This is not the case for Tolt Dam where the leading edge of a dam failure flood wave would take at least 1.5 hours to reach the City of Carnation.
- Given the decades long history of the siren system's existence and testing, some public officials and residents in and around Carnation believe that the sirens are necessary to protect the community.
- Sirens provide a more rapid initial warning than other available methods. However, given at least 1.5 hours before a dam failure flood would arrive, research shows that other methods would likely provide adequate warning without the sirens.

3. Roles, Responsibilities, and Teamwork

3.1 – There is confusion about who is responsible for warning and evacuation.

- For many decades, the City of Seattle has maintained and operated the siren system to warn people in and around the City of Carnation to evacuate in the remote event of a Tolt Dam incident or failure. While the City of Seattle does not provide on-the-ground response during an evacuation, the siren system instructs residents to evacuate, which implies that the City of Seattle has assumed decision making responsibilities for both warning and issuing evacuation recommendations.
- Within the United States, dam owners do not typically have any responsibility for evacuation or warning of the public. The Federal Guidelines for Dam Safety (FEMA, 2013) and FERC Engineering Guidelines (FERC, 2015) stipulate that, "Dam owners should not assume or usurp the responsibility of government entities for evacuation of people" except in cases where response time is extremely limited (which is not the case for Tolt Dam).
- The City of Seattle has for decades assumed some of the warning and evacuation responsibilities (with the siren system), which may have contributed to an overreliance on the siren system and a weaker state of readiness by the City of Carnation, which is still developing its own plan for evacuating people at risk.
- This unique situation has created confusion. Many stakeholders including public safety officials are not clear about who has the authority to issue an evacuation recommendation for the City of Carnation.

3.2 – Under state law, King County and the City of Carnation are responsible for warning and evacuation.

- The State of Washington delegates emergency management responsibilities to local (i.e., county or city) governments. Under the Washington Administrative Code (WAC 118-30) and the Revised Code of Washington (RCW 38.52), political subdivisions are directed to establish local organizations for emergency management which prepare and implement comprehensive emergency management plans for pertinent hazards that could impact local residents. These plans include warning and evacuation responsibilities.
- By law, the City of Carnation is responsible for emergency management within its incorporated limits. The City of Carnation has limited avenues to share information or warn its residents of a hazard apart from the Tolt Early Warning System. A community Facebook page and city website can be used to post information. In an actual emergency, the City of Carnation would rely on King County OEM and other regional partners to communicate warning information. They would rely on limited contract support from the King County Sheriff and Eastside Fire and Rescue to implement traffic control or evacuation.
- By law, King County is responsible for emergency management in unincorporated areas that would be impacted by a dam failure. This includes areas around the incorporated limits of Carnation including those residences that are furthest upstream and would be the first impacted in a dam failure scenario. In an emergency at Tolt Dam, the county would activate ALERT King County upon being notified by City of Seattle that there is a confirmed incident or failure of the dam.

3.3 – Current emergency management coordination efforts need improvement.

- Collaboration and coordination between local emergency managers and other stakeholders appear to have improved over the last few years.
- King County OEM regularly facilitates Zone 1 Coordination and Tolt Dam Regional Work Group Meetings.
- Some participants in these coordination meetings indicate frustration with a lack of accountability and results.
- Participation in the meetings is voluntary, and while King County OEM facilitates the meetings, they do not have authority to enforce actions or deadlines.

3.4 – Local emergency planning is improving but still needs work.

- The City of Carnation's Comprehensive Emergency Management Plan is being actively updated and improved. This plan provides an important framework for the City of Carnation to develop the tools and capacities it needs to effectively respond to an emergency. The City of Carnation also hired a part-time emergency manager in 2023 and developed Hazard Mitigation Plan Annex to the King County Hazard Mitigation Plan in 2025. The Annex was approved by Carnation City Council in June 2025.
- The latest version of the City of Carnation's Comprehensive Emergency Management Plan does not include a detailed evacuation plan for any of the identified hazards. The City

of Carnation has developed a pedestrian evacuation concept to move people to higher ground as well as evacuation driving routes within City limits, but more detailed and comprehensive evacuation planning is needed to come up with optimum strategies and plans for implementing those strategies.

- While the Comprehensive Emergency Management Plan is intended to address all hazards that could occur in the City of Carnation (e.g., wildland fires, riverine flooding, and earthquakes), the Review Team observed that the City of Carnation and its residents have placed a considerable focus on dam failure even though its risk ranking is lower than severe weather, flood, and earthquake hazards (City of Carnation, 2025). This is understandable given the attention, fear, and distrust that the recent Tolt Early Warning System false alarms have created.
- The responses of residents and staff during past false alarm events suggest that the City of Carnation lacks the resources and capacity to implement their plan, support emergency response, or issue warnings during an actual emergency. They would be heavily reliant on King County OEM, King County Sheriff, Eastside Fire and Rescue, and other regional partners.

C. Summary Recommendations

1. Establish Emergency Management Roles and Responsibilities in Accordance with Washington State Law

In order to establish a path forward for the Tolt Early Warning System and general emergency management in the region, local emergency managers and public safety officials must establish a unified understanding of agency roles and responsibilities. Both King County and the City of Carnation should acknowledge and coordinate responsibility for emergency management within their jurisdictions as required by law (see Summary Finding 3.2). This includes warning and evacuation responsibilities unless formally delegated to and accepted by the City of Seattle. The City of Seattle should focus its dam owner efforts on the safe operation and maintenance of the dam and transfer its warning activities in a responsible and deliberate manner to King County and the City of Carnation unless otherwise agreed upon. The City of Seattle retains the responsibility to assess the condition of the dam and provide notification and evacuation recommendations to King County, the City of Carnation, and other relevant emergency management agencies as outlined in the Emergency Action Plan for Tolt Dam.

Given this lack of alignment as well as past grievances, it may be difficult for all parties to implement the transfer of responsibilities and agree upon specific emergency management roles and responsibilities amongst themselves. The Review Team recommends that the City of Seattle engage an independent mediator experienced in government policies and law to help address these issues and lay the groundwork for improved coordination. Possible mediators include the State of Washington Emergency Management Division which provides planning assistance to local governments and emergency planners or the William D. Ruckelshaus Center, a joint effort of Washington State University and the University of Washington, which helps parties involved in

complex public policy challenges work together to develop shared solutions. At a minimum, participants should include the City of Seattle, King County OEM, and the City of Carnation.

The outcome of these mediation efforts should be a formal written agreement between all parties that outlines emergency management roles, responsibilities, and areas of collaboration in the region in accordance with state and local laws. Regional coordination meetings that are currently being facilitated by King County OEM should also continue with a greater commitment by all parties to accountability and action.

2. Invest in Local Emergency Planning and Preparedness during a Transition Period

While recent efforts have been made by the City of Carnation to improve emergency planning, additional work is needed. The City of Carnation currently lacks the resources and capacity to implement their Comprehensive Emergency Management Plan, support emergency response, or issue warnings during an actual emergency. As noted in Summary Finding 3.1, the City of Carnation appears to be in a weaker state of readiness in part due to the City of Seattle's long-term assumption of warning and evacuation responsibilities.

To facilitate the orderly transfer of warning responsibility to local authorities, the City of Seattle should provide short-term support to the City of Carnation in the form of financial or other resources. The intent of this support is to allow the City of Carnation an opportunity to develop additional emergency management capabilities to warn and evacuate its residents. Specifically, the City of Seattle should assist the City of Carnation in improving their Comprehensive Emergency Management Plan and developing:

- Evacuation Plan. More detailed evacuation planning is needed to come up with optimum strategies and plans for implementing those strategies. This should include a traffic study to guide the development of evacuation zones and routes and gain an understanding of the time needed to evacuate the area. Furthermore, evacuation plans should be developed based on an all-hazard approach. The current pedestrian evacuation plans focused only on dam failure are not a comprehensive strategy.
- Communication Plan. A communication plan and strategy is needed to keep affected residents informed and educated. In the event that another warning occurs, there should be multiple official sources where residents can go to obtain timely, consistent information about the emergency.

It would also be appropriate for the City of Seattle to support the addition of a full-time, professionally trained emergency manager to City of Carnation staff for multiple years, the extent to be negotiated during mediation. While it is not the City of Seattle's long-term responsibility to finance or support emergency planning and management within the City of Carnation, this temporary support can accelerate the improvement of the City of Carnation's capabilities and preparedness, thereby reducing the dependence that has been created by decades of reliance on the City of Seattle's siren system.

As new and improved emergency plans are developed, the City of Carnation should request the participation and technical assistance of King County OEM in order to strengthen collaboration and mutual support. Joint exercises should also be conducted to validate the City of Carnation's emergency plans and identify opportunities for improvement.

In addition to obtaining technical and financial support from others, the City of Carnation should explore other opportunities to enhance its internal emergency communication and management capacity. The City of Carnation ultimately holds legal responsibility for supporting its residents, and strengthening local capability in a manner that will endure without continued external support is essential for effective, long-term emergency preparedness and response.

3. Modify or Remove the Siren System

Changes to the Tolt Early Warning System are needed to reduce the complexity of system and address the loss of confidence. The detection elements of the Tolt Early Warning System have performed well and should be maintained by the City of Seattle, including the dam failure and incident detection equipment at Tolt Dam and the communication network which allows continuous remote monitoring of the dam. Problematic elements include the indoor and outdoor siren system in and around the City of Carnation as well as the complex and frequently exercised testing protocols.

At present, the decision whether to remove or retain the siren system lies with the owner and operator of the system: the City of Seattle. If the City of Seattle elects to decommission the siren system, there is justification for such an approach as outlined below. However, there is also justification to retain the siren system if the City of Carnation and/or King County were willing to accept ownership and operation as entities who are legally responsible for warning and evacuation of the public. It would be best if this decision was made after the City of Carnation has had time to develop more mature emergency management capabilities as described in Recommendation #2. While that capacity is being developed, it is recommended that the siren system remain disconnected and only non-siren warning methods be used.

When King County OEM and the City of Carnation are prepared to move forward, they should make a collaborative decision whether or not to adopt the siren component of the Tolt Early Warning System. In deciding which option to choose, the benefits of a siren system must be weighed against the cost of maintaining the sirens and the negative impacts of potential future false alarms on members of the community. The Review Team recommends that one of two options be implemented to improve reliability and decrease the complexity of the system:

- Option 1: Remove the Siren Component of the System – There is justification to remove the siren part of the system given that there are no regulatory requirements for such a system, a diverse and effective collection of modern warning channels is already in place, a minimum of 1.5 hours is available to implement those warning channels should a dam incident occur, and there is potential for negative impacts on warning-weary residents should future false alarms occur. Removal of the siren component of the system would

greatly simplify the Tolt Early Warning System, eliminate siren soundings, and significantly reduce the potential for future false alarms.

If this siren removal option is selected, improvements to the existing network of warning channels should be considered. One primary way to enhance the effectiveness of existing channels would be to increase the number of people opting in to King County's warning service (ALERT King County). This would require a fairly intense and collaborative effort, going beyond mere public information. Various community events as well as outreach by the Carnation-Duvall Citizen Corps could be utilized to encourage people to sign up. A coordinated effort with the School District could also be employed to educate students on the need for opting in.

Physical improvements to improve early warning could include installing electronic highway signs for use with all hazards (not just dam failure) and distributing NOAA weather alert radios to residents who do not have cell phones or wireless network coverage at their place of residence. One other possibility would be to construct cell phone towers to provide service to areas that don't currently have reception.

- Option 2: Retain and Simplify the Siren System – If the City of Carnation and/or King County decide to retain and take ownership of the siren part of the system, then it needs to be simplified to ensure greater reliability (See Summary Finding 2.2). The siren system is the most rapid means of warning and would add an additional layer of redundancy to existing warning channels. Public officials and residents in and around Carnation appear to have mixed feelings about the siren system. Some feel it is necessary to protect the community, while others experience stress and anxiety during routine siren tests.

  If the siren system is retained and recommissioned, the design should be simplified in a variety of ways. This could include decoupling the siren system from the dam monitoring system and satellite connection so that sirens must be manually activated. Another suggestion would be to eliminate the voice capability of the sirens which has caused confusion and frustration. A single siren signal pattern could be adopted for both testing and warning situations, and residents could be directed to seek additional information from pre-determined official sources when they hear the sirens go off rather than immediately evacuate.

  Regardless of the selected modifications, it is also recommended to dramatically reduce the frequency of live testing of the sirens. The established approach of weekly testing creates several problems including alienating the public and diminishing public trust in the system. The Review Team recommends either a yearly or twice-yearly testing of the sirens, preferably in conjunction with a hazard preparedness event.

As noted, there is justification for either approach. Neither option will be without controversy in the community given the troubled history of the system. Mediation may be required to address the potential transfer of ownership if the City of Carnation or King County decides to retain the

system either individually or under a joint agreement. If the siren system is removed, mediation may also be helpful in determining what additional physical improvements (if any) should be installed and who will be responsible for initial costs and long-term maintenance. The City of Seattle should remain engaged in the project until the siren system is either fully decommissioned and other alternative methods of warning have been improved; or the siren system is simplified and fully commissioned, and ownership is transferred to local authorities.

4. Bolster Community Outreach Efforts

Regardless of whether or not the siren system is retained, additional outreach and education are necessary to inform residents about the various hazards that could impact the City of Carnation and the surrounding areas, including the potential for dam failure. There is a significant amount of mistrust within the community that is directed towards any government authorities that are perceived to be associated with Tolt Dam or the Early Warning System, and long-term efforts are required to rebuild that trust. Both on an individual and collaborative basis, the City of Seattle, City of Carnation, and King County OEM should continue to administer and improve community engagement, education, and preparedness outreach efforts within their respective spheres. It would best serve the community if an all-hazard emergency management approach is implemented and emphasized among residents. The Carnation-Duvall Citizen Corps and other local organizations may be helpful partners in these efforts. Residents should opt in to ALERT King County to be promptly notified in the event of an emergency.

Specific to the City of Seattle's efforts, a reset on community engagement and outreach regarding Tolt Dam is warranted and would be facilitated by creating a community advisory group. This would consist of a group of local residents who are active in emergency preparedness who meet at least quarterly with dam safety engineers, information officers, and emergency managers from the City of Seattle and King County. This group would work to identify opportunities for better engagement with and education of community members. The City of Seattle should develop a Communications Plan that includes continuing involvement in community education and outreach activities such as annual tours of the dam for residents and participation in the "Be Dam Ready" community event. This plan should also clarify coordination between Seattle Public Utilities and Seattle City Light.

Consistent with newer practices within the dam safety industry, City of Seattle should publicly release the complete set of dam breach inundation maps from the Tolt Dam Emergency Action Plan. This increases transparency and will help communities and their residents make more informed decisions about protective action planning.

CHAPTER 1: Introduction

A. Need

The South Fork Tolt Dam (Tolt Dam) is owned and operated by Seattle Public Utilities (SPU) and is licensed under the Federal Energy Regulatory Commission (FERC) with Seattle City Light (SCL) as the licensee. SPU and SCL are two utility departments of the City of Seattle and are collectively referred to in this report as "City of Seattle". Tolt Dam is a 200-foot-high earth fill embankment impounding a 57,900 acre-foot[1] reservoir located in the Cascade Mountains, 30 miles due east of Seattle, WA. The main purpose of the South Fork Tolt Project is to provide water to the metropolitan Seattle area with power generation as a secondary purpose. The safety of the dam is regulated by the FERC.

The dam is equipped with an automated data acquisition system that monitors dam performance and provides data as part of a dam failure early warning system. The Tolt Early Warning System consists of several video cameras, dam monitoring instruments, seven outdoor sirens, and four indoor sirens to provide warning notifications in the remote case of a dam safety emergency to residents along the Tolt River and in the City of Carnation in the downstream flooding zone.

There have been several false alarms or unplanned soundings of the Tolt Early Warning System, the most significant of which occurred in July 2020 when the old system's sirens falsely sounded for 38 minutes and led to evacuation of downstream residents. In response to that event, the City of Seattle expedited replacement of the siren system, which was already underway. During the construction, commissioning, and testing of the new system, additional false alarms or unplanned soundings occurred. Many residents of the City of Carnation were deeply impacted by the chaotic and stressful experience of evacuation during the 2020 false alarm. The community has continued to experience trauma during subsequent unplanned soundings of the sirens. Public officials, City of Carnation residents, and City of Seattle staff have decreased confidence in the Tolt Early Warning System because of the multiple false alarms and unplanned soundings.

With support from FERC, the City of Seattle engaged a team of independent experts to conduct a review of the Tolt Early Warning System. During this period of review, the siren system has been turned off to eliminate the potential for any additional false alarms or unplanned soundings. The dam is continually monitored and inspected on regular intervals. In the remote chance of a major incident at or failure of Tolt Dam, several non-siren methods would be used to warn the public including ALERT King County – a multi-faceted emergency notification system.

This report was written by the independent Review Team at the conclusion of their review. While input was received from many people and organizations, the report recommendations were arrived at solely by the Review Team.

[1] *An acre-foot is a volume measurement equivalent to the amount of water needed to cover one acre of land to a depth of one foot. On average, one acre-foot is enough water to serve a family of four for a year.*

B. Report Organization

The report consists of six chapters and seven appendices. The first two chapters introduce the independent investigation effort and provide the history and background of Tolt Dam and the associated Early Warning System. Chapters 3 through 5 describe the Review Team's findings and recommendations related to dam safety, emergency management, and risk communication, respectively. Chapter 6 summarizes the Review Team's overall findings and recommendations regarding a path forward for the system. Excerpt quotations from public surveys have been included throughout the report to provide context and acknowledge the wide range of perspectives associated with the Tolt Early Warning System. These quotations are meant to be illustrative in nature and do not represent the perspectives of all members of the public or other stakeholders.

The appendices provide supplemental information on specific topics. The Reader will find definitions of any unfamiliar acronyms in Appendix A. A summary of general dam-related information which will be helpful to readers who are unfamiliar with dams and dam safety is provided in Appendix B. The Reader can view dam failure inundation maps for Tolt Dam in Appendix C. A summary of false alarms and other incidents related to the Tolt Early Warning System is documented in Appendix D. A listing of other known siren installations at dams in the United States is provided in Appendix E. Recent dam safety assessment and inspection reports are summarized in Appendix F. Lastly, best practice information related to emergency management is provided in Appendix G.

C. Team Formation, Authorization, and Independence

In consultation with FERC and the Carnation City Council, the City of Seattle elected to hire a team of third-party experts to independently review the Tolt Early Warning System. The review was established to solicit recommendations from the Review Team for the City of Seattle to consider in their decision making about the system and other related matters. The Review Team was selected and fully engaged in January 2025. Team members include:

- **Team Lead / Dam Safety and Risk Expert: Mark Baker, P.E., Dam Crest Consulting.** Mark is an industry leader with extensive dam safety and risk experience working at the U.S. Bureau of Reclamation (USBR), the National Park Service (NPS), and Bureau of Indian Affairs (BIA). He has also performed independent dam incident investigations and led the Spencer Dam Failure Investigation team. He worked extensively with USBR/BIA installing early warning systems at dams and worked for years on improving their reliability. He understands issues related to dam failure warnings and evacuations, including false alarms and response related to them. He also covered the human factors portion of Spencer Dam investigation and is a leader in that regard. He is the founder and co-chair of the Association of State Dam Safety Officials' (ASDSO) Dam Failures & Incidents Committee.
- **Emergency Management and Public Alerting Expert: John Sorensen, Ph.D., Independent Researcher.** John is a recognized expert with decades of experience in hazard and emergency management. He has researched evacuation and warning

throughout his career. He worked on HEC-Lifesim, a software widely used in the dam industry for evaluating the consequences of dam failures. He has authored several key guidelines for the U.S. Army Corps of Engineers (USACE) on the public alert and warning for dam and levee emergencies. He was involved in the evaluation of the Oroville Dam spillway incident to develop understanding of the evacuation of the downstream communities. He has done studies on false warning and its impact on evacuation.

- **Risk Communication Expert: Ann Bostrom, Ph.D., University of Washington.** Ann is a recognized expert in risk communication and has collaborated on investigations of public and professional communication for diverse hazards, including earthquakes, flashfloods, and hurricanes. She has contributed to numerous studies on risk perception, communication of warning systems, and responses to hazard forecasts and warnings. She has advised several federal agencies on science and risk communication through her work on science advisory committees and on National Academies of Sciences, Engineering, and Medicine committees.
- **Project Manager: Greg Richards, P.E., CFM, Gannett Fleming, Inc**. Greg is a senior project manager at GFT (formerly Gannett Fleming). He is responsible for the management and execution of dam design projects with emphasis on hydraulic, hydrologic, and consequence analyses. Greg has contributed to several dam safety policy documents on both the federal and state levels and led the development of ASDSO's DamFailures.org and DamToolbox.org websites. Greg currently serves as a member of ASDSO's Dam Failure and Incidents Committee and as Chair of the DamFailures.org Subcommittee.

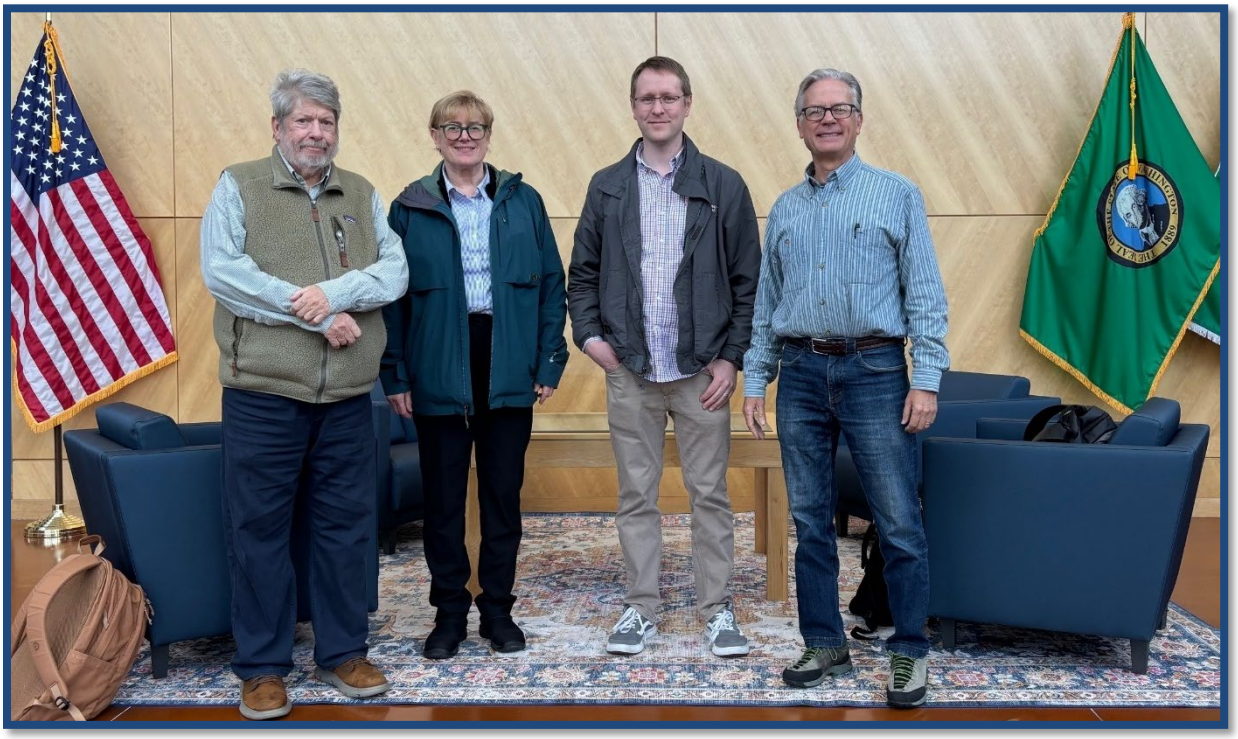


Figure 1.1 – Tolt Early Warning System Independent Review Team members (from left to right): John Sorensen, Ph.D.; Ann Bostrom, Ph.D.; Greg Richards, P.E., CFM; and Mark Baker, P.E.

Although the Review Team members are contracted through the City of Seattle, the team has carried out its work independently, and its efforts have not been directed or controlled by the City of Seattle. The Review Team is also independent of other stakeholders, including regulatory bodies and government agencies.

D. Purposes of the Investigation

The purpose of this investigation was to:

1. Review the Tolt Early Warning System including its history of false alarms and unplanned soundings,
2. Review recent assessments regarding the safety of Tolt Dam,
3. Evaluate organizational performance of the City of Seattle and their partners related to emergency management support and public communication, and
4. Identify opportunities for improvement in each of these areas as well as recommendations regarding a path forward for the Tolt Early Warning System

The Review Team evaluated these items with respect to current regulations or best practices. The resulting findings and recommendations will be considered by the City of Seattle in their decision making about the future of the Tolt Early Warning System. The findings also highlight opportunities for the City of Seattle and other stakeholders to improve education outreach, emergency preparedness, and notification and warning methods in downstream communities in the remote event of a major dam incident or failure while minimizing negative effects of false alarms or other external influences.

E. Methodology and Limitations of the Investigation

The Review Team's examination and evaluation were largely performed through review of available documentation and stakeholder interviews. The Review Team developed and submitted an extensive data request to the City of Seattle. Additional documentation was provided by other stakeholders. Online research of news articles and other records was also performed. Documentation that was reviewed included records of dam inspections, early warning system design and construction documents, dam safety surveillance and monitoring records, emergency planning documents, dam safety program audits, siren testing logs, siren incident reports, after-action reports, public meeting presentations and videos, community survey results, communication logs, and other correspondence. Stakeholders were forthcoming with information about all matters regarding the Tolt Early Warning System.

The Review Team performed their first site visit on January 7 through January 9, 2025. During the site visit, the team:

- Visited Tolt Dam and the downstream regulating basin,

- Visited the City of Carnation including the location of several sirens, Evacuation Hill, and other landmarks of note, and
- Interviewed representatives from the City of Seattle, City of Carnation, King County Sheriff's Office, King County Office of Emergency Management (OEM), Eastside Fire & Rescue, and the City of Duvall.

The Review Team performed a follow-up visit to the area on March 17 through March 19, 2025. During this visit, the team:

- Visited the City of Seattle's Operations Control Center,
- Interviewed representatives from the Carnation-Duvall Citizen Corps, Riverview School District, Sno-Valley Senior Center, Remlinger Farms, NORCOM, and National Weather Service, and
- Interviewed additional representatives from the City of Seattle, City of Carnation, King County Sheriff's Office, and King County OEM.

The team met virtually with the Federal Energy Regulatory Commission (FERC). The Review Team also obtained information from Federal Signal (the manufacturer of the siren system) and owners of similar early warning systems around the country. The team met regularly to discuss findings and coordinate the investigation.

The scope of this investigation is limited to the topics addressed herein. The Review Team did not perform an in-depth review of the physical and human factors that led to past incidents (e.g., hardware and software malfunction). Rather, efforts were focused on identifying a recommended path forward for the Tolt Early Warning System as well as opportunities to improve the preparedness of downstream communities based on current best practices and regulations.

F. Acknowledgements

The Review Team acknowledges the following organizations and individuals for supporting the investigation:

- Carnation-Duvall Citizen Corps
- City of Carnation
- City of Duvall
- City of Seattle (SPU and SCL)
- Eastside Fire & Rescue
- EnviroIssues
- Federal Signal
- Federal Energy Regulatory Commission
- King County OEM
- King County Sheriff's Office
- KPFF Consulting Engineers
- National Weather Service
- NORCOM
- Remlinger Farms
- Riverview School District
- Sno-Valley Senior Center

The team also gratefully acknowledges the assistance of numerous dam owners, emergency managers, and regulators around the country who shared their experiences and insights regarding early warning siren systems.

CHAPTER 2: Overview of South Fork Tolt Dam and the Early Warning System

This chapter gives an overview of Tolt Dam. For a deeper understanding of this chapter, it may be helpful to read Appendix B on the basics of dams and dam safety.

A. Tolt Dam

1. History and Background

Tolt Dam is located 30 miles east of Seattle on the South Fork of the Tolt River in the foothills of the Cascade Mountains. The City of Carnation, WA is 14 river miles downstream. The reservoir formed by Tolt Dam is the South Fork Tolt Reservoir.

Tolt Dam was constructed by the City of Seattle in 1962 to supply raw (untreated) water. Water is collected and stored in the reservoir primarily in the spring from rainfall and snowmelt and metered out for continuous, reliable supply throughout the year (including through drier seasons and times of drought). In 1995, a hydroelectric powerplant was added downstream of the dam.

The City of Seattle has assigned its water utility Seattle Public Utilities (SPU) to own, operate, and maintain Tolt Dam. The dam safety program for Tolt Dam is also managed by SPU. As Seattle's electric utility, Seattle City Light (SCL) has responsibilities for the hydropower plant and oversight of the safety of the dam as the FERC licensee.

Figure 2.1 – Map showing the City of Carnation (left), Tolt River, and South Fork Tolt Reservoir (right).

2. Benefits of the Dam

The primary purpose of Tolt Dam is to provide water supply. The reservoir supplies water to about 1.6 million people or about 30% of the water needed for the City of Seattle and surrounding areas. Secondary benefits of the dam include:

- The associated hydroelectric powerplant generates enough power for 5,000 homes.
- The dam and reservoir provide habitat for local wildlife. Year-round water releases from the dam also support fish habitat in the river downstream from the dam.
- During winter months, the reservoir level is lowered to provide flood management storage. This allows the reservoir to store and reduce some flood flows from a portion of the Tolt River watershed, thereby reducing the risk of downstream flooding.

3. Components of the Dam

At 200 feet high, Tolt Dam is a tall dam, though there are over 40 dams in Washington that are taller. The main components of the facility are the embankment dam, reservoir, spillway, and outlet works. Figure 2.2 provides an overview of the dam that illustrates the location of these key components. Each component is described more fully in the following paragraphs.

Figure 2.2 – Aerial view of the Tolt Dam and its components from (SPU, 2024).

Dam Embankment

The dam is an embankment dam constructed of earth fill (soil) that was compacted in layers during construction. The crest of Tolt Dam is 20-feet-wide and 980-feet-long. The crest has a 3.5-feet-high concrete wall along its upstream edge to add additional flood handling capacity during an extremely large flood. The upstream slope of the embankment is 50 percent (2 horizontal feet per vertical foot). This upstream slope is covered with rock riprap to prevent waves from damaging the slope. On the downstream side, the slope of the top 100 feet is also 50 percent, while the bottom portion is a much flatter slope. The downstream slope is covered in grass. Figures 2.3 and 2.4 are photographs of the upstream and downstream slopes of the dam embankment.

Reservoir

The Tolt Dam South Fork reservoir is 3.5 miles long and averages 0.5 miles wide. The reservoir has a volume of 57,900 acre-feet. The downstream end of the reservoir is shown in Figure 2.3 in the vicinity of the dam.

Figure 2.3 – The rock-lined upstream slope of the Tolt Dam embankment and South Fork Tolt Reservoir.

Figure 2.4 - The downstream slope of the Tolt Dam embankment.

Spillway

To pass floods without damaging the dam, Tolt Dam has a morning glory spillway inlet. The name of this type of spillway is derived from its shape like a morning glory flower (see Figures 2.5 and 2.6). The top of the morning glory inlet has a moveable, 3-foot-tall ring to provide additional reservoir storage during the filling season. Human operation of the spillway is not required to pass flood flows. When the reservoir level rises during a flood, it simply spills over the crest and down into the morning glory inlet much like water flowing into a bathtub drain. The spillway inlet is connected to a large underground spillway conduit that carries water from the reservoir under the dam. This conduit discharges into an above ground spillway chute that takes the water to the river downstream from the dam. The conduit outlet and spillway chute are shown in Figures 2.7 and 2.8.

Outlet Works

The outlet works of Tolt Dam consist of an intake tower (see Figure 2.5) and a below ground conduit that combines with the downstream spillway tunnel. The intake tower has several gates to make releases from the dam for the following:

- Water supply to water treatment and distribution systems
- Releases to a downstream hydropower plant to generate electricity
- Releases to maintain instream flows for fish habitat.

Figure 2.5 – The morning glory spillway inlet (foreground, right side) viewed from the crest of the dam. A bridge leads from the spillway inlet to the top of the outlet works control tower (left side).

Figure 2.6 – Looking down into the morning glory spillway inlet from the access bridge.

Figure 2.7 – The downstream slope of the Tolt Dam embankment and outlet channel of the combined morning glory spillway and outlet works tunnel.

Figure 2.8 – Discharge chute at the downstream end of the spillway outlet channel.

Regulating Basin and Powerhouse

Separate from Tolt Dam itself, there is also downstream infrastructure associated with hydropower generation and water distribution. Approximately 4.5 miles downstream of Tolt Dam, there is a Regulating Basin which is a small reservoir formed in a natural basin with two 30-foot-high earth embankments (South Dam and West Dam) at each end. This basin helps maintain level pressures in the system. A single hydropower turbine is located in the Powerhouse near the Regulating Basin and is fed by water that flows from the reservoir through a penstock. Depending on water supply needs and habitat release requirements, flow from the Powerhouse can either be returned back to the South Fork Tolt River or diverted to the Regulating Basin. Photographs of the Regulating Basin and Powerhouse are provided in Figures 2.9 and 2.10, respectively. The Regulating Basin dams are not expected to put people or property at risk if they were to fail; therefore, they are not a focus of this review.

Figure 2.9 – Regulating basin and dam located approximately 4.5 miles downstream of Tolt Dam.

Figure 2.10 – South Fork Tolt Powerhouse located near the downstream regulating basin.

4. Hazard, Risk, and Safety of the Dam

A *hazard* is something that has potential to do harm. Note that for something to be called a hazard has nothing to do with its likelihood of it happening. *Hazard* only describes its ability to do harm. Most large dams create a hazard because if they fail, the resultant flood wave would probably cause loss of life if people downstream did not evacuate.

Because many communities need year-round water supply and protection from floods, it is very common for them to build dams upstream despite this hazard. Dams present a potential hazard to many millions of people in the United States, but most dams are subject to inspection and regulation by a government agency to ensure their safety. Of the 92,000 dams in the United States, 15,600 dams would probably cause loss of life if they failed. These dams are classified as *high hazard* potential dams.

Tolt Dam is classified as a high hazard potential dam because in the remote chance that it failed, the resulting flood would probably cause loss of life in and around the City of Carnation, WA if people did not evacuate.

Dam Failure Inundation Study

The City of Seattle has developed an Emergency Action Plan to facilitate timely response of City personnel and local emergency managers in case of an incident at Tolt Dam. Emergency Action Plans have been found to be an effective tool for dam owners to trigger notification of and emergency response by local authorities, thereby minimizing loss of life and property damage in the unlikely event of a dam incident or failure. In addition to outlining responsibilities and actions during an emergency, the plan includes inundation maps which show a conservative estimate of flood depths, velocities, and travel times during various hypothetical dam failure scenarios.

Development is sparse in the first 11 miles downstream of Tolt Dam. In the remote event of Tolt Dam failure, there would be major environmental damage in the river canyon, but hazards to human lives in the canyon would be limited to City of Seattle staff in the vicinity of the Powerhouse and Regulating Basin. The first and only developed area that would be subject to hazardous flooding that could cause loss of life is in and around the City of Carnation. See Appendix C for dam failure inundation maps. Most of the City of Carnation could expect flood depths ranging from 5 to 20 feet. The most upstream areas along the Tolt River in unincorporated King County could expect flood depths greater than 20 feet. The leading edge of this flood wave would take approximately 1 hour and 35 minutes to travel from the dam to the City of Carnation. The peak of the flood wave would occur about 20 minutes later (1 hour and 55 minutes after the dam fails).

Near Carnation, the Tolt River joins the much larger Snoqualmie River. As the dam failure flood wave exits the Tolt River Canyon, it would spread out and be significantly weakened. The river could rise by as much as 6 feet in the vicinity of the downstream communities of Duvall, Monroe, and Snohomish, but would be much less hazardous since the flood wave would be largely contained within the Snoqualmie River channel and would take over half a day to reach its peak.

Maximum anticipated flood depths during a dam failure in the vicinity of Carnation are depicted in Figure 2.11. Dam failure inundation maps are provided in Appendix C. Note that these flood wave travel time and inundation depth estimates are based on hydraulic modeling that is intentionally conservative to provide worst-case conditions for emergency planning purposes. Additionally, any advance notice that a failure is about to occur would provide additional response time beyond the flood wave travel time of 1.5 hours. Given the level of instrumentation and monitoring at Tolt Dam, it is highly likely that problems at the dam would be observed well in advance of dam failure and that advance notification could be given to downstream areas to prepare for a potential evacuation.

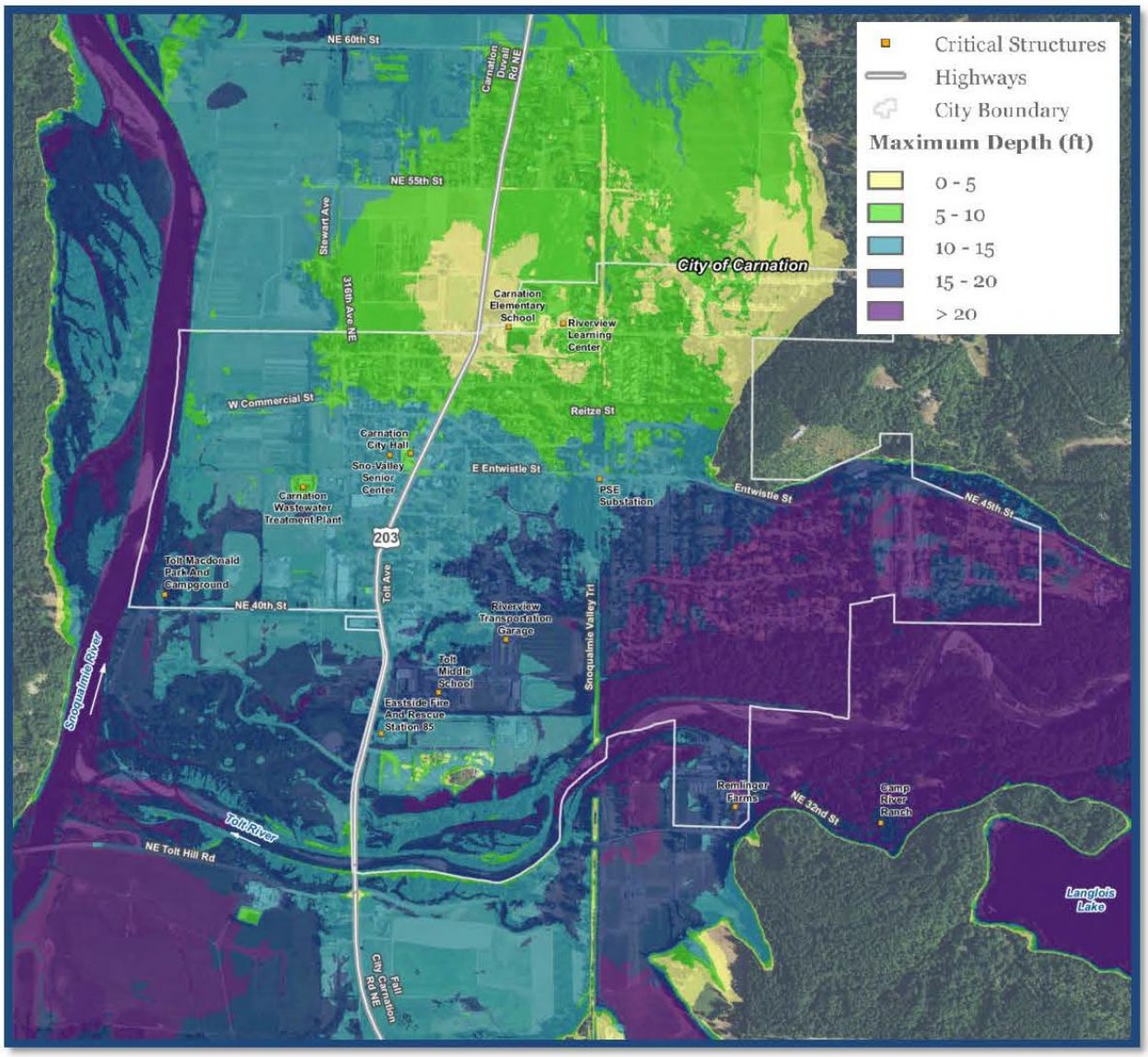


Figure 2.11 – Inundation mapping for a hypothetical dam failure of the Tolt Dam. Maximum flood depths in the vicinity of the City of Carnation are shown for an extreme scenario which assumes major flooding is occurring on both the Tolt River and Snoqualmie Rivers in addition to the flood wave caused by failure of the dam (see also Appendix C).

Additional information regarding the adequacy of response time can be obtained from the FERC-required Sudden Failure Assessment (SPU, 2024). Using data from the dam failure inundation study, this assessment consists of estimating the time it would take for a flood wave to impact the first non-project downstream structure. This is then compared with the estimated time required to detect and verify a problem at the dam, coordinate with emergency managers, and send out a warning to the affected public. In a few instances, FERC has required a warning system to be installed where residences or other facilities are near the dam and response time is limited. There is no definitive guidance regarding when a warning system is required, but warning systems are generally considered only when the Sudden Failure Assessment finds very limited or inadequate

response time. This is not the case for Tolt Dam where the time required to detect and verify a problem and initiate notification of the public is estimated to be between 7 minutes (with sirens) and 13 minutes (without sirens) while the leading edge of a dam failure flood wave would take at least 1.5 hours to reach the City of Carnation.

Condition of the Dam

Hazard is different from the word *dangerous*. The term *dangerous* includes the presence of both a hazard and a high likelihood of occurring. Dams that are in good condition (well maintained, inspected, analyzed, repaired) and have owners that are prepared to respond to an incident at the dam are generally not considered to be dangerous – their probability of failure is extremely small. Of the 92,000 dams in the United States, about 22 fail each year. Most of these failures occur at small dams (less than 25 feet high) and dams that are in poor condition. Loss of life due to dam failure in the United States is rare. Only one person has lost their life from a dam failure in the past 19 years. More deaths due to dam failure occurred in the 1900s, but these have been reduced through improved dam design, construction, monitoring, and emergency management.

Although Tolt Dam presents a hazard to people downstream, it is not dangerous because the hazard is well managed, and the probability of its failure is extremely low. See Chapter 3 for a more complete summary of safety assessments of Tolt Dam.

Risk and Safety

One of the most common technical definitions of risk is (a) the consequence or harm if failure occurs multiplied by (b) the probability that failure will happen, given a population exposed to a hazard, occurring over a specified time period. Broadly speaking, *risk* is the chance of harm. For a dam to pose a high risk, it would have a combination of high consequence were it to fail and a high probability of failure. If a dam has high hazard potential but it is well-managed and the probability of failure is low, it is rated as having a low, acceptable risk and is *safe*. Conversely, a high hazard potential dam that is not well-managed and has a high probability of failure is termed an unacceptably high risk and is *unsafe*. This relationship is depicted in Figure 2.12.

Although there are hazards associated with any dam and Tolt Dam presents a potential hazard to people living downstream, the dam is regularly reviewed and the probability of failure is extremely small (an estimated 1 in 10,000 chance per year). This risk is generally acceptable by dam safety state-of-practice standards (FERC, 2015; FEMA, 2015). Surveillance of the dam is effective, with daily inspections by a well-trained crew that is supported by experienced dam safety personnel. In the most recent assessment of Tolt Dam, the risk of the dam (incorporating both probability and consequences of dam failure) is classified as “moderate” (HDR, 2023). Based on the findings of the 2023 assessment, the City of Seattle is taking actions to better understand the potential impacts of extreme seismic events on the dam.

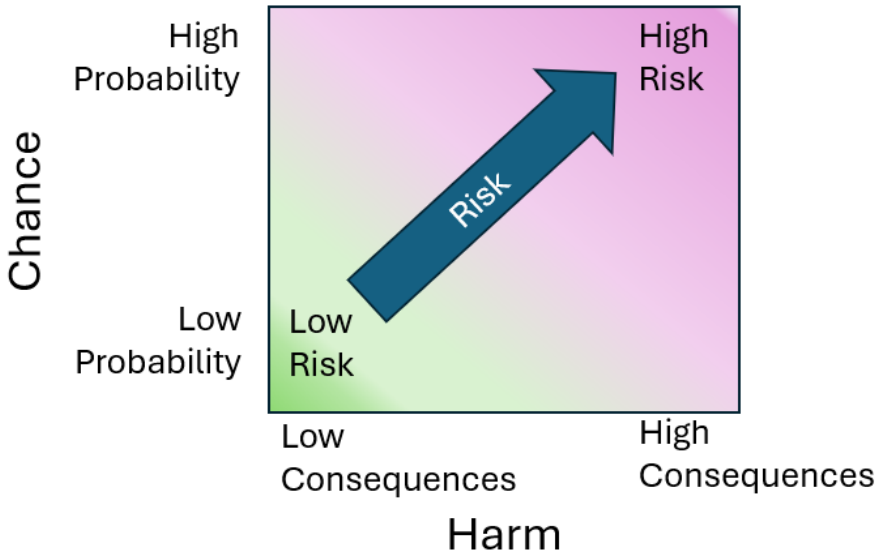


Figure 2.12 – Risk is the combination of probability of failure (chance) and consequences if failure were to occur (harm).

While engineering estimates of risk have been essential to help make dams and many other technologies safer, studies as far back as the 1970s from around the world show that people do not judge the acceptability of risks solely on the size and chance of harm. When considering the need for risk regulations or additional risk management efforts, people also consider the familiarity of the technology, who benefits from it, how controllable the risk is, and who controls the risk among other factors (Fischhoff et al., 1978, 1981; Fox-Glassman & Weber, 2016).

B. The Early Warning System

1. History and Background

City of Carnation

Prior to 1865, the area surrounding the confluence of the Tolt and Snoqualmie Rivers was inhabited by the Snoqualmie Tribe of Native Americans. Early maps show the area named after the native word “Toltxw” which translates to “swiftly rushing water”. Non-native settlers began arriving in 1865 and later changed the settlements name to “Tolt”. The Town of Tolt was officially incorporated in 1912. In 1917, the state legislature approved the controversial change of the town name from Tolt to Carnation after the nearby Carnation Evaporated Milk Farm.

Though it started out as a farming community, the City of Carnation has become a home for many commuters on the east side of Seattle. The population of the area has grown significantly since the 1970s. Per the 2020 Census, the City of Carnation has a total population of 2,158 people. The City of Carnation is managed by a professional city manager appointed by a publicly elected Mayor and City Council. The City of Carnation employs 13 staff to provide municipal services to residents.

During the 1950s, the growing City of Seattle began investigations and plans for a water supply dam on the South Fork Tolt River. Construction of the dam began in 1959 and was completed in 1962. There are no public access roads near the dam, and the watershed and reservoir are closed to the public to protect water purity. As such, most Carnation residents have a limited knowledge of the structure and its condition. This may have contributed to the dam being a point of contention for residents and community leaders who feel that they are being exposed to an imposed risk at the expense of the City of Seattle's water supply.

Adding to this contention is the fact that the City of Carnation does not receive water directly from the dam, rather it obtains its water supply from a nearby spring. Given the limitations on public access, there is also no recreational benefit from the South Fork Tolt Reservoir. The dam does provide some flood management storage during winter months which reduces the risk of flooding along the Tolt River in the City of Carnation. Additionally, there are several indirect benefits of the dam and reservoir to community members. For example, the electricity produced by the Tolt hydroelectric system is transmitted to Puget Sound Energy's Stillwater substation that in turn distributes electricity to Puget Sound Energy customers, including residents in the City of Carnation. Residents who work or visit areas whose water is provided by the City of Seattle (including the nearby City of Duvall) also indirectly benefit from the Tolt Dam water supply.

In an effort to be prepared, the City of Carnation maintains land atop a nearby hill to allow for the evacuation of residents on foot should a flood or dam failure occur. This location is commonly referred to as Evacuation Hill. Every year as part of a dam failure evacuation drill, students from schools in Carnation hike to the top of the hill, which is approximately 250 feet above the surrounding community. Trailers with emergency supplies are stored at the top of the hill.

Early Warning System Installation and Ownership

As early as 1967, residents of the City of Carnation and Tolt Valley expressed concern about the hazard posed by the dam and requested a flood warning system. Due to lack of regulations and precedent for such a system, there was no progress made in this regard for about a decade. In 1977, the King County Executive committed to installing a warning system, and the City of Seattle offered to pay half of the cost. The first early warning system for Carnation was implemented in 1978 as a single, radio-activated siren that was owned and operated by King County. However, the County relinquished control of the siren system a few years later. In December 1980, King County requested that the City of Seattle take ownership and assume responsibility for operation of the early warning system. This was formalized by Seattle City Council Resolution 26525 on March 9, 1981.

From its early days, the Tolt Early Warning System has proved to be both problematic and contentious for Carnation residents and other stakeholders. As the new system owner, the City of Seattle performed the first improvement to the system in 1985 by adding three additional sirens in the upstream reaches along Tolt River Road. In December of that same year, the first documented false alarm of the system took place resulting in "great alarm" in the community and especially by the school district. As a result, four more indoor sirens were eventually added to the fire station and school facilities in the area.

In 1986, Carnation City Council and other concerned agencies approved weekly testing of the siren system at full volume for a duration of one minute every Wednesday at noon. As early as 1987, the City of Seattle received complaints and requests for removal of the sirens from residents who found them to be loud and upsetting. City of Seattle staff also expressed concerns at that time regarding the reliability and vulnerability of the system. By 1988, however, it appears that the system had achieved some regularity. Public school and local officials had a mostly favorable view of the system, though at least one resident still voiced strong objections to the noise.

> *"One location of your Tolt Dam Warning System sirens is directly across from our home. We feel that even for its warning value this siren is unnecessary and superfluous. The probability of a catastrophic dam failure is very small.*
>
> *"People who have been visiting us during this sirens testing have said that it is frightful, nerve wracking, terrorizing, painful to the ears, and leaves them unable to function.*
>
> *"We have tried to live with this siren but find that it is adversely affecting our nerves and our health. We ask that you remove or relocate the siren."*
>
> Letter from Carnation resident to Seattle Water Department, June 1988

The original early warning system was subsequently upgraded several times over the subsequent years. Operation of the system continued without major incident for several decades though there were several maintenance concerns and mistimed soundings over the years. Of note is an incident in December 1994 in which erroneous instrumentation readings triggered an internal emergency response within the City of Seattle (though the sirens did not sound). Also of note is a human error in April 2011 when the weekly siren test was performed on Tuesday instead of Wednesday. Beginning in 2016, the City of Seattle initiated design efforts to complete a comprehensive replacement and modernization of the aging siren system and other components of the Tolt Early Warning System. This was necessary because several components of the system were outdated, created security vulnerabilities, and were no longer supported by manufacturers.

July 2020 False Alarm

On Tuesday, July 28, 2020, at about 11:15 AM, the early warning system sirens sounded an alert that instructed residents to evacuate. Unbeknownst to the people hearing the siren, it was a false alarm. The system did not provide notification of the alert to the City of Seattle Operations Control Center as designed, which created confusion and delay in notifying residents that it was a false alarm. Furthermore, the sirens would not respond to controls at the Operations Control Center which limited their ability to turn off the erroneous siren alerts or give an all clear notification. Because of these and other factors, the sirens sounded for 38 minutes without interruption.

Shortly after the sirens began to sound, Carnation City staff tried to contact the City of Seattle to verify the need to evacuation. With no response, Carnation's City Manager and Clerk began notifying their staff that the warning was real and that they needed to evacuate. In the meantime,

there was significant confusion and trauma as residents evacuated, tried to find loved ones, or sought additional information. Given the limited routes out of town, roadways became clogged with traffic. Some aggressive evacuees drove through yards to avoid traffic jams. Others abandoned their vehicles and fled on foot to higher ground. Older and disabled residents had limited options, leaving some to assume the worst. Traffic was also a problem on the paved road up Evacuation Hill which is intended only for pedestrian and first responder traffic during an emergency.

> *"I remember children running up the dam evacuation trail barefoot with their pets frightened because they were home alone in 2020. We are all traumatized and are constantly frightened every Wednesday at noon when we still all double check the time and date. Living in constant fear."*
>
> ---
>
> *"We are now afraid to spend any time in Carnation Valley, since we're concerned that we all might get trapped... The horrific traffic backups and lack of accommodations or planning for the disabled, elderly, children and pets resulted in gridlock and the roads being inaccessible."*
>
> ---
>
> *"DRAIN THE DAM!!!!! And stop traumatizing the city who reaps nothing from it!!!!"*
>
> Local Resident Responses to Early Warning System Survey

At 11:24 AM, 911 Dispatch was able to contact the City of Seattle and determine that it was a false alarm. They subsequently notified the City of Carnation, Riverview School District, NORCOM, Eastside Fire & Rescue, and other agencies. By 11:30 AM, fire and police began announcing to the public that it was a false alarm, even while the sirens continued to blare. Reverse 911 notifications of the false alarm were also sent to some residents' cell phones at 11:49 AM, shortly before the sirens stopped sounding.

Following the incident, the City of Seattle launched an investigation into the cause of the false alarm. Evidence suggests that the false alarm was caused by a short circuit in a backup controller unit. During maintenance activities near the controller, a hole was drilled in the panel, and it is believed that metal shavings shorted out the system. This activated the sirens and resulted in a condition where the controls in the Operations Control Center did not respond. The only way to turn off the sirens was to either clear the short (which they were unaware of at the time) or cut power to the individual sirens.

Early Warning System Modernization Project

The events of July 2020 caused much distress, undermined residents' trust in the Tolt Early Warning System, and may have, by extension, reduced trust in the safety of Tolt Dam. As a result, the City of Seattle decided to accelerate the early warning system modernization project in coordination with downstream stakeholders. The City of Seattle contracted with ADCOMM

Engineering Company to finalize the design of the new system. Federal Signal was selected as the contractor and supplier for the new siren system.

The first phase of the modernization project included replacement of the four existing outdoor sirens; installation of three additional outdoor sirens (see Figure 2.13); replacement of four existing indoor alert devices at Carnation Elementary School, Tolt Middle School, the Carnation Bus Maintenance Facility, and Carnation Fire Station 85; installation of an additional unit at Riverview Learning Center; new siren controllers at City of Seattle operations facilities; and upgrades to radio frequency and microwave communications systems. This effort was largely complete by the end of 2023 when the old sirens were deactivated and the new sirens were fully commissioned.

It was anticipated that a second phase of the project would follow which would include removal of the old siren system infrastructure, addition of an indoor alert device at Riverview School District's administration building in Duvall, and two new electronic message signs on the highway north and south of the City of Carnation to alert motorists to not enter the inundation zone in the event of a dam failure. The project was put on hold in 2024, and these components of the second phase have not yet been completed.

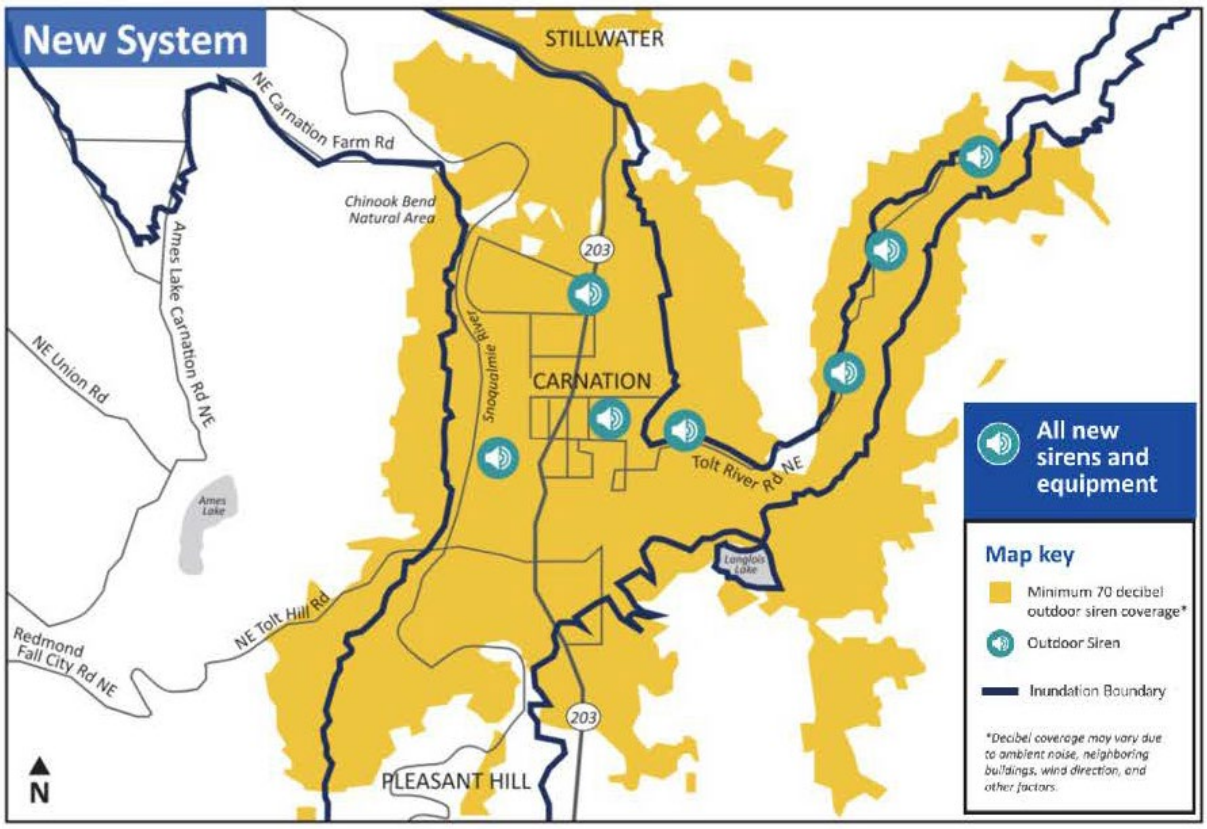


Figure 2.13 – Map of the Existing System's Outdoor Siren Locations (7 Total).

Subsequent Unplanned Soundings and System Deactivation

During the construction and commissioning of the new sirens for the Tolt Early Warning System, there was a significant increase in the number of reported false alarms, unplanned soundings, and other incidents related to the old and new siren systems. This can be attributed primarily to three factors: 1) the increased scrutiny and attention on the Tolt Early Warning System following the July 2020 false alarm, 2) the continued aging of the old system, and 3) human errors, which are an expected part of the construction and commissioning of a new and complex siren system. More than 15 separate incidents related to the siren systems are documented between July 2020 and March 2024 (see additional details and complete listing and timeline of documented incidents in Appendix D).

> ***"All you really have time to register is that the flood alarm is going off at the wrong time, which means 'leave now or die'. The feeling you get is 'We've just lost everything. Will we make it?' Having it happen multiple times, where you think your family might die, is absurd and negligent."***
>
> ***"There was no source of truth, no text message or website or known location to see if the siren was in error or if we needed to evacuate. All we had to base our decision on is the siren noise and garbled speech."***
>
> ***"People are upset, but I don't think it is a big deal… part of the process of implementing a new and complex system. People are overreacting."***
>
> ***"Myself, along with many others in our community, have been conditioned to not take this alarm seriously. That's a major problem."***
>
> Local Resident Responses to Early Warning System Survey

These incidents occurred in both the new and old siren systems, and they varied in scope, cause, and impact. Some were relatively minor maintenance or commissioning issues in which individual sirens did not sound during the normal weekly testing or sounded only briefly. Others were not caused by the systems at all, but rather a result of residents mistaking a separate and unrelated siren test at the local Girl Scout Camp for the Tolt Early Warning System sirens. Unfortunately, there were also a few instances where unplanned soundings were more extensive and led to significant confusion and resurfaced trauma. In total, all these incidents in recent years have had a negative effect on public perception of the system reliability.

In October 2023, the old siren system was officially deactivated. At that time, the new siren system was operational and became the primary warning component of the Tolt Early Warning System. In December 2023, Phase I of the Early Warning System modernization project was fully commissioned. Only a few months later on March 27, 2024, a significant incident occurred in

which at least one of the new system's sirens sounded the weekly test at 10:00 AM (two hours early). This caused significant confusion among City of Carnation residents and staff, many of whom could not understand the verbal test messaging, and it prompted some to begin evacuating.

Once they were notified of the mistimed test, City of Seattle operations staff verified that the dam was safe and the siren was activated in error. The Emergency Action Plan was activated to notify stakeholders of the unplanned sounding. City of Seattle sent an "all clear" message over the new siren system at 10:21 AM, though this may have also contributed to confusion and panic since many residents could not understand the verbal messaging. At 10:37 AM, King County OEM sent an email to subscribers and a recorded message to Reverse 911 contacts notifying them of the unplanned sounding. At the request of the City of Carnation, the regular noontime siren test was cancelled. A subsequent investigation determined that the incident was caused by the siren system contractor who accidentally set off the test alert while doing remote work on the system (see Appendix D for more details).

On Thursday, March 28, 2024, the new siren system was temporarily deactivated and isolated from the rest of the Tolt Early Warning System, requiring manual activation by a human operator to sound an alert. Initial revisions were also made to the Emergency Action Plan to reflect the deactivation and expedite emergency alerts through King County OEM, if necessary.

In response to the incident (and those which preceded it), the regulatory agency FERC sent a letter and request to the City of Seattle on March 29, 2024. The letter stated:

> *We note that there have been multiple false alarms with the alert systems over the past several years. The intention of any alert system is to provide timely warning to the population downstream of the project in the event of emergency, yet this system appears to have instead distressed the residents of the City of Carnation and decreased confidence in the safety of the dams. We believe that this is an unacceptable situation and immediate actions must be taken to assure the residents of the City of Carnation that the dams are safe, no more false alarms will occur, and that any systems in place will provide adequate warning in the event of an emergency.*
>
> *We acknowledge that while the new system may be an improvement from the system that was recently decommissioned, the audible alarm system for the City of Carnation both predates the project's FERC license as well as the prevalence of cell phones and reverse-911 alert systems. The current siren warning system does not appear to be consistent with standard of practice at other FERC regulated projects with similar public alert requirements and circumstances[2]. The combination of the alarm testing frequency*

[2] *Currently, there are no federal regulations regarding early warning systems for dams. In a few instances, FERC has required an early warning system to be installed where residences or other facilities are near the dam and response time is limited. In other cases, downstream communities have worked with dam owners to install sirens in the community. Most instances of sirens being installed downstream of dams can be categorized in three groups: 1) individual sirens immediately downstream of a dam or spillway to warn fishermen or other recreationists of a pending release from the opening of a gate or valve, 2) siren systems in communities downstream of a dam where response time during a dam failure would be extremely limited*

and series of false alarm events has clearly become detrimental instead of beneficial to public safety.

As part of the letter, FERC requested that the City of Seattle develop a plan to evaluate and implement alternatives to the siren system. In response to this request, the City of Seattle proposed to fully disconnect the siren system while an independent evaluation was performed by industry experts. This evaluation (which is summarized herein) was intended to aid the City of Seattle in the "development of a long-term plan to evaluate and propose alternatives to the current [siren system] by June 30, 2025." This plan was approved by FERC, and the siren system was deactivated. The non-siren components of the Tolt Early Warning System that provide continuous monitoring of the dam from the City of Seattle's Operations Control Center remain active.

Figure 2.14 – Timeline of Tolt Early Warning System (see Appendix D for more details)

(less than 15 minutes), or 3) siren systems in areas with significant transient populations (e.g., campgrounds, recreation areas) and limited response time. Overall, only a small number of the 92,000 dams nationwide have siren-based warning systems. A listing of known installations is provided in Appendix E.

2. Current Components of the Early Warning System

The indoor and outdoor sirens are just one component of the currently installed Tolt Early Warning System. Components of the system also include continuous physical and video monitoring of the dam, monitoring and controls at the City of Seattle's Operations Control Center, and communication infrastructure to send information including operation commands between the dam, the Operations Control Center in Seattle, and each individual siren.

Instrumentation at Tolt Dam

The field instruments at Tolt Dam that are part of the early warning system include the following:

- Reservoir Level Indicator. This would indicate if the reservoir level were approaching the dam crest and at risk of overtopping during an extreme flood. It would also trigger a warning if there was a sudden drop in reservoir level which would occur during dam failure.
- Dam Integrity Monitor. This consists of three independent electrical cable loops in the dam crest. If at any point the electrical circuit in one of the loops is broken, this could indicate a problem with the integrity of the dam embankment.
- River Gaging Stations. There are two gaging stations that measure streamflow in the river downstream of the dam. They are located approximately 0.25 and 2.0 miles downstream. These gages are used to alert operators should a sudden increase in flow be observed.

Additional instrumentation is provided to measure seepage and groundwater levels within the dam embankment and its foundation (see Figure 2.15). Thresholds are set for each of these instruments to alert operators whether the Tolt Dam is potentially failing or has failed. The system continuously monitors real time performance of the dam and detects dam failure conditions.

Video Surveillance, Monitoring, and Siren Controls at Control Center

The instrumentation system is monitored by the operators in the City of Seattle's Operations Control Center who are on duty 24 hours a day, 7 days a week. This system allows personnel at the Operations Control Center to monitor key instruments on a continuous basis. All instrument readings can be displayed with intuitive graphical presentation on computers (see Figure 2.16).

If an instrument reading is over its preset threshold, an audible sound is made in the Operations Control Center, and a flashing display is shown on the computer screens to alert operators in the room. If City of Seattle staff are not at the dam during an emergency, operators in the Operations Control Center can verify the condition of the dam through multiple remotely controlled video cameras. On-site lighting is provided to allow surveillance during nighttime.

Figure 2.15 – Seepage measurement instrumentation at Tolt Dam.

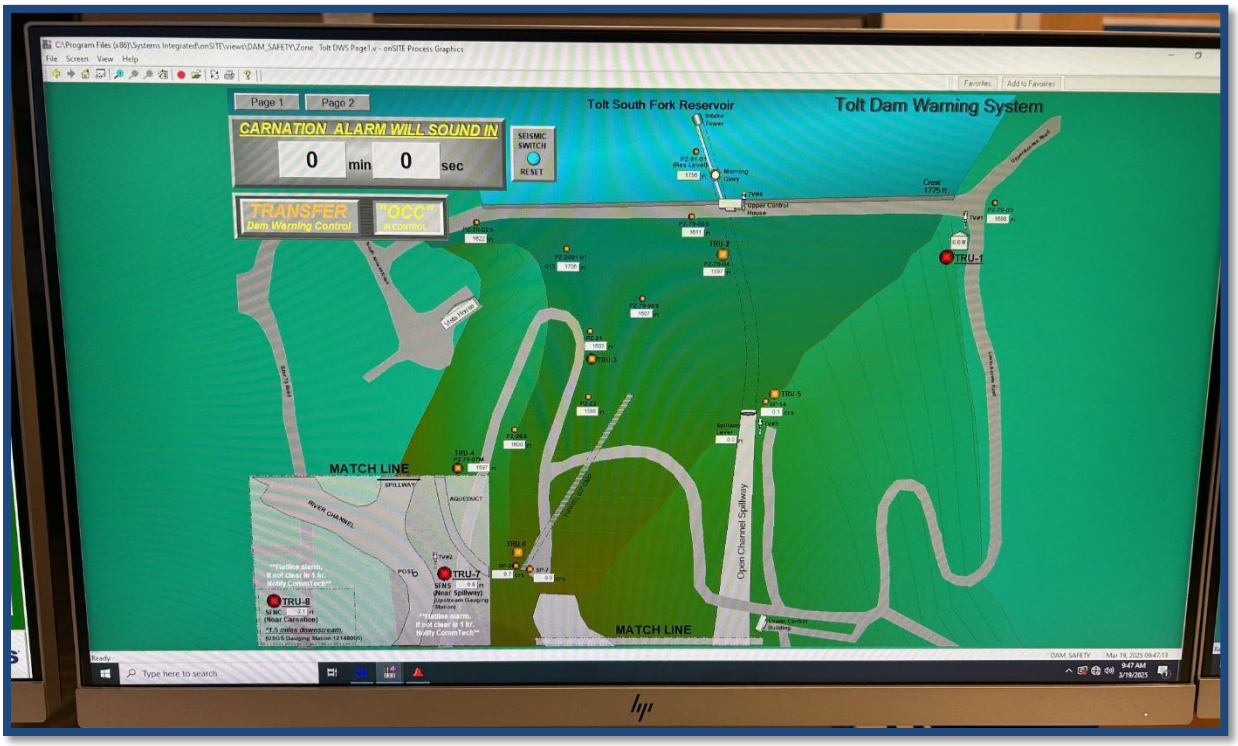


Figure 2.16 – Display of monitoring instrument readings at Tolt Dam that is continuously monitored in the City of Seattle's Operations Control Center.

If the video and other instrument alarms verify that a failure of the Tolt Dam has occurred or is about to occur, operators can activate the sirens from the Operations Control Center. The new Federal Signal siren system software used by operators includes a map interface display and controls for downstream sirens (see Figure 2.17). Alternately, the sirens can be automatically activated by the computer under a pre-programmed set of conditions if the operator does not complete visual confirmation of the dam's condition and intervene within a 20-minute period.

To ensure operators can turn off the sirens in case of an unplanned sounding or false alarm, a push button control has been added to the new system (see Figure 2.18). Primary and secondary siren controllers are located at separate operation sites for redundancy.

Communications Network

Communication among the various instruments at Tolt Dam is through hard wire transmission to the transmitter facility. Information is transmitted through broadband channels to the computers in the City of Seattle Operation Control Center. The Tolt Dam project site is connected to the City of Seattle network via a fiber connection. An independent microwave radio network is used as a backup for redundancy (see Figure 2.19). From the Operation Control Center, commands to activate the siren system are sent primarily via microwave radio network. Secondary communication with some sirens can also be performed via satellite.

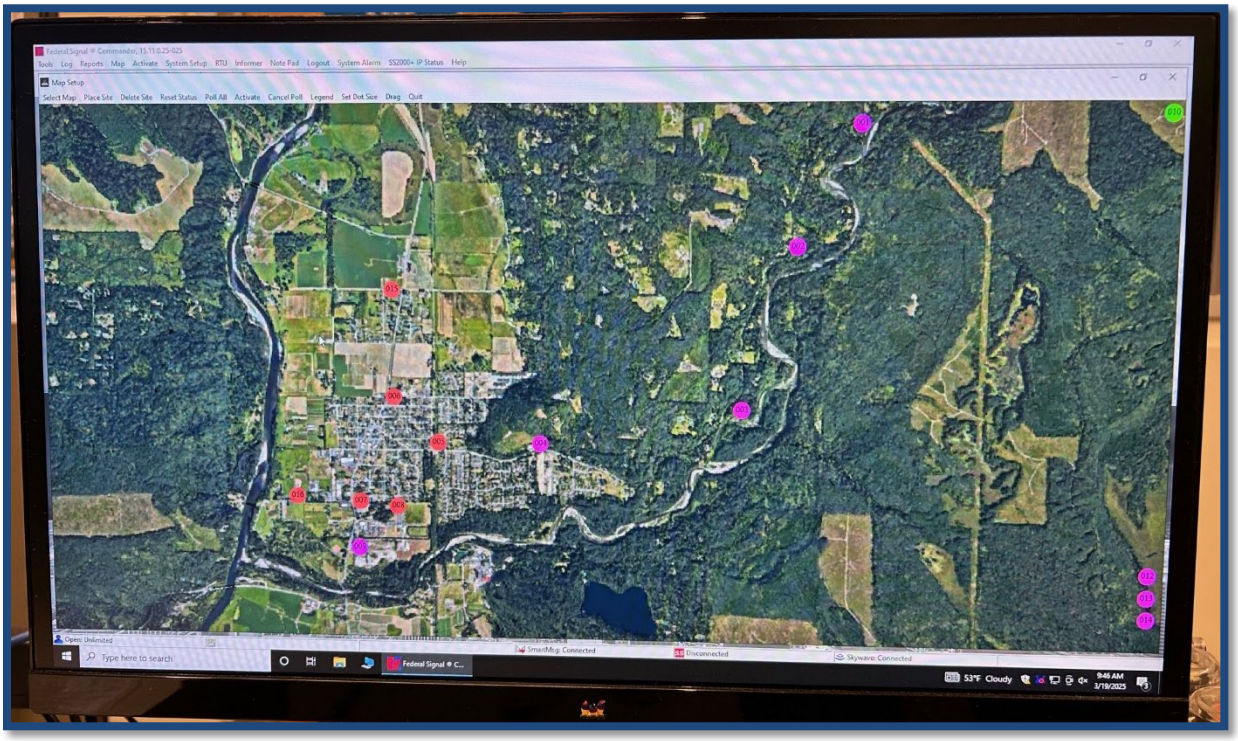


Figure 2.17 – Monitor display of the new siren system locations and control status in City of Seattle Operations Control Center.

Figure 2.18 – Alert and push button controls for the new siren system in the City of Seattle Operations Control Center.

Figure 2.19 – The Tolt Dam microwave radio transmission facility provides redundant communications with the City of Seattle Operations Control Center.

Warning Sirens in Carnation and Tolt Valley

The updated Tolt Early Warning System includes seven Federal Signal outdoor sirens (replacing four similar Whelen sirens) and five indoor alert devices. The outdoor sirens are non-rotating, electronic sirens with remote control and diagnostics providing uniform 360-degree sound patterns.

Four sirens are located along Tolt River Road to provide warning to the most upstream potential impact areas (see Figure 2.20). Many of the homes in this area are outside of the City of Carnation within unincorporated King County. Some of these areas along Tolt River Road experience limited cell phone coverage. One siren is located in downtown Carnation near the intersection of Milwaukee Avenue and Entwistle Street (see Figure 2.21). This is near the location of the original siren installed by King County in 1978. Additional sirens have been installed north of Carnation on NE 60th Street just west of Highway 203 and at Tolt-MacDonald Park. Of the seven outdoor sirens, three are located within City of Carnation limits. The other four are in unincorporated King County. A map of all outdoor siren locations is provided in Figure 2.13.

For each outdoor siren, the siren transceiver and electronics are in an above ground, water resistant vault at the base of each pole. Power comes from the utility distribution grid through an adjacent city facility. Battery backup power is provided and checked periodically for serviceability. The sirens can run for 30 continuous minutes on battery power.

Figure 2.20 – Pole-mounted sirens located on Tolt River Road (old siren shown on right, new siren shown on left).

Figure 2.21 – Pole-mounted sirens located in downtown Carnation (old siren shown on left, new siren shown on right).

Additionally, five indoor alert devices have been installed at critical public facilities within Carnation City limits. These include Carnation Elementary School, Tolt Middle School, Riverview Learning Center, the Carnation Bus Maintenance Facility, and Carnation Fire Station 85. These devices are equipped with receivers only and battery backup is provided similar to the outdoor sirens.

The City of Seattle also maintains one siren and two indoor alert devices at the South Fork Tolt Powerhouse and Regulating Basin, the closest hazard area to the dam. These sirens are activated from the City of Seattle Operations Control Center using the same system as the sirens in and around Carnation. These sirens provide warning to the crews working in these facilities.

CHAPTER 3: Key Findings – Dam Safety

A. Dam Safety Roles & Responsibilities for Tolt Dam

Dam safety is a shared responsibility. Key entities involved in dam safety include the dam owner, regulatory agencies, engineering consultants, and downstream entities which could be impacted by a dam failure. This section describes what these entities typically do to keep dams safe. The dam safety engineering profession does not have one authoritative source of best practices. However, currently accepted practices for dam safety professionals are documented by multiple sources and agencies, including federal guidelines, research publications, and professional associations.

This chapter describes what these entities are doing to fulfill their dam safety responsibilities for Tolt Dam and an assessment of whether the entity is meeting the current dam safety industry practices. Note that entities responsible for emergency management (including warning and evacuation in the event of a dam failure) are described more fully in Chapter 4: Key Findings – Emergency Management.

1. Dam Safety Regulators

Regulators define what dam owners must do to keep their dams safe. They independently verify on an ongoing basis that dam owners are fulfilling their responsibilities. In general, dam safety regulator activities include:

- Establishing dam owner safety requirements,
- Performing regular independent dam inspections,
- Ensuring safety/risk analyses are completed periodically,
- Ensuring that the dam owner takes risk reduction actions when needed,
- Ensuring the dam owner has an Emergency Action Plan for the dam, and
- Reviewing and approving dam repair plans and designs.

The regulator of the safety of Tolt Dam is the Federal Energy Regulatory Commission (FERC). FERC is the dam safety regulator for over 2,500 hydropower dams in the United States. The State of Washington Department of Ecology's Dam Safety Office also regulates dams within the state; however, the state's regulatory jurisdiction does not include any of 145 dams in the state that are owned or regulated by federal agencies (as is the case for Tolt Dam).

FERC requires the City of Seattle to do the following for Tolt Dam:

- Perform dam owner engineering inspections,
- Have an identified Chief Dam Safety Engineer,
- Have a Dam Safety Surveillance and Monitoring Plan,
- Annually report on their Surveillance and Monitoring Plan,

- Document their Owner Dam Safety Program,
- Conduct an independent audit of their Owner Dam Safety Program every 5 years,
- Issue a letter from the organization leader to all staff acknowledging their dam safety responsibility as dam owner,
- Hire an independent expert in dam safety to perform a comprehensive inspection of their dams every 5 years,
- Hire an independent expert in dam safety to perform a comprehensive Potential Failure Modes Analysis and Risk Assessment every 10 years, and
- Develop, regularly update, and exercise an Emergency Action Plan.

Based on an independent review of FERC's actions as regulator of Tolt Dam, the Review Team believes that FERC is meeting or exceeding current dam safety industry practices for regulation of the safety of Tolt Dam.

2. The Dam Owner

A dam owner has primary responsibility for the safety of their dam. If a dam fails, the legal precedent has long established that a dam owner can be held liable for any damage that is caused by failure of the structure. For non-federal dams with hydropower, dam owners must meet FERC's dam safety requirements to continue their license to generate hydropower. Dam owner responsibilities include dam operation, maintenance, monitoring, analyzing the dam's safety/risk, and repairing a dam when necessary. If an incident arises at their dam, the dam owner responds to address the problem and notifies downstream public safety officials so they can warn and evacuate the public in case of dam failure. The owner creates and exercises a dam Emergency Action Plan to fulfill its incident/failure response and notification roles. The dam owner supports downstream public safety officials in planning for the remote chance the dam fails by developing dam failure flood inundation maps and conducting Emergency Action Plan exercises with downstream public safety officials.

The dam owner of Tolt Dam is the City of Seattle. The City of Seattle has assigned its water utility department, SPU, to fulfill its dam owner responsibilities. Its sister department for electrical power, SCL, is the FERC licensee. Both SPU and SCL have dedicated dam safety teams of experienced engineers who work together to fulfill dam owner and licensee responsibilities. A full-time engineer is employed by the City of Seattle to serve as the Chief Dam Safety Engineer.

The City of Seattle has an Owner Dam Safety Program (ODSP), the latest update of which occurred in 2023. This program was last audited in 2021. Under this program, the City of Seattle is doing the following to ensure the safety of Tolt Dam:

- Continuous Monitoring
  - Trained staff visit and inspect the dam every day.
  - Remote video cameras are used by staff at the City of Seattle's Operations Control Center to view the dam during nights and weekends. The Operations Control Center is staffed 24 hours per day, 7 days per week.

- Instrumentation at the dam is used to notify the City of Seattle of developing issues such as increasing seepage. This real-time data is also available remotely to staff in the Operations Control Center.

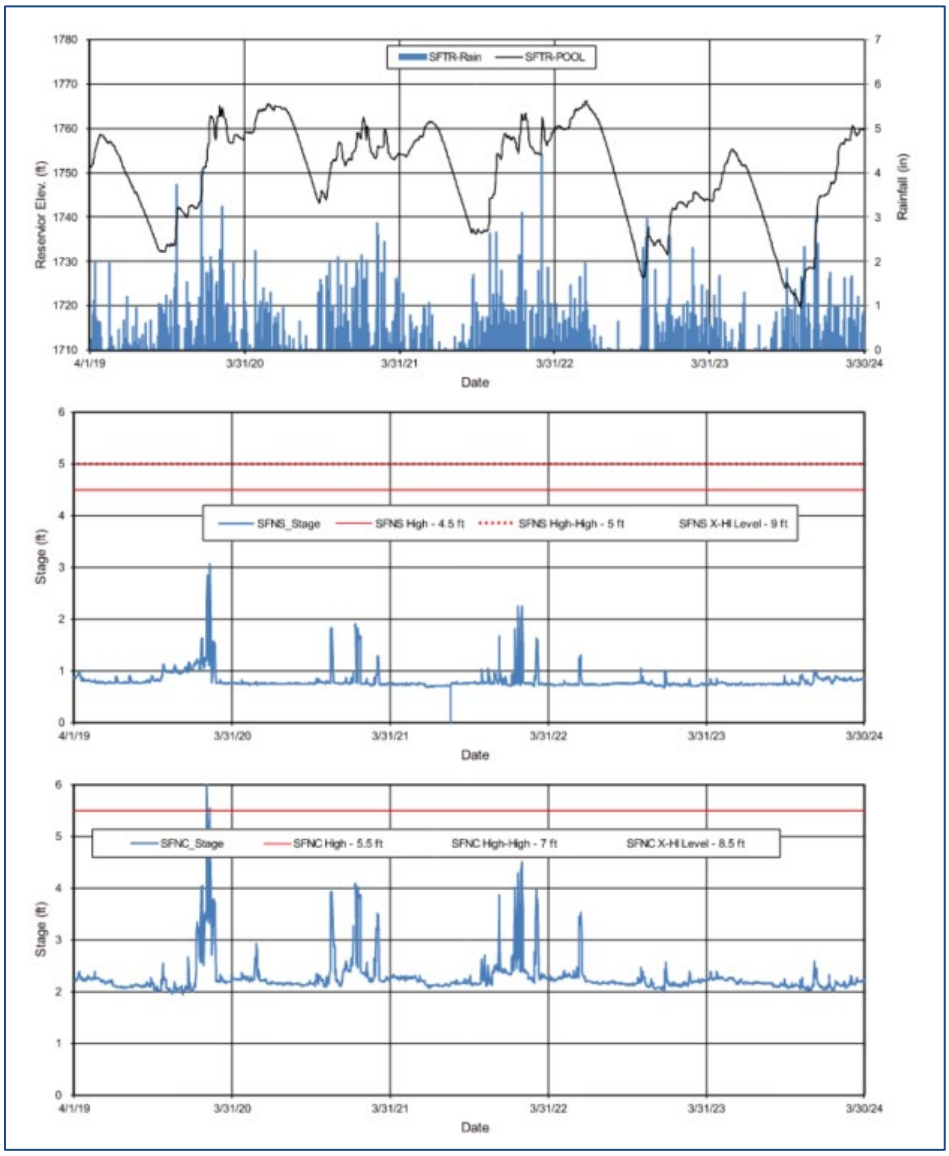


Figure 3.1 Example of streamflow and reservoir level instrumentation data recorded for Tolt Dam (SPU, 2024)

- Inspections and Assessments
  - Trained staff visit and inspect the dam every day.
  - City of Seattle engineers and FERC representatives perform engineering inspections annually.
  - Independent consulting engineers are hired to perform a comprehensive inspection every 5 years.

  - Independent consulting engineers are hired to perform a Potential Failure Mode Analysis (PFMA) and Risk Assessment every 10 years.
  - As needed, additional engineering studies and assessments are performed to confirm the safety of the dam or inform the design of needed repairs.
- Maintenance, Repairs, or Modifications to the Dam
  - Regular maintenance occurs at the dam and its components.
  - When warranted, modifications to the dam and its components are designed and constructed to improve the safety of the dam and extend its useful life.
- Preparing for Dam Emergencies
  - An Emergency Action Plan specific to the South Fork Tolt Hydroelectric Project was developed and is updated at least annually.
  - Dam failure inundation maps were developed.
  - The Emergency Action Plan is exercised with downstream public safety officials at least once every five years.
  - Plans have been made to access materials (sand and gravel) and equipment to respond to dam incidents.

The Review Team has reviewed documentation of the City of Seattle's efforts to comply with FERC requirements and perform their duties as the owner of Tolt Dam. All FERC requirements for dam owners are being met at the present time. Based on its independent review, the team believes that the City of Seattle is meeting or exceeding current dam safety industry standards for dam owners with respect to Tolt Dam.

3. Engineering Consultants

FERC requires dam owners under their regulatory jurisdiction to hire FERC-approved engineering consultants to perform independent inspections, assessments, and audits of dam safety.

The most recent Comprehensive Assessment and inspection of the safety of Tolt Dam by engineering consultants was performed in 2023 by HDR, Inc., a respected consulting firm in the dam safety industry. This effort included an on-site dam inspection, a potential failure modes analysis to identify ways the dam could fail, an analysis of the probability of dam failure given the postulated potential failure modes, an analysis of the consequences of dam failure, an assessment and documentation of the dam risk, and developing recommendations for improving the safety of dam, if necessary, to address any potential deficiencies. Two registered professional engineers from HDR, Inc. led the Comprehensive Assessment and inspection.

The most recent audit of the City of Seattle's Owner Dam Safety Program was in 2021 by Dam Safety Intelligence, an international team of five people with dam safety experience from the Bureau of Reclamation, the California Department of Water Resources, Southern California Edison, and BC Hydro. As part of the audit, consultants visited the dam, reviewed documentation, reviewed the City of Seattle's Owner Dam Safety Program document, interviewed City of Seattle staff and executives with dam safety responsibilities, and wrote an independent report on how well the dam owner is keeping their dam safe.

More information on these consultant-developed reports and their findings are summarized in Section 3.B below and Appendix F – Summary of Recent Dam Safety Assessments. Based on review of available documentation, the Review Team believes that the dam safety engineering sector is fulfilling their role in maintaining the safety of Tolt Dam.

4. Downstream Entities

Downstream entities do not directly affect the safety of the dam; however, they have critically important roles to prepare for and respond in the remote event that Tolt Dam has a major incident or fails. Both King County and the City of Carnation are political subdivisions of Washington State and are subject to the Revised Code of Washington, Emergency Management (RCW 38.52). Under this law, political subdivisions are directed to establish local organizations for emergency management which prepare and implement comprehensive emergency management plans for pertinent hazards that could impact local residents.

Other local and regional entities that would have either formal or informal emergency response roles in the remote chance that Tolt Dam has a major incident or failure include the National Weather Service, NORCOM, Eastside Fire and Rescue, and the Riverview School District. All these agencies as well as the public have a general responsibility to be aware of hazards (e.g., floods, earthquakes, chemical spills, dam failures) and plan for such events. The responsibilities and performance of these downstream entities are addressed more completely in Chapter 4: Key Findings – Emergency Management.

B. Summary of Recent Dam Safety Assessments

This section describes the dam safety assessments available for Tolt Dam and the City of Seattle's dam safety program, states whether the assessments meet current dam safety industry practice and summarizes the assessment results including the current condition of the dam and the dam's safety/risk. The following assessments were reviewed:

- Audit of the City of Seattle's dam safety program,
- Most recent FERC engineering inspection of Tolt Dam,
- Most recent Comprehensive Assessment of Tolt Dam, and
- Assessment of current version of the Emergency Action Plan for Tolt Dam.

A more complete summary of these documents including pertinent excerpts and significant findings is provided in Appendix F – Summary of Recent Dam Safety Assessments.

1. Owner Dam Safety Program Audit

FERC requires each of its licensees to have an independent review/audit of their dam safety program every five years to ensure that it is working well and identify any areas of concern or opportunities for improvement. The latest audit of the City of Seattle's dam safety program occurred in August 2021. The audit meets or exceeds current dam safety industry regulator

practices in the United States. The audit found that the City of Seattle's "safe management of dams and reservoirs is guided by their well-established Standard Operating Procedure (SOP) I-604 Owners Dam Safety Program, approved by [the City of Seattle's] Chief Operating Officer". The audit found that the City of Seattle is achieving "Good Industry Practice" or "Best Industry Practice" partially or fully across all program elements. At a high level, the results indicate that the City of Seattle's Dam Safety Program has significant strengths in the dam surveillance, audits and reviews, and governance elements. There were no elements of the Dam Safety Program with an "intermediate", "needing development", or "leading edge" rating.

2. FERC Annual Inspection Report

As dam safety regulator, the FERC performs an annual engineering inspection of Tolt Dam. The most recent inspection report available for review was dated May 24, 2023. The annual FERC engineering inspection meets and exceeds current dam safety industry regulatory practices. The inspection did not identify any conditions or instrument readings which indicated an imminent threat to dam safety or required immediate follow-up action. Overall, the dam was found to be in satisfactory condition. It was noted that the spillway was in fair condition with some concrete deterioration and issues with joints and its drainage system. To address these issues, the City of Seattle has completed a comprehensive assessment of the spillway which is the first step in completing a future spillway repair project.

Figure 3.2 – Recent FERC inspection of spillway outlet tunnel.

3. Independent Consultant's Comprehensive Assessment

FERC recently implemented guidance which requires a thorough assessment of the safety and risk of regulated hydropower dams every 10 years. This process is referred to as a Comprehensive Assessment. The City of Seattle volunteered to be one of the first dam owners in the country to perform a Comprehensive Assessment. The assessment included:

- Hiring of a FERC-approved dam engineering Independent Consultant with extensive dam safety experience,
- The review of original design and construction documents, monitoring reports, and inspection reports,
- Visual inspection of the dam by the Independent Consultant,
- Review of monitoring data and instrumentation,
- Testing operable equipment,
- Performing new or review of existing engineering analyses,
- Review of the Emergency Action Plan,
- A multi-day workshop to identify ways the dam could fail (i.e., Potential Failure Mode Analysis), and
- A multi-day workshop to estimate the risks associated with Potential Failure Modes. This is referred to as a Level 2 Risk Assessment (L2RA).

The 2023 Comprehensive Assessment and inspection of the safety of Tolt Dam was performed by engineering consultants from HDR, Inc. Based on review of the 2023 Comprehensive Assessment Report, the Review Team found that the assessment meets current dam safety industry practices. Regarding the site inspection, HDR, Inc. noted that "primary water-retaining structures were inspected with no significant unusual observations or adverse indications noted. Conditions appeared to be consistent with previously reported observations… The Project overall is well maintained and there were no observations indicating loss of capacity to meet design intent… No observations were made that caused concern about public safety, the current condition of the dam and other Project features, or continued operation of the Project."

During the Potential Failure Mode and Risk Assessment workshops, a total of 201 potential failure modes were brainstormed for the dam. The Comprehensive Assessment team found "no observations or findings that indicated that a potential failure mode was developing or in progress. No urgent or insufficient information potential failure modes were identified."

The Comprehensive Assessment team estimated that a failure of Tolt Dam has a 1 in 10,000 (0.01%) chance of happening in any given year. This indicates that the likelihood of failure is extremely low. For comparison purposes, the Federal Emergency Management Agency's (FEMA) floodplain maps estimate that most of the City of Carnation would be inundated by a naturally occurring 500-year flood (see Figure 3.3), which has a 1 in 500 chance of happening in any given year (FEMA, 2020). It is much more likely that Carnation experiences major inundation due to natural flooding than a dam failure.

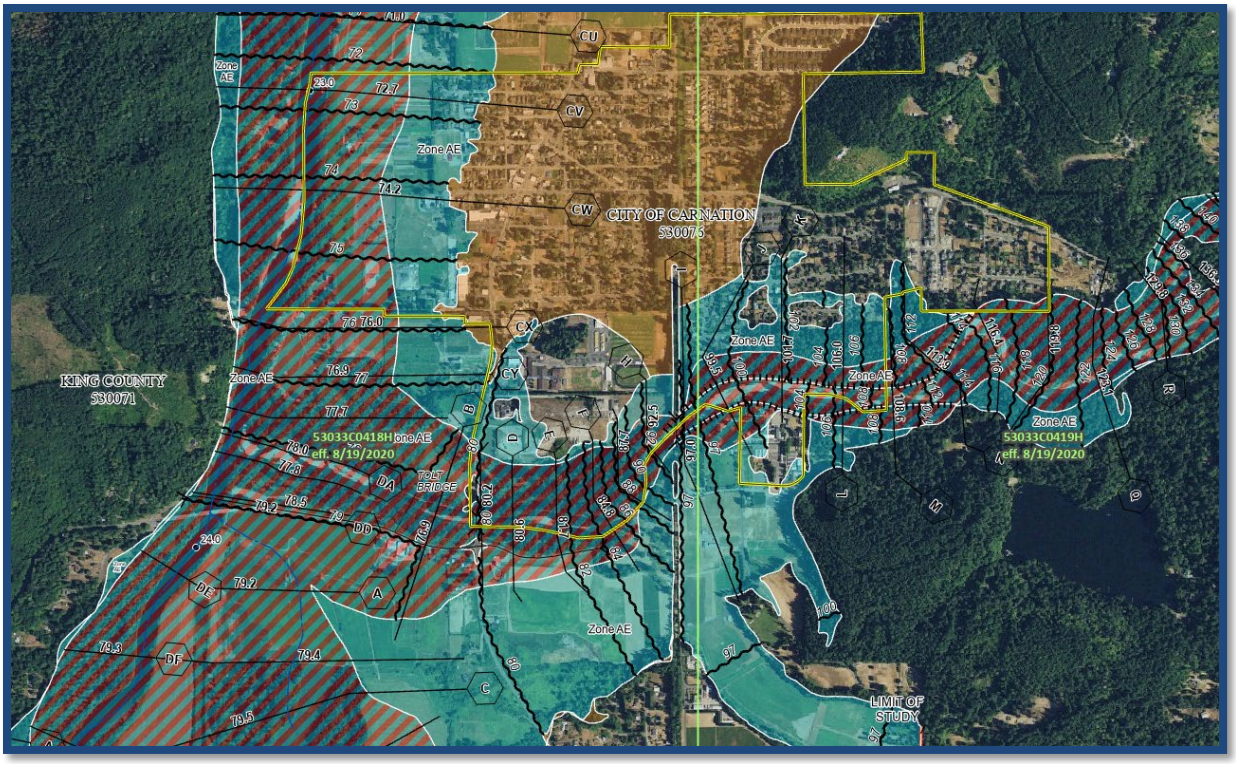


Figure 3.3 – FEMA Floodplain Map for non-dam failure riverine floods in the vicinity of Carnation, WA. Blue shaded and red hatched areas are anticipated to flood during a 1 in 100-chance per year event. Orange shaded areas are anticipated to flood during a 1 in 500-chance per year event.

Considering both the likelihood of failure and the potential downstream consequences, the Independent Consultants assigned a “moderate’ risk classification to Tolt Dam and recommended that the City of Seattle perform studies to better understand or reduce risks for extreme seismic events. Based on the findings of the Comprehensive Assessment, the Independent Consultants “judge the Project to be suitable for continued safe and reliable operation. No immediate actions are required to ensure the safety, stability, and/or structural integrity of the Project. No potential failure modes identified during the [assessment] are judged to be active or developing.”

4. Emergency Action Plan Review and Exercise

As part of their annual inspection in 2023, FERC performed a review of the Emergency Action Plan for Tolt Dam. They found that “the Emergency Action Plan document and testing procedures are adequate… City of Seattle staff are knowledgeable about Emergency Action Plan procedures and their responsibilities. Updated Emergency Action Plan flowcharts were observed in the SPU operations center. Communication methods discussed with City of Seattle staff are consistent with methods described in the plan. The licensee’s Emergency Action Plan training is considered sufficient. Equipment and materials needed for a response to an emergency are readily available and in acceptable condition.” As part of the 2023 Comprehensive Assessment, the Independent Consultants also reviewed the Emergency Action Plan and found it to be “adequate”.

FERC also requires the City of Seattle to perform a functional Emergency Action Plan exercise at least once every five years. The most recent exercise was conducted in two phases: a tabletop exercise on September 5, 2024, and a functional exercise on October 2, 2024. During the exercise, a hypothetical Tolt Dam failure scenario was simulated which consisted of a significant flood event that was compounded by debris management challenges from a simulated wildfire in the watershed. The exercise scenario included activation of the Emergency Action Plan under both ”Potential Failure” and “Failure is Imminent or Has Occurred” emergency levels, allowing participants to collaborate in addressing pre-failure and post-failure challenges. These exercises were conducted after the siren system was turned off – the exercises assumed that alternative warning methods including ALERT King County would be used.

Many local and regional emergency management or government agencies participated in the exercise including Carnation-Duvall Citizen Corps, City of Carnation, City of Duvall, Duvall Fire, Eastside Fire and Rescue, King County Sheriff, King County OEM, King County Floods Center, King County Roads, National Weather Service, NORCOM, Snohomish County OEM, Snoqualmie Tribe, Washington Department of Health, Washington Emergency Management Division, and Washington State Patrol. The exercise was used to identify opportunities to improve the Emergency Action Plan and strengthen coordination and planning among local emergency management agencies. Lessons learned from the exercise included:

- Formal protocols are needed within the City of Seattle’s Emergency Action Plan to establish a joint SCL/SPU Incident Management Team during a dam emergency.
- Duplicative efforts across various 911 centers and dispatch units created inefficiencies and other communication challenges.
- Enhanced evacuation planning is needed including traffic modeling and improved public education initiatives.
- Further collaboration and strengthening of relationships within the newly formed South Fork Tolt Regional Work Group and other regional partners is needed. This should include additional trainings and collaborative drills.
- Mass care and sheltering plans should be in place at both local and county-wide levels.

5. Summary of Dam Safety Findings

The Review Team has examined documentation of the City of Seattle’s efforts to comply with FERC requirements and perform their duties as the owner of Tolt Dam. The audit of the City of Seattle’s Owner Dam Safety Program shows that it is well-established, and all elements of the program meet or exceed dam safety industry standards. The 2023 FERC inspection report found that the dam is in satisfactory condition. The inspection did not identify any conditions which indicated an imminent threat to dam safety or required immediate follow-up action by the licensee. The 2023 Comprehensive Assessment of the safety and risks of Tolt Dam completed by an Independent Consultant concluded that the dam is “suitable for continued safe and reliable operation.” The assessment found that the likelihood of dam failure was extremely low (1 in 10,000 chance of happening in any given year). The Emergency Action Plan was also found to

meet industry standards and federal requirements. It is being regularly updated, tested, and exercised.

CHAPTER 4: Key Findings – Emergency Management

A. Roles and Responsibilities for Emergency Management

Local governments and first responder agencies have the responsibility to protect the safety of the public by planning and responding to any reasonable natural or man-made hazard that may exist or occur. For dam hazards, downstream public safety officials rely upon information provided in the dam owner's Emergency Action Plan to plan for and respond to emergencies. These public safety officials coordinate to:

- Understand which areas and people would be flooded or otherwise impacted by a dam failure,
- Develop warning and evacuation plans,
- Provide updated contact information to the dam owner for inclusion in the Emergency Action Plan,
- Educate and help people in the dam failure flood plain to know and plan for protective actions (e.g. evacuation),
- Participate in the dam owner's Emergency Action Plan exercises,
- Receive notifications from the dam owner in the remote chance of a major dam incident or failure, and
- Issue warnings and evacuation recommendations to the affected public and aid in evacuation.

These responsibilities are often shared or overlap between agencies depending on the nature of the hazard and emergency. Federal and state emergency management agencies provide resources, guidance, and oversight pertaining to emergency management, but planning and execution of emergency response is generally left to local or regional government agencies except in the event of a major or widespread disaster.

In the remote chance that Tolt Dam has a major incident or failure, key emergency management players include the following organizations: City of Seattle (as the dam owner); King County OEM; the City of Carnation; and the National Weather Service. Other local and regional entities that would have an emergency response role include King County Sheriff, NORCOM, Eastside Fire and Rescue, the Carnation-Duvall Citizen Corps, and the Riverview School District. Private groups such as Remlinger Farms and Sno-Valley Senior Center also play a role in planning for and facilitating evacuation of their patrons during an emergency. All these agencies as well as the public have a general responsibility to be aware of hazards (e.g., floods, earthquakes, chemical spills, dam failures) and plan for such events. The roles and responsibilities of these various entities are outlined herein.

1. Federal and State Agencies

Federal Emergency Management Agency (FEMA)

FEMA provides resources and general guidance to states and local communities regarding emergency management and preparedness. FEMA also plays a leading role at the federal level for alert and notification systems. The Integrated Public Alert & Warning System (IPAWS) is FEMA's national system for local alerting that provides authenticated emergency and life-saving information to the public through various technologies and channels. The operations concept for IPAWS is depicted in Figure 4.1.

A request for an alert comes from officials at the federal, state, territorial, tribal or local level. After going through a verification process, a mix of warning technologies and channels are used to disseminate the alert to the public. Technologies used within the IPAWS network include:

- Wireless Emergency Alerts (WEA) via cell phone. WEAs are short emergency messages, either 90- or 360-character messages from public alerting authorities that can be broadcast from cell towers to any WEA-enabled mobile device in a locally targeted area.
- Emergency Alert System (EAS) via broadcast systems. EAS delivers alerts via AM, FM and satellite radio, as well as broadcast, cable and satellite television.
- NOAA Weather Radio (NWR). NWR is a nationwide network of radio stations broadcasting continuous weather information directly from the nearest National Weather Service office. NWR broadcasts official Weather Service warnings, watches, forecasts and other hazard information 24 hours a day, 7 days a week.

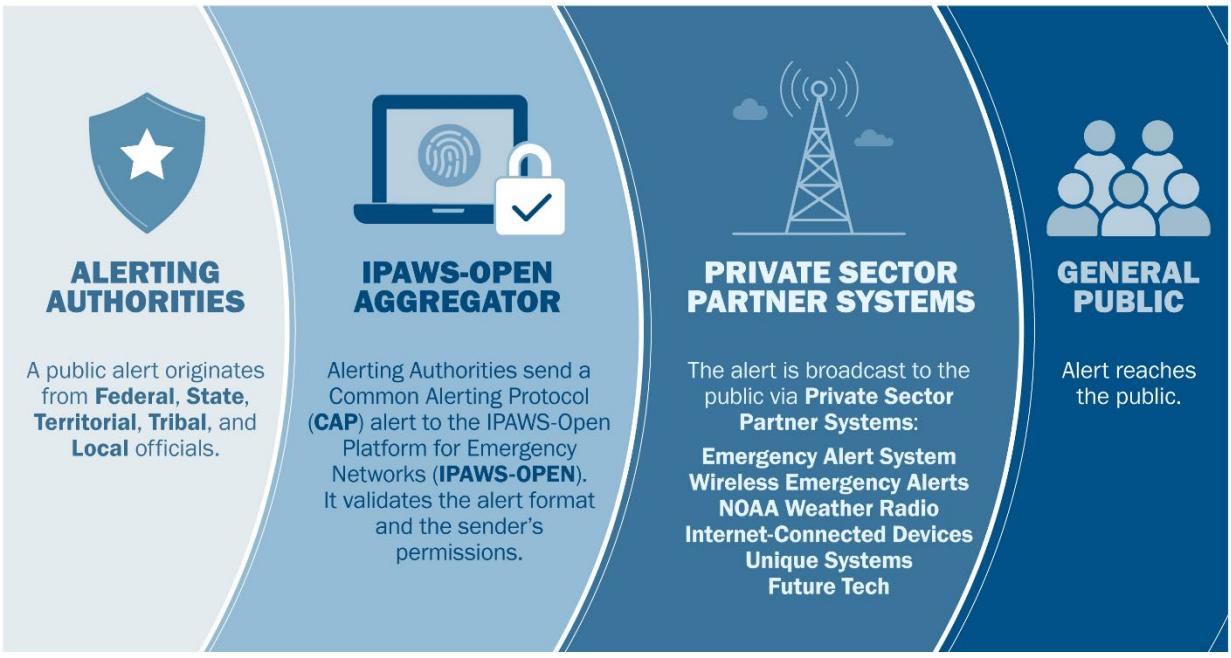


Figure 4.1 – FEMA's Integrated Public Alert & Warning System (IPAWS) Concept of Operations (FEMA, 2025a)

Federal Energy Regulatory Commission (FERC)

As described in Chapter 3, FERC serves as regulator for the South Fork Tolt River Hydropower Project and defines what the City of Seattle must do to keep Tolt Dam safe. One regulatory requirement related to emergency management is that a dam owner must develop, regularly update, and exercise an Emergency Action Plan (FERC, 2015). While FERC's jurisdiction is limited to individual dam owners, these activities related to emergency action planning can and should include reaching out to local public safety officials for input or participation in exercises. During an actual emergency, FERC does not play an active role in facilitating the emergency response.

State of Washington Military Department, Emergency Management Division

As part of the State of Washington's Military Department, the Emergency Management Division manages the state Emergency Operations Center (EOC) during state emergencies. This includes gathering information, coordinating response, and prioritizing the use of state resources needed to respond to an emergency.

For local or less widespread emergencies, the state delegates emergency management responsibilities to local (i.e., county or city) governments. The Emergency Management Division does provide planning assistance to these local governments and emergency planners. This includes support for developing or reviewing Comprehensive Emergency Management Plans and hazard-specific annexes. Per RCW 38.52.070, the Emergency Management Division must periodically review and approve the Comprehensive Emergency Management Plan for each local jurisdiction within the State of Washington.

2. Dam Owner (City of Seattle)

During an emergency, a dam owner is generally responsible for detecting and evaluating problems at their dam, classifying the incident (e.g., unusual condition requiring additional monitoring, potential failure, imminent failure), notifying public safety officials in the event of a potential or imminent failure, and taking appropriate actions to try to stop or delay failure of the dam (FEMA, 2013; FERC, 2015).

The City of Seattle maintains an Emergency Action Plan which outlines the following:

- Actions they would take to moderate or alleviate a problem at Tolt Dam,
- Actions they would take in coordination with local emergency managers to respond to incidents at the dam,
- Procedures they will follow to notify emergency managers and others of any dam incident or failure,
- Inundation mapping to help emergency managers plan for and respond to a dam failure event, and
- Delineation of responsibilities of all involved in managing an incident or failure.

As noted in Chapter 3, this Emergency Action Plan is regularly updated and exercised with input from local stakeholders. Staff are regularly trained and prepared to fulfill the dam owner duties should an emergency at Tolt Dam arise.

In addition to maintaining their Emergency Action Plan and the siren system, the City of Seattle has recently made efforts to improve emergency preparedness in the City of Carnation by financing dam failure evacuation signage (see Figure 4.2) and supporting the City of Carnation's annual "Be Dam Ready" community events.

Within the United States, dam owners do not typically have any responsibility for evacuation or warning of the public. However, for many decades, the City of Seattle has operated, maintained, and managed a siren system to warn people in the City of Carnation to evacuate in the remote event of a Tolt Dam incident or failure. The siren system has been the primary method for warning residents about a problem at the dam and initiating an evacuation recommendation. Rather than downstream public safety officials being responsible for warning downstream people and issuing evacuation recommendations, the City of Seattle has assumed these roles.

Figure 4.2 – Evacuation route signage has been installed in and around Carnation.

The *Federal Guidelines for Dam Safety: Emergency Action Planning* (FEMA, 2013) caution dam owners against assuming such responsibility:

> *Dam owners should not assume or usurp the responsibility of government entities for evacuation of people. However, there may be situations in which routine notification and evacuation will not be sufficient, as in the case of a residence located immediately downstream of a dam or a campground that would be inundated within minutes of a dam failure. In some cases, dam owners may arrange to notify the residence or campground directly. Such procedures should be coordinated with the appropriate authorities before an emergency situation develops.*[3]

In the case of Tolt Dam, it would take approximately 1.5 hours for the leading edge of the flood wave resulting from failure of the dam to reach the City of Carnation (see inundation maps in Appendix C). Advance notice that a failure is about to occur would provide additional response time beyond the flood wave travel time of 1.5 hours. Given the level of instrumentation and monitoring at Tolt Dam, it is highly likely that problems at the dam would be observed well in advance of dam failure and that advance notification could be given to public officials and emergency managers in downstream areas so that preparations could be made for a potential evacuation. Given the amount of available response time, the need for the City of Seattle to assume warning responsibility is questionable. Additionally, the Review Team was unable to locate any evidence that formal or legal authority for warning or evacuation was transferred to the City of Seattle when King County relinquished control of the first siren system in the early 1980s.

3. Local Government Agencies

Warning and evacuation planning and implementation are responsibilities of local emergency management authorities with the legal authority to perform these actions (FEMA, 2013; FERC, 2015). Both King County and the City of Carnation are political subdivisions of Washington State and are subject to the Revised Code of Washington, Emergency Management (RCW 38.52). Under this law, political subdivisions are directed to establish local organizations for emergency management which prepare and implement Comprehensive Emergency Management Plans for pertinent hazards that could impact local residents.

King County Office of Emergency Management

In Washington, counties are responsible for unincorporated areas including small towns that have not incorporated. Legally, the County Executive has the authority to recommend an evacuation in unincorporated King County. The County is not responsible for warning and evacuating incorporated cities such as Carnation. The authority to recommend an evacuation within incorporated areas is typically addressed in municipal code and varies from one incorporated jurisdiction to another.

[3] This language is also included in FERC's *Engineering Guidelines for the Evaluation of Hydropower Projects, Chapter 6: Emergency Action Plans* (FERC, 2015).

King County has established an Office of Emergency Management (OEM) to fulfill its responsibilities regarding emergency management. King County OEM has assumed two primary roles related to emergency management:

- Warning and evacuating residents in unincorporated areas.
- Providing support to incorporated areas of King County with training, expertise and resources to aid their emergency management planning and capabilities.

The County also has a regional responsibility for coordination of emergency management. King County OEM describes their role in warning King County residents as follows:

> *Several communication tools and channels will be used for accurate, timely, and accessible emergency communications … within the King County region. These include mass notification systems (e.g., ALERT King County), translated written materials, [translatable blog content to reach diverse communities], in-person and telephone-based interpretation services, and community-based social media networks (e.g., Facebook).*
>
> *ALERT King County is the name of the county's mass notification system, hosted by King County OEM. It utilizes the CodeRed/OnSolve platform. It has several different ways to send alerts using texts, email and voice. For immediate life safety messages, the system can access the 'reverse 9-1-1' database, which encompasses all landline phone numbers (excluding VoIP). The system can utilize WEA alerts for wireless devices, sending messages to an affected area(s) by geofencing or geocoding. Additionally, the last database is the opt-in database, where people sign up to receive alerts by including their desired contact preference (cell, email, home phone, text). [To inform populations who speak languages other than English, there are processes] in place to access certified interpreters, qualified bilingual staff, and certified translators. In addition, machine translation is used to initially capture a draft of an alternate language communication; then reviewed and edited for proper context, meaning, and tone by a native speaker, when available. (King County, 2022)*

In an emergency at Tolt Dam, the county would activate ALERT King County when they receive a call from the City of Seattle indicating that the dam may fail or has failed. The County's maintenance and operation of this system is a key component of warning dissemination for a hypothetical dam failure emergency.

As part of their technical assistance, King County OEM maintains a Zone Liaison Program for coordinating with communities in the county. The county representative meets regularly with communities. Zone coordinators are responsible for reaching out to cities to see how they can help with technical resources and provision of resources. In addition, the county has a dam safety specialist that oversees issues at all of dams in the county. The County has facilitated regional working group meetings including a group focused on evacuation planning for the City of Carnation.

King County OEM has made efforts to assist the City of Carnation with emergency management-related grant applications, though they have largely been unsuccessful to date since the City of Carnation did not have a Hazard Mitigation Plan which is a prerequisite for FEMA grant funds. As of June 2025, the City of Carnation has developed and adopted a Hazard Mitigation Plan which should facilitate future grant assistance efforts. The County has also been an active participant in Tolt Dam emergency exercises and has participated in local community outreach and preparedness events.

City of Carnation

By law, the City of Carnation is responsible for emergency management within its incorporated limits. While the City of Carnation empowers the Mayor to have emergency powers for civil disobedience and civil crimes [Chapter 9.22 of Carnation Municipal Code], the city code does not include measures that authorize the mayor or their representative to issue an evacuation recommendation for residents in a manmade or natural disaster.

The City of Carnation is doing the following related to emergency planning, warning and evacuation preparedness/implementation generally and for the Tolt Dam hazard specifically:

- A part-time Emergency Operations Manager position was created and staffed in 2023.
- A Comprehensive Emergency Management Plan (Basic Plan and Emergency Support Functions) specific to the City of Carnation has been developed as required under WAC 118-30 and RCW 38.52.070.
- The City of Carnation holds an annual “Be Dam Ready” community event dedicated to educating residents about emergency readiness, including responding in the remote event that there is a major incident or failure of Tolt Dam. As part of the event, residents can experience the walk up Evacuation Hill to the assembly area. The event is supported by the City of Seattle.
- Carnation staff participate in Tolt Dam Emergency exercises hosted by the City of Seattle.
- The City of Carnation participates in a monthly emergency preparedness meeting with the City of Duvall, King County, and others.
- The City of Carnation has an Emergency Preparedness Resources website that includes information regarding personal and family preparedness, business and employee preparedness, disaster preparedness, generator safety, and the Carnation-Duvall Citizen Corps.

The original version of Carnation’s Comprehensive Emergency Management Plan (CEMP) was prepared in 2006. This has been revised several times since its inception, and the most recent version of the plan is dated March 2025. The most recent approval letter from the Washington Emergency Management Division is dated June 2, 2022. Within this letter, it is noted that “continued work [is] required for your CEMP to meet requirements.”

The plan includes a hazard risk ranking table which identifies severe weather, flooding, and earthquake as having higher risk than dam failure (see Table 4.1). While the Comprehensive Emergency Management Plan is intended to address all hazards that could occur in the City of

Carnation (e.g., wildland fires, riverine flooding, and earthquakes), the Review Team observed that the City of Carnation and its residents have placed a considerable focus on dam failure even though its risk ranking is lower than severe weather, flood, and earthquake hazards (City of Carnation, 2025). This is understandable given the attention, fear, and distrust that the recent Tolt Early Warning System false alarms have created. Nonetheless, the Review Team notes that it would best serve the community if an all-hazard emergency management approach is implemented and emphasized among residents.

Table 4.1 – Hazard Risk Ranking from Carnation Emergency Management Plan

Rank	Hazard Type	Risk Rating Score (Probability x Impact)
1	Severe Weather	48
1	Severe Winter Weather	48
3	Flood	42
4	Earthquake	32
5	Dam Failure	18
6	Landslide	12
7	Wildfire	9
8	Volcano	7

Within their Comprehensive Emergency Management Plan, the City of Carnation outlines its responsibilities during an emergency. Each City Department develops Standard Operating Procedures (SOPs) which outline how they will carry out tasks within the plan, conducts training on SOPs, assigns a representative to the designated Emergency Operations Center during times of disaster, and keeps records of emergency actions and expenditures. The City Council is to provide emergency legislative support including proclamations of emergency and activation of emergency powers. The City Manager implements emergency statues, approves evacuation orders, informs the public, enters into mutual aid agreements, and acts as or appoints a Public Information Officer. The City Manager is also responsible to plan in advance of an emergency by developing and maintaining the Comprehensive Emergency Management Plan and associated SOPs, planning drills and training, and coordinating with local and regional partners.

The plan also includes assumed responsibilities or assistance that local and regional agencies such as King County, the Riverview School District, Salvation Army, Carnation-Duvall Citizen Corps, and others may be able to provide. The City of Seattle is not mentioned within the plan as having any role in warning or evacuation.

As of June 2025, the City of Carnation has developed and adopted a Hazard Mitigation Plan Annex as part of their Comprehensive Emergency Management Plan. This annex includes a summary of hazard risk and vulnerability, hazard and asset maps, and hazard mitigation strategies. Hazards addressed within the annex include avalanche, acts of violence and terrorism, cyberattack, dam failure, earthquake, extreme weather, flood, hazardous materials incident, health incident, landslide, structural fire, tsunami, volcano, and wildfire. Hazard mitigation strategies laid out in the annex address dam resilience (highest priority), flood resilience (high priority), fire resilience (medium priority), terrorism resilience (low priority), and expanding an alert warning system (low priority).

The plan outlines a broad range of emergency planning information including transportation, communication, public works and engineering, firefighting, information and planning, public health and medical services, public safety and security, long term community recovery, and external affairs among others. The latest version of the document does not include an Evacuation Plan for any of the identified hazards. The City of Carnation has developed a conceptual plan for the evacuation of residents in the event of a dam failure (see Figures 4.3 and 4.4). A major part of the concept is to use pedestrian evacuation to move people to higher ground.

Even though the City of Carnation has a Comprehensive Emergency Management Plan and has made recent strides in furthering their preparedness, the responses of residents and staff during past false alarm events suggest that the City of Carnation lacks the resources and capacity to implement their plan, support emergency response, or issue warnings during an actual emergency. They would be heavily reliant on King County OEM, King County Sheriff, Eastside Fire and Rescue, and other regional partners.

In an actual emergency, the City of Carnation would rely on limited contract support from the King County Sheriff and Eastside Fire and Rescue to implement traffic control or evacuation. With regards to notification and warning, the City of Carnation has limited avenues to share information or warn its residents of a hazard apart from the sirens and indoor warning devices of the Tolt Early Warning System. There is a city website, a community Facebook page and other social media where the City of Carnation posts information. Otherwise, the City of Carnation does not maintain any means of sharing warning information, and residents do not have identified sources (emails, websites) to receive additional information about hazards or confirm whether a siren activation is real or false. In an actual emergency, the City of Carnation would rely on King County OEM and other regional partners to communicate warning information.

The City of Seattle has for decades assumed some of the warning and evacuation responsibilities (with the siren system), which may have contributed to an overreliance on the siren system and a weaker state of readiness by the City of Carnation, which is still developing its own plan for evacuating people at risk. This is true of any hazard that could impact the community (e.g., flood, earthquake, fire), not just dam failure.

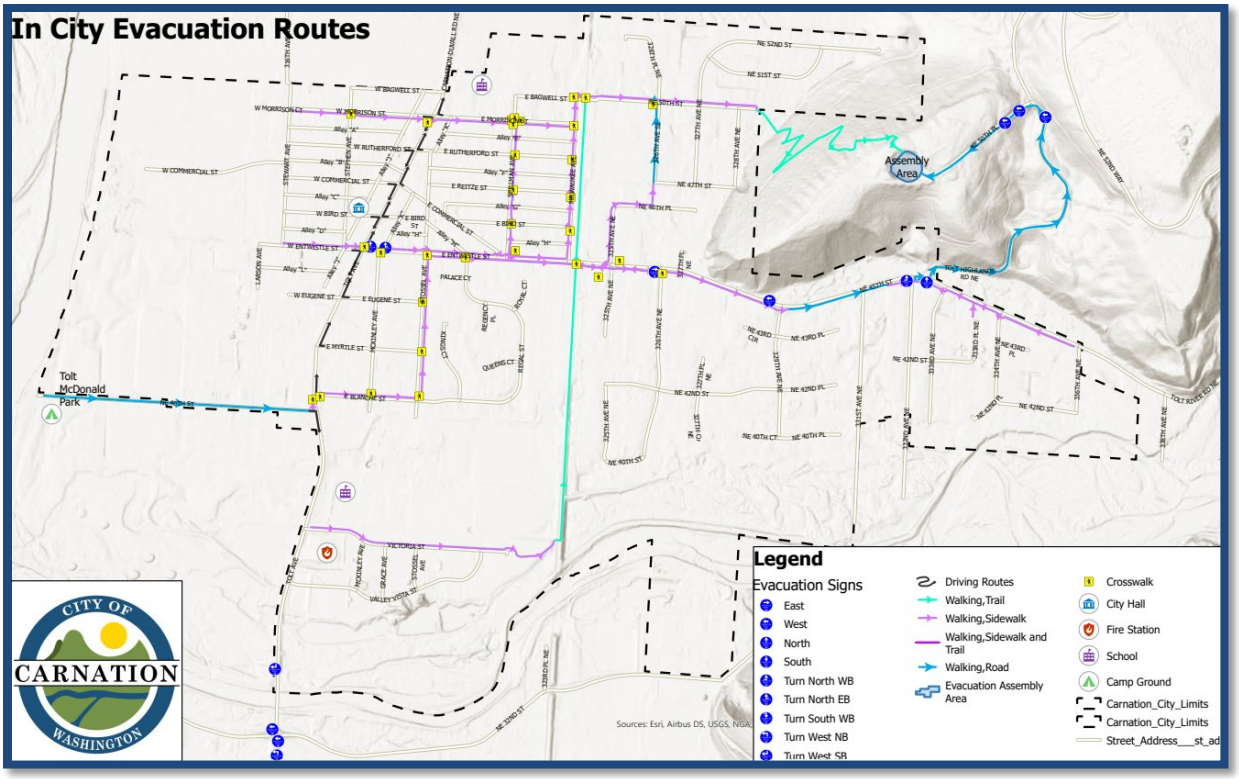


Figure 4.3 – City of Carnation Pedestrian Evacuation Route Map

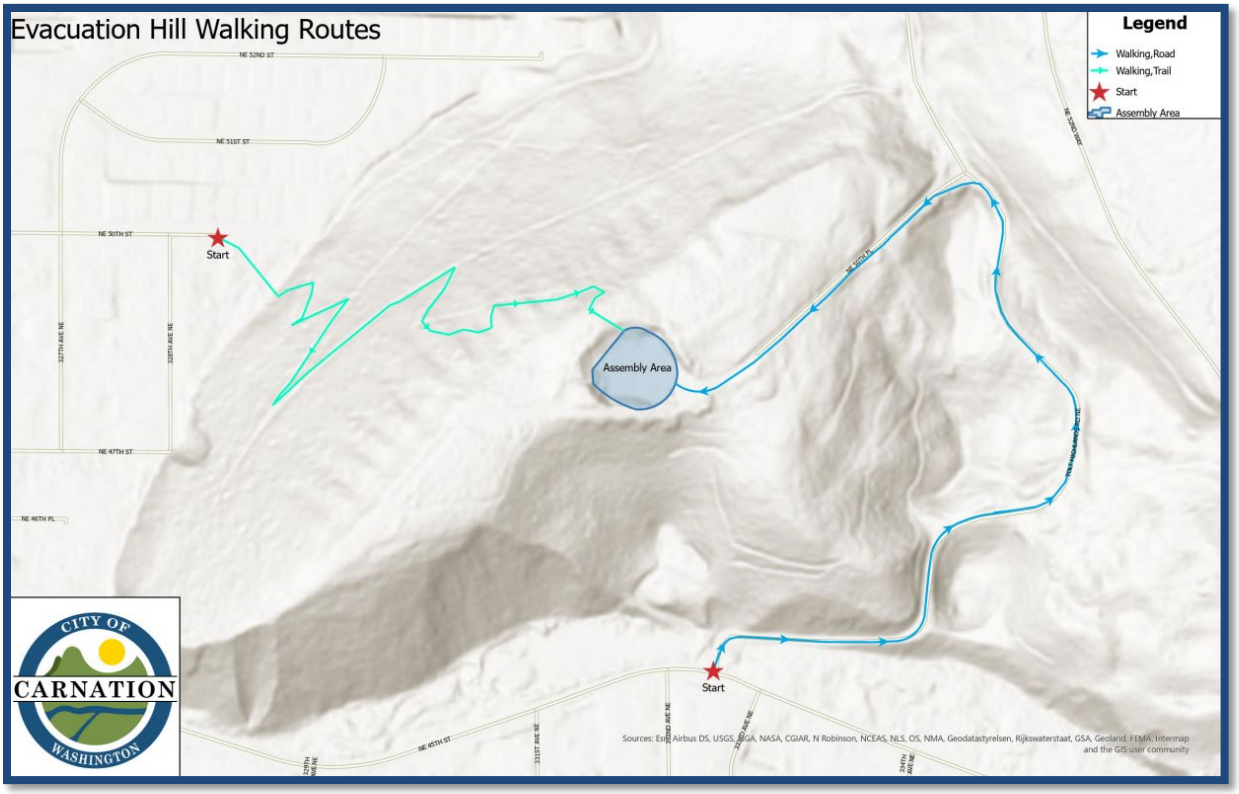


Figure 4.4 – City of Carnation Evacuation Hill Trail Map

4. Supporting Organizations for Warning and Evacuation of the General Public

National Weather Service (NWS)

The NWS is responsible for issuing flood warnings including flooding due to dam failures. Local NWS offices work closely with dam owners to provide technical assistance with flood forecasting, inundation modeling, and warning messaging. NWS staff also regularly participate in dam owner Emergency Action Plan exercises.

The NWS uses multiple methods to disseminate warnings within the IPAWS framework. Those most relevant to Tolt Dam include NOAA Weather Radios, Wireless Emergency Alerts (WEA) which send text messages via cell phone networks, and the National Weather Wire Service (NWWS), and Emergency Alert System (EAS) which broadcast over television and radio networks. More detailed information about these warning channels is provided in Appendix G.

The nearest NWS office to Tolt Dam is located in the City of Seattle. Local staff have participated in Tolt Dam emergency exercises but were not involved in the Tolt Early Warning System false alarm events.

NORCOM

NORCOM is a consolidated 911 dispatch center. It was founded in 2007 by twenty public safety organizations in the northeast region of King County. Eastside Fire and Rescue who provides fire protection services to the City of Carnation is one of these agencies. The consolidated structure of NORCOM was created in an effort to improve regional coordination and decrease opportunity for misinformation.

The NORCOM dispatch center serves as a communication hub during emergencies: receiving and managing calls for help, coordinating appropriate response with emergency responders, and obtaining and sharing pertinent information. NORCOM is not authorized to distribute EAS or WEA alerts. They defer to King County to distribute these types of public emergency alerts. For community members who subscribe, NORCOM shares information regarding local incidents (e.g., traffic accidents, floods, etc.) via a mobile application called PulsePoint . Because of the false alarms at Tolt Dam, “false alarm” has been entered into their system as a flooding call type.

When the Snoqualmie Valley floods, NORCOM will assist in dispatching resources over to the other side of the river prior to areas becoming isolated or cut off. They also participate in dam owner Emergency Action Plan exercises including the most recent exercise for Tolt Dam.

Because NORCOM has received calls from residents about false alarms, the City of Seattle notifies them via phone call of any known incidents with either the dam or the siren system. NORCOM can share that information with callers to confirm the validity of a siren sounding. During the July 2020 incident, NORCOM was informed by the City of Seattle that it was a false alarm within 6 minutes even though the dam siren sounded for 38 minutes.

King County Sheriff

The King County Sheriff's Office provides police services to over half a million people in unincorporated areas and twelve contract cities within the County. The City of Carnation is one of those cities that is under contract with King County Sheriff. A King County Deputy works 40 hours per week for Carnation. If there are any calls outside of that window, response would be provided by a regional police group through mutual aid agreements.

If an incident were to occur at Tolt Dam, the King County Sheriff would be notified of the emergency by City of Seattle. Given the time it would take for a flood wave to arrive if the dam failed, the Sheriff's Office believes they would have at least 40 minutes to assist with evacuation prior to evacuating their own staff and resources.

Eastside Fire and Rescue

Eastside Fire and Rescue provides fire and emergency medical services. The agency is a non-profit that provides service to Carnation, Duvall, and surrounding unincorporated areas. Legally, they do not have emergency management responsibilities but work with the local cities and King County to prepare for emergencies. The agency provides many related services including construction fire code plan reviews, disaster preparedness and education, emergency medical aid, fire and life safety inspections, fire protection and suppression, hazardous materials and confined space services, public fire safety and prevention education, specialized technical and swift water services, and wildland fire services.

Carnation-Duvall Citizen Corps

The Carnation-Duvall Citizen Corps Council is a FEMA-sponsored and trained non-profit organization that was incorporated in 2003. They are a community response team that meets once per month to bolster emergency preparedness in the cities of Carnation and Duvall. Volunteers can receive a wide range of training including first aid, sheltering, and crowd/traffic management. 1,200 volunteers have been trained over 20 years, largely with courses to help their own families in the event of an emergency. There are currently over 100 active members of the Corps who have background checks and could assist during an emergency.

The Corps has a Memorandum of Understanding (MOU) with the City of Carnation regarding their role in supporting emergency response. If deployed by a local official, some of the things that the Citizen Corps could do to help include:

- Assist setting up shelters using supplies stored on Evacuation Hill,
- Set up a HAM radio network for communications, and
- Help man barriers/traffic control stations.

The Citizen Corps also reaches out to the community to increase awareness of hazards (particularly earthquake preparedness) and encourage residents to have an emergency plan and survival kit.

5. Supporting Organizations for Warning and Evacuation of Targeted Groups

Riverview School District

The Riverview School District includes the Cities of Carnation and Duvall as well as surrounding areas. Three of its six schools are located in the Tolt Dam breach inundation zone (Tolt Middle School, Carnation Elementary, and the Riverview Learning Center). Each of these facilities has been equipped with an indoor alert device that is tied to the Tolt Early Warning System. The District's bus maintenance facility is also located in Carnation and includes an indoor alert device.

Figure 4.5 – Pedestrian trail on the northeast side of Evacuation Hill.

Because of their location in the inundation zone and their responsibility for children and staff, the District has long been a proponent of emergency preparedness. The District performs an annual evacuation drill in which students and staff evacuate on foot from school facilities via the pedestrian trail to Evacuation Hill (see Figures 4.4 and 4.5). Within the community, it is frequently expressed that the students and school district staff are the most prepared to respond to a dam emergency thanks to these annual drills.

While Riverview School District has buses, equipment, and other facilities that may be helpful to the community during an emergency, they understand their first and foremost responsibility is to plan for the evacuation and safety of their students and staff. They have a reunification plan and instruct parents not to put themselves in danger by coming to the schools searching for their children in the event of an actual emergency. Per their evacuation plan, the children would have already evacuated on foot. There are school programs for students with disabilities in Carnation, and these students would need to be evacuated by vehicle.

Because of the District's role in evacuating students, they do participate in King County coordination meetings about emergency preparedness as well as the recent Emergency Action Plan exercise.

Sno-Valley Senior Center

The Sno-Valley Senior Center is a facility in downtown Carnation that provides services (e.g., meals, health and dental services, social activities, counseling, transportation) to seniors from across the region. They also provide affordable senior housing near their facility in Carnation. While the Senior Center has an emergency evacuation plan, it does not hold itself responsible for evacuating seniors out of Carnation in the event of a dam emergency. Seniors who participate in the services of the center are independent and typically have their own vehicles in which to evacuate. The center does operate a few shuttle vans which can also be used to evacuate seniors or staff at the facility (as they did in the March 2024 mistimed warning). There is a significant population of seniors in the area which would require special attention and assistance from neighbors and first responders in an actual evacuation event.

Remlinger Farms

Remlinger Farms is a family-owned and operated farm and activity center which is open to the public. In addition to the farm, the site includes a brewery, store, and amusement park. The farm regularly hosts festivals and other public events. Recently, Remlinger Farms began hosting summer concerts which can draw as many as 6,000 people to the venue.

In order to protect staff and customers, Remlinger Farms has developed an Emergency Plan including means of evacuating everyone on site to safety in the event of a dam failure. The plan requires evacuation of all farm facilities on foot to nearby Girl Scout Hill (which is less than a three-minute walk from the main office). This hill is large enough to hold even the largest anticipated crowds during summer concerts and includes facilities with water supplies. The plan was tested

during the 2020 false alarm when about 100 customers were successfully evacuated in approximately 11 minutes.

Residents from Carnation have voiced concern that evacuations during summer concerts could be detrimental to traffic and evacuation of residents. These concerns are understandable given that it typically takes 45 minutes to clear the parking lot after a concert with normal traffic control. However, given that the Emergency Plan of Remlinger Farms assumes evacuation of all participants on foot, there should be little to no impact on vehicle traffic. During concert events, the farm employs a significant security presence which could be used to restrict vehicular traffic and enforce pedestrian evacuation of concert-goers to Girl Scout Hill.

6. Downstream Public

People living downstream of dams should seek information to know if they are in a dam failure flood zone and, if so, which protective actions they need to perform (such as where and how to evacuate) if instructed to by public safety officials. The public may also participate in drills or exercises.

From reports of the confusion and traffic congestion during the response and evacuation of the July 2020 false alarm and subsequent unplanned soundings of the siren system, the team believes that additional effort is required to prepare residents in the evacuation zone. The City of Seattle, City of Carnation, King County OEM, and other agencies should continue to administer and improve community engagement, education, and preparedness outreach efforts.

B. Organizational Factors and Operational Performance

Studies of organizational and operational performance in emergencies have led to the identification of three categories or factors that differentiate good from poor performance. These factors are:

1. Having written plans and procedures,
2. Practicing the plans and procedures, and
3. Avoiding communication breakdowns.

In addition to these three factors, a key aspect of the performance of the Tolt Early Warning System is the false alarms and unplanned soundings which have plagued both the old and new siren systems since 2020. These events have had a significant impact on organizational and operational performance on many levels.

A more in-depth description of these factors is provided in Appendix G – Emergency Management Best Practices. In completing this review, the Review Team has considered these items in assessing the organizational and operational performance of the City of Seattle and other stakeholders who have navigated the incidents associated with the Tolt Early Warning System. This section summarizes key observations relating to these factors.

1. Having Written Plans and Procedures

City of Seattle Emergency Action Plan

The Emergency Action Plan for Tolt Dam is well thought out and lays out a good decision-making framework for issuing a warning. The threat tables linking various indicators to action levels are excellent. An example of these threat tables is illustrated in Table 4.2. The City of Seattle appears to be well-positioned to implement this plan should the need arise.

City of Carnation Comprehensive Emergency Management Plan

The City of Carnation's Comprehensive Emergency Management Plan provides an important framework for their staff to develop the tools and capacities they need to effectively respond to an emergency. However, the City of Carnation lacks the resources and capacity to implement their plan, support emergency response, or issue warnings during an actual emergency. In their emergency plan, they have delegated all warning responsibilities to King County.

Additionally, the latest version of the document does not include an Evacuation Plan for any of the identified hazards. More detailed and comprehensive evacuation planning is needed to come up with optimum strategies and plans for implementing those strategies. This should include a traffic study to guide the development of evacuation zones and routes. This study can also be used to develop an understanding of the time needed to evacuate the area for both pedestrian and vehicular evacuations.

Table 4.2 – Example of Response Table from Tolt Dam Emergency Action Plan

No.	Event Description	SPU Control Center	SPU Tolt Crew Chief	SPU Operation Response Center	Emergency Level for Notification
6	TDWS Alarm 6 Downstream River Gauging Station (SFNC) reading exceeds "High-High" threshold. SFNC stage > 7.0 ft. Flow rate > 5,000 cfs	• Immediately use video camera to verify condition, AND • Notify Tolt Crew Chief. Contact Transmission Manager if the Tolt Crew Chief does not respond within 15 minutes. • Closely monitor video and instrument status on computer screen.	• Dispatch crew to visually check the condition of the dam. Verify alarm condition by visually checking the stream flow below the dam or have crews manually measure the gauge "High-High" alarm immediately. • Notify SPU Dam Safety Supervisor immediately if alarm is true and • Send written Incident Log to SPU Dam Safety by next working day, EVEN IF ALARM IS FALSE.	If requested, make calls in Notification Flowchart 2.	Potential Failure Notification Flowchart 2
7	TDWS Alarm 7 Upstream River Gauging Station (SFNS) reading exceeds "Extreme High" threshold. SFNS stage > 9 ft. Flow rate > 8,000 cfs	<u>When any ONE of the 4 alarms is on and local siren is sounding:</u> • *Immediately* use video camera to verify condition. • Closely monitor video and instrument status on computer screen. • Notify Tolt Crew Chief. Contact Transmission Manager if the Tolt Crew Chief does not respond within 15 minutes. <u>When any TWO of the 4 alarms is on:</u> • Verify failure condition by video. See Table G-1 for conditions to sound sirens. • Make calls as shown on Notification Flowchart 3, unless it is clear that the dam is NOT failing, AND • Sound the sirens if it is clear that the dam is failing, OR • Push the "over-ride" button if it is clear that the dam is NOT failing.	• Dispatch crew to visually check the condition of the dam. Verify alarm condition by visually checking the stream flow below the dam or have crews manually measure the gauge "Extreme High" alarm immediately. • Notify SPU Dam Safety Supervisor immediately if alarm is true and • Send written Incident Log to SPU Dam Safety by next working day, EVEN IF ALARM IS FALSE.	<u>When any ONE of the 4 alarms is on and local siren is sounding:</u> Make calls as shown on Notification Flowchart 2. <u>When any TWO of the 4 alarms is on:</u> Make calls as shown on Notification Flowchart 3.	Potential Failure Notification Flowchart 2 Failure is Imminent or Has Occurred Notification Flowchart 3
8	TDWS Alarm 8 Downstream River Gauging Station (SFNC) reading exceeds "Extreme High" threshold. SFNS stage > 8.5 ft. Flow rate > 10,000 cfs				
9	TDWS Alarm 9 Dam Crest Monitor Loops continuity is broken.				
10	TDWS Alarm 10 Reservoir level drops over 6" within 5 minutes.				

Local Organization Emergency Plans

In general, local organizations such as Riverview School District, Sno-Valley Senior Center, and Remlinger Farms have emergency plans in place that are appropriate for their respective needs.

2. Practicing the Plans and Procedures

Tolt Dam Emergency Action Plan Exercise

The 2024 Tolt Dam Emergency Action Plan tabletop and functional exercises were regarded as a success by most parties. They were well attended and received positive reviews. One of the lessons learned from the exercise was that many did not have a good grasp of the consequences of a Tolt Dam failure. Other lessons learned or opportunities for improvement that were formally documented in the Emergency Action Plan Exercise After Action Report are summarized in Chapter 3, Section B.4.

Local Drills and Outreach

The Riverview School District performs an annual evacuation drill in which students and staff evacuate on foot from school facilities via the pedestrian trail to Evacuation Hill. Within the community, it is frequently expressed that the students and school district staff are the most prepared to respond to a dam emergency thanks to these annual drills.

The City of Carnation also holds an annual “Be Dam Ready” community event where residents can experience the walk up Evacuation Hill to the assembly area.

3. Avoiding Communication Breakdowns

Responsibility for and Coordination of Warning Issuance

The Tolt Early Warning System is somewhat unique because it is the dam owner (City of Seattle) and not the community (City of Carnation and King County) that has assumed responsibility for issuing dam failure warnings via the siren system. This is confounded by the fact that several other organizations (King County OEM, National Weather Service, NORCOM) will also issue warnings related to dam failure (See Chapter 4, Section A). At present there seems to be little coordination between the multiple organizations that issue warnings. Such activities should be well-coordinated to prevent mixed messages from being disseminated. Furthermore, many stakeholders including public safety officials are not clear about who has the authority to issue an evacuation recommendation for City of Carnation residents.

Stakeholder Communication

Personnel from local organizations know each other personally and meet on a regular basis. This is a key factor in efficient emergency operations. However, there still seems to be considerable mistrust between some organizations. Given past grievances, it may be difficult for all parties to address difficulties amongst themselves. Some form of mediation may be required to clearly establish emergency management roles, responsibilities, and areas of collaboration in the region and lay the groundwork for improved coordination.

Effectiveness of Planning and Coordination

King County OEM maintains a Zone Liaison Program for coordinating with communities in the county. The County has also facilitated a Tolt Dam Regional Work Group to work on evacuation planning. Although various organizations report that they do regularly participate in these meetings, some participants indicate frustration with a lack of accountability and results. Participation in the meetings is voluntary, and while King County OEM facilitates the meetings, they do not have authority to enforce actions or deadlines.

False Alarms

While false alarms may create frustration for individuals, experience from many incidents and industries has shown that they generally do not reduce willingness to respond. Rather, they can provide helpful opportunities for residents to learn appropriate responses for future warnings. However, it has been found that over-warning due to frequent tests, unplanned soundings, and/or multiple false alarms have reduced the credibility of warning systems. This appears to be the case for the Tolt Early Warning System where some residents, public officials, and City of Seattle staff have expressed a loss of confidence in the sirens. This mistrust may hinder communication and timely response of residents in and around Carnation during an actual emergency event.

C. Performance of the Emergency Notification System

The goal of an effective warning system is to rapidly alert and notify the public in the event of an impending emergency or disaster and to get them to take appropriate protective actions. Alerting is defined as signaling by audio or other means that something is out of the ordinary. Notification is defined as providing people with the information necessary to make a protective action decision. Social scientists have studied a variety of emergency warning situations over the past 75 years and have developed a collective knowledge about how to achieve those goals.

In general, there are a few key considerations which can improve the performance of a warning system. These include:

1. Rapidly disseminating the alert and notification.
2. Using a diverse range of multiple channels to disseminate the warning message. This should include a mix of both modern technologies (e.g., text messaging) and traditional technologies (e.g., route alerting or television).
3. Using messaging that is geared towards the intended audience and is scientifically-based.

A more in-depth description of this information is provided in Appendix G – Emergency Management Best Practices. In completing this review, the Review Team has considered these items in assessing the Tolt Early Warning System as well as other warning systems that are applied in the area by King County OEM and others. This section summarizes key observations relating to these factors.

1. General Performance of Sirens

Siren systems use an audible signal to rapidly alert a threatened population. Modern electronic sirens have public address capabilities as well, although the quality of the message is often poor because of background noise or overlap with another siren. Thus, siren systems are somewhat limited in their ability to provide clearly legible instructional messages. They are best in alerting people to seek further information unless there has been an intensive program of public education used to instruct people on what to do when the signal sounds. This is possible only in situations in which the same response would be appropriate every time the siren sounds and therefore limits their use for multi-hazards warning situations unless that initial response is to always seek more information. In fact, people who receive their first warnings from sirens are more likely to respond by seeking additional information when compared with those receiving a more personal warning.

The public rarely differentiates multiple types of siren signals, such as a wavering signal versus short blasts, whoops and wails. Consequently, reliance on different signals for diverse hazards is not well supported. Other problems that constrain the use of sirens are false alarms because of technical failures, equipment failures in emergencies, maintenance problems, coverage problems (particularly in adverse weather), difficulties in propagating sounds into buildings, and sometimes, public indifference to sirens.

Nevertheless, siren systems remain a component of warning systems nationwide. Their main benefit is to rapidly diffuse a signal, that if heard, interrupts a normal environment and signals a person to take a preplanned action or seek more information. A major issue concerning the effectiveness of sirens systems concerns their ability to alert people in vehicles and structures, particularly at night, when people are asleep. Although it can be debated how loud a siren must be to be effective, it has been an industry standard that a sound level of 10 dB above ambient noise levels is an appropriate goal.

2. Need for Tolt Dam Sirens

At present with the siren system turned off, emergency alerts and notifications would be disseminated using a variety of channels. These include wireless emergency alerts (text messages), radio and television broadcast, tone alert and weather radio, reverse 911 phone calls, social media, and potential route alerting and loudspeakers by King County deputies or other first responders. This is generally considered to be a diverse and effective collection of warning channels. As with any warning system, there would be challenges reaching certain demographics depending on the nature and timing of the dam emergency. There may also be difficulties contacting residents in the most upstream impact zone where cell coverage is limited.

> ***"My biggest concern, many residents in the pathway of harm will not trust a real alarm, staying in place when they should be evacuating. Using social media to determine actions to take, especially if the original alarm was positive for an event, is potentially disastrous. You will have to build trust among the residents of Carnation."***
>
> ***"Please listen to unincorporated King County residents as well as City of Carnation officials and residents… We don't all want alarms removed and reliance solely on texts and emails for notifications. Cell coverage throughout the valley is inconsistent. It also requires smart phones and that's an economic and accessibility issue when audible alarms serve everyone. Removing alarms is not a reasonable response."***
>
> ***"When the student asked what the sound was, several of the others just shrugged and said 'it is Wednesday' and some said 'it is fake, it always is fake'"***
>
> Local Resident Responses to Early Warning System Survey

Given this relatively effective system (without the sirens), a major question regarding the Tolt Early Warning System is whether sirens are essential to enhance warning of the downstream population at risk. There is no precise answer to this question without additional study to obtain the information needed to perform a simulation of the Tolt Early Warning System. Some insight into this question can be garnered from studies performed using the LifeSim model developed by the U.S. Army Corps of Engineers which simulates the diffusion of emergency warnings. In a study conducted for another dam with an almost identical set of warning technologies in place, the results in Table 4.3 were produced to evaluate the benefits of installing sirens. This table

shows the percent of the population warned over time for both daytime and nighttime responses with and without sirens. These numbers are best estimates, and several factors could either increase or decrease the diffusion results.

According to this research, the major benefit of sirens is that more people are reached quickly, but as time passes the difference becomes small and eventually equalizes. Sirens provide an added layer of speed to the dissemination process. This must be weighed against the cost of maintaining the sirens and the negative impacts of potential false alarms in the future.

Table 4.3 – Example Comparison of Warning Diffusion with and without Sirens.

Time from Initial Warning	Daytime Response with Sirens	Daytime Response without Sirens	Nighttime Response with Sirens	Nighttime Response without Sirens
15 Minutes	56	16	30	5
30 Minutes	92	65	70	23
60 Minutes	99+	99	93	75
90 Minutes	99+	99+	99+	96
120 Minutes	99+	99+	99+	99+

3. Considerations for Future System Performance

There are three basic options for the future of the Tolt Early Warning System. First, turn the siren system back on and maintain the status quo. This is not recommended as it is unlikely to bring closure to the warning issues facing the system. Second, keep the siren system as designed or with a modified design. Third, eliminate the siren system in favor of other warning technologies and dissemination mechanisms. This could involve using the other mechanisms currently present or enhancing or adding additional channels.

Keeping the Siren System

If it is decided that there is a need to keep sirens as part of the warning system, then there are several directions that could be pursued. The first would be to keep the current siren warning system design and do the necessary work to get the system recommissioned and back online. Alternatively, several ways to improve the siren system were suggested in our interviews. Most of these involve simplifying the system design. Among these were decoupling the warning system from the Tolt Dam monitoring system to eliminate machine-based warning decisions; in other words, all activation of the warning system would be manual and have a human involved. Another suggestion was to simplify the system to make it an alert system only and eliminate the voice capability of the sirens. A single siren signal pattern for both testing and warning events could also be adopted. If this were the case, residents would be directed to seek additional information when they hear the sirens go off rather than immediately evacuate. Regardless of the selected

approach, it is also recommended to dramatically reduce the frequency of live testing of the sirens. The current approach of weekly testing creates several problems including alienating the public and diminishing trust in the system. The Review Team recommends either a yearly or twice-yearly testing of the sirens.

Eliminate the Siren System

If the decision is made to eliminate the sirens, the current warning technologies in place should suffice to provide a warning to downstream residents; however, some improvements could be made. While King County OEM's alert system includes some non-voluntary notification channels such as Reverse 911, notification through some of the system's channels relies on people to opt into the system. Accordingly, the number of people opting in needs to be increased. This would require a fairly intense effort, going beyond mere public information. Various community events could be utilized to get people to sign up. Involving the School District to educate students on the need for opting in would be another strategy.

If the sirens are eliminated, additional warning technologies are warranted as well. The current plan for electronic highway signs is highly desirable. NOAA weather alert radios should also be considered. These would be a fairly economical means of providing warning to residents including those who do not currently have wireless network coverage. This would have the additional benefit of providing warnings for all hazard events. For those areas that are out of cell phone range, some limited route alerting could also be investigated. One other possibility would be to construct cell phone towers to provide service to areas that don't currently have reception.

CHAPTER 5: Key Findings – Dam Safety Risk Communication and Outreach

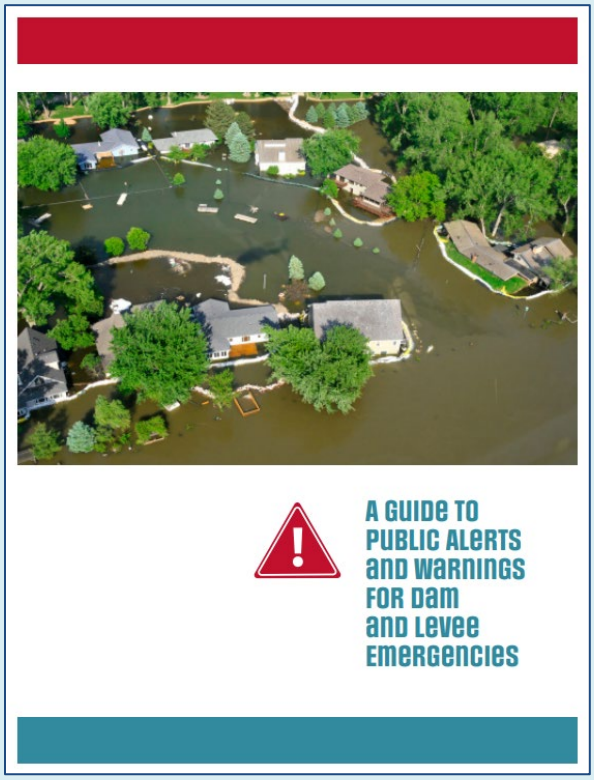
A. Best Practices

Best practices for dam safety outreach and risk communication follow guidance from dam warning studies by Sorensen and Mileti (2014a,b,c; USACE, 2019), as well as best practices for risk communication across other industries and hazardous situations, such as flash flooding (Lave & Lave, 1991; Lazrus et al., 2016), tsunami (NRC, 2011; Lindell et al., 2021), and chemical plant safety.

Much of the advice from Sorensen and Mileti pertains specifically to warning practices, but it also references broader dam safety risk communication and outreach factors that contribute to the effectiveness of such practices (USACE, 2019). These include all of the factors they identify as primary influences on minimizing decision delay time, including having a written emergency public information plan and standard operating procedures to support that plan, pre-identified triggers to distinguish flood threat classes and public messages, and clear rules and procedures for communications between dam operators and emergency managers. They also identify the central importance of knowing the audience and the unique characteristics of the community, including what activities they may be engaged in, where, and when, and with what personal resources; engaging in pre-event public education efforts, both broadly and in ways that reach socially isolated groups; and periodic training exercises, including understanding the warning communications processes and being familiar with the people who are involved in those processes.

Learn more about dam safety risk communication from this U.S. Army Corps of Engineers' guide written by John Sorensen, Ph.D. and Dennis Mileti, Ph.D.:

- *A Guide to Public Alerts and Warnings for Dam and Levee Emergencies*



Best practices for dam safety alerts and warnings are relatively well researched and understood, as compared to what is known specifically about community engagement, outreach and risk communication regarding dams. Available dam safety risk management guidance from FEMA includes guidance on risk communication (see textbox on this page) that generally aligns with best practices for risk communication in other domains (FEMA, 2015).

However, this specific piece of guidance from FEMA fails to acknowledge the importance of recognizing that risk communication is neither one-way, nor linear, and can fail when prior beliefs and expectations of the various parties involved do not agree; for example, if people do not agree on what benefits and risks there are from infrastructure, its management, or on which contextual information is appropriate and relevant.

The checkered history of public use of risk comparisons provides many examples of the dangers of using these without understanding one's audience and working with audience representatives to evaluate the effects of and interpretation of specific comparisons (Roth et al., 1990; Slovic et

al., 1990). This is further supported by the fact that risk acceptability judgments have been shown to depend on many more factors than probabilities of mortality or expected harms.

Principles for Dam Safety Risk Communication

Enhance communication with the public, internally within dam owning and regulating organizations, and Emergency Management Agencies.

Emergency Action Plans and communication with the public are important and integral aspects of reducing risk to life.

Communications should be open and transparent.

When presenting dam safety issues at a given dam, focus on the benefits and the risks posed by the infrastructure.

Integrate risk communications early in the process of responding to dam safety issues.

Provide context for risk communications (compare with other risks).

Focus communications on actions that individuals or organizations need to take.

Discuss uncertainty in risk estimates and the dam safety case: What is certain; What is likely, but not certain?

Federal Emergency Management Agency (FEMA, 2015)

Risk acceptability judgments can depend on how familiar a risk is, who if anyone has control over the risk, and how much dread the risk evokes, among other factors (Slovic et al., 1990; Slovic, 2016; Fischhoff et al., 1978). Differing types of expertise (e.g., expertise in engineering, vs. expertise in biological or geophysical sciences, vs. expertise in human behavior or cognition) as well as differing levels of expertise can lead to stark differences in risk perceptions (Bostrom, 1998). This is in part due to perspectives on and understanding of hazardous processes, but also due to these other factors (e.g., familiarity). Attributing such differences to knowledge deficits alone is a mistake that can lead to conflicts with regard to risk management (see NASEM, 2017).

Collaborative, all-hazard approaches have emerged as best practice in emergency management. Best practices and policies for risk communication in other domains, such as flash flooding, tsunami, and chemical plant safety, illustrate important opportunities for improving dam safety risk communication. A good example of this is the suite of communications and outreach activities under the Emergency Planning and Community Right-to-Know Act or EPCRA (CFR, 2025). EPCRA provisions establish state, tribal, and local implementing agencies and are intended to

help communities prepare for chemical emergencies. EPCRA requires facilities to report on the presence of Extremely Hazardous Substances and requires Local and Tribal Emergency Planning Committees to develop community emergency response plans and to share chemical information with residents in the community. King County OEM is designated as the organizational home for this function in King County for all areas except Seattle and Kent.

Local Emergency Planning Committee members are volunteers who through their work contribute to the National Preparedness Goal for national domestic all hazards, “A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk” (FEMA, 2025b). Local Emergency Planning Committees approach readiness through community involvement (Christie, 2017), consistent with Presidential Policy Directive 8 (2011), which calls for efficiency in emergency management through strategies such as those in the National Incident Management System (NIMS). These emergency management strategies are scalable, collaborative, and use training to practice all-hazards capability. Research on Local Emergency Planning Committees has found that they take an all-hazards approach and act proactively. They also generally comply with policies by requiring a chair, emergency and information coordinators, and members representing groups named in the EPCRA; holding formal, publicly advertised meetings; and submitting an emergency response plan to the state (Christie, 2017; Matheny, 2012). Proactive actions can include annual updates, practice of plans, and regular (at least quarterly) meetings. Available studies suggest that Local Emergency Planning Committees see community emergency preparedness, hazard vulnerability assessment, and hazard awareness as top priorities and yet are more likely to hold tabletop exercises to practice their emergency operation plans than to hold public briefings (Christie, 2017).

In sum, best practices for dam safety risk communication and outreach include:

- Close collaboration and regular coordination of involved parties, including periodic exercises and review and practice of written communications plans. These activities improve stakeholders’ understanding of the characteristics and resources of involved communities, provide opportunities to get to know each other, and maintain up-to-date, comprehensive contact information.
- An all-hazards approach to practicing all-hazards capability.

It is crucial that the management of dam safety risks be done collaboratively in ways that increase understanding and enhance communication of risks, shared needs, and opportunities. “Although those who suffer the consequences of infrastructure failure may have little or no control over the infrastructure, everyone can help reduce the consequences, if not the risk, of failure. Understanding individual and organizational roles and responsibilities with respect to personal, financial, and other types of risk associated with potential dam and levee failure scenarios is a starting point for enhancing community resilience” (NRC, 2012).

B. State of the Practice

In the early 2000s, federal policies and practices restricted access to information critical to public risk awareness, mitigation, preparedness, and response and recovery—such as inspections, Emergency Action Plans, and inundation maps. This information was not readily available to all community members and stakeholders who would make mitigation, preparedness, and response decisions. Furthermore, dam safety programs were often operated independently of other community functions.

In 2012, the National Research Council (NRC) recommended a cultural shift in which dam professionals go beyond standards-based approaches and participate in community engagement, including making an effort to understand factors critical for community well-being and thereby creating more effective Emergency Action Plans. This recommendation has been implemented inconsistently across the dam safety industry. Many state and federal regulators still view dam documentation including inundation maps to be sensitive information that should not be shared with the public. However, some states and federal agencies have made significant policy changes in the past ten years to facilitate public sharing of dam information. Of note is the U.S. Army Corps of Engineers which released a major update to the National Inventory of Dams website in 2021. This website includes general information about dam safety and the national inventory, detailed information on over 92,000 dams within the United States, and the ability for states and regulatory agencies to share dam failure inundation maps for individual dams.

A 2025 survey of dam owners by the Association of State Dam Safety Officials (ASDSO) touched on several issues relevant to dam safety/risk communication and engagement best practices and gives a small sampling of the state of the practice (ASDSO Dam Safety Initiative survey on Best Practices for Emergency Management Communications; 20 responses). Many respondents noted the importance of:

- Simplicity (manually contacting people via phone or email),
- Coordination between stakeholders, and
- Exercising of emergency plans.

However, respondents also noted that manually contacting people can be slow, that many parties/stakeholders are involved but may not always participate in exercises, and that they experience difficulties keeping contact lists up to date.

Additionally, the Review Team performed an informal survey of a half dozen publicly available dam safety brochures in addition to the South Fork Tolt River Reservoir and Dam Failure Warning Information brochure. This review revealed significant variation in practices across the dam safety industry. Some brochures included an inundation map (both with and without evacuation routes shown), but there was large variability in the quality and content of the maps.

C. Risk Communication and Community Outreach for Tolt Dam

The following is a summary of risk communication and community outreach efforts and observations as they relate to the previously discussed best practices and state of the practice:

- To at least some extent, many of the issues identified in the survey of dam owners and review of dam safety brochures appear to apply to Tolt Dam.
- Collaboration and coordination appear to have improved over the last year or two, with increases in local government (City of Carnation) capacity, the Emergency Action Plan tabletop and functional exercise in 2024, and revived or new coordination committee activities (King County OEM facilitated Zone 1 Coordination Meeting and Tolt Dam Regional Work Group). Based on feedback from stakeholders, there is room for further improvement.
- There is evidence of commendable community engagement in raising risk awareness and preparedness from various community groups, including the Carnation-Duvall Citizen Corps, Riverview School District, and Remlinger Farms. This includes the City of Carnation's annual "Be Dam Ready" community education event which is held with support from the City of Seattle.
- Community engagement by dam safety professionals associated with the dam (e.g., City of Seattle and to a limited extent FERC) is evident from flyers and other community outreach materials, although much of that engagement appears to have been prompted by the Tolt Early Warning System false alarms and mis soundings.
- Since 2020, some form of inundation mapping has been provided to the public to assist with awareness and evacuation planning, but map quality and completeness is not ideal. Illustrating the perceived need for this, in 2021 the Snoqualmie Valley Record published a 2019 inundation map obtained through a public records request, which showed estimated arrival times of inundation in the event of a Tolt Dam breach.
- An all-hazards approach is nominally in place in the City of Carnation, but does not appear comprehensive, and does not appear to extend fully to warning and evacuation considerations.

Outreach materials shared with the Review Team focused almost entirely on the replacement of the old siren system with the new siren system, and some of the problems encountered with false alarms. The materials included contact information, progress updates, responses to questions, and additional sources of information to increase awareness and preparedness. Some of these materials referred to an interactive Tolt Dam breach inundation mapping website that was developed by King County using inundation information provided by the City of Seattle (see Appendix C), as well as to other online sources of information about local flood risks. Illustrating an attempt to increase awareness of the full warning system, a "Project Update and Schedule" mailer that was sent to residents by the City of Seattle in December 2022 included among other things the following information:

> *The sirens are just one piece of the warning notifications. The outdoor and indoor sirens are designed to reach as many people as possible in the Carnation area in the unlikely*

event of a dam failure. But the sirens are just one of several alerting tools. Other alert and warning systems that will be used include:

- ***ALERT King County notifications** to everyone who is signed up: www.kingcounty.gov/alert*
- ***Wireless Emergency Alerts** to all available mobile devices in the area, similar to Amber Alerts. Double check that emergency and/or public safety alerts are enabled on your phones.*
- ***On-the-ground evacuation notices** by local police and firefighters in Carnation including knocking on doors and loudspeaker messages.*
- ***Emergency TV and radio alerts** to the Puget Sound area.*
- ***Social media alerts** by local agencies on Facebook, Twitter, and Nextdoor.*
- ***National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS) weather radio warnings**.*
- ***Hearing** from family, friends, coworkers, and neighbors.*

False alarms, interrupted construction, and repeated commissioning of the replacement siren system for Tolt Dam also disrupted communication and outreach plans. Seattle contracted with EnviroIssues in 2020 to assist with Tolt Early Warning System project communications. At that time, there was a series of town hall meetings and virtual sessions with broad community engagement. Once construction of the new siren system began, staff developed content for notifications about construction, responses to public inquiries, and updates to Carnation City Council.

Although a public involvement plan was developed early on under the assumption that there would be a single commissioning period for the updated siren system, delays in construction disrupted this plan, eventually leading to separate plans for the four or five different commissioning periods. The communications team aimed to send information out two to three weeks early and to send updates closer to actual tests, some of which were audible and some of which were silent tests. From the perspective of the contractor, the project was unique among construction projects, in that the testing periods were a few months apart. During about every other testing period there was something unexpected, sometimes something audible other than actual Tolt Early Warning System sirens, resulting in questions about whether the siren was real or not, and confirmations the next day that there was nothing to be concerned about.

The contractor developed communications materials for the City of Seattle, who disseminated them through multiple channels including email (list of about 2,000 subscribers), postcard mailers, the City of Seattle project website, and materials that could be posted by the City of Carnation on social media and their website, as well as electronic signage boards for some testing periods.

A reset on community engagement and outreach is warranted and would be facilitated by creating a community advisory group. This would consist of a group of local residents who are active in emergency preparedness who meet at least quarterly with dam safety engineers, information officers, and emergency managers from the City of Seattle and King County. This group would work to identify opportunities for better engagement with and education of community members.

Interviews with the Carnation-Duvall Citizen Corps and others suggested that there are many well-informed, engaged community members who could contribute meaningfully to this kind of effort and would be willing to do so.

The King County interactive dam failure inundation map website has several positive features; however, additional features and information could be incorporated to help the public understand and use the maps. Some of the technical guidance developed by Lindell et al. (2021) for tsunami evacuation maps is relevant here. This guidance identifies features of maps that can either help or hinder their understanding and use (See Section 2.3 of Lindell et al., 2021). For evacuation due to a possible dam failure, relevant features that could be considered to improve the King County interactive maps include:

- Depiction of local infrastructure such as major buildings or other landmarks for orientation,
- Inundation zones including estimated flood wave travel time and maximum depth of inundation under different scenarios,
- Evacuation route systems as well as their designation and labeling,
- Evacuation guidance including recommendations for evacuating on foot or via vehicle,
- Terrain features that might hinder or slow evacuation, and
- Assembly areas including a description of how they are designated.

Interviews conducted by the Review Team suggested that some members of the community think of the risk due to failure of Tolt Dam as less controllable and more catastrophic than the most extreme engineering estimates (e.g., “20 feet in 20 minutes”, rather than the actual modeled results that a flood wave that would begin to reach Carnation 90 minutes after a dam failure with more gradually increasing inundation depths). To take advantage of such opportunities to improve communications, it might be helpful for one of the County’s coordination groups to host a public workshop or session to elicit feedback on the accessibility and interpretation of inundation maps including how to improve them and the inundation mapping tool. The City of Seattle should also continue to be a partner in community education and outreach activities such as hosting annual tours of the dam for residents and participating in the “Be Dam Ready” community event.

CHAPTER 6: Path Forward

A. Summary Findings

This section summarizes the key findings and observations of the Review Team with respect to Tolt Dam, the Tolt Early Warning System (specifically the siren system), and emergency management roles and responsibilities.

1. Tolt Dam

1.1– The dam is continuously monitored, well-maintained, and safe.

Based on recent expert assessments by independent, FERC-approved consultants, the City of Seattle is operating a sound dam safety program and Tolt Dam is well monitored and maintained. It is in good condition. FERC has standard of practice regulations for dam safety and is requiring the City of Seattle to follow those regulations for Tolt Dam. The Emergency Action Plan for Tolt Dam was found to meet industry standards and federal requirements. It is being regularly updated, tested, and exercised.

A recent dam safety comprehensive assessment estimated that the dam has an extremely small chance of failing (a 1 in 10,000 or 0.01% chance of happening in any given year) and assigned the dam a “moderate” risk classification. The risk assessment of the dam found it to be in satisfactory condition with no significant adverse conditions observed. Based on the findings of the assessment, the City of Seattle is performing studies to further understand or reduce risks for extreme seismic events. While continued monitoring of the dam and studies of potential vulnerabilities are warranted, the risk assessment concluded that the dam can continue to be operated normally. If higher risks were to be identified in future assessments, the City of Seattle would be required to take additional actions (e.g., investigations, repairs, changes in operation, or emergency planning efforts) to reduce risk within acceptable limits (FERC, 2015).

2. Tolt Early Warning System

2.1– There is a loss of confidence in the early warning system.

Over-warning due to frequent tests, unplanned soundings, and/or multiple false alarms reduce the credibility of warning systems. In the case of the Tolt Early Warning System, some residents, public officials, and City of Seattle staff have expressed a loss of confidence in the associated siren system. This loss of confidence may hinder communication and timely response of the public during an actual emergency event. There is a need for continued community engagement, public outreach, and other efforts to rebuild trust.

2.2 – The early warning system is complex. High reliability cannot be guaranteed.

The system is inherently complex with multiple indoor and outdoor sirens, computer and manual remote activation options, multiple communication technologies, power supplies, dam monitoring equipment, and complex and frequently exercised testing protocols. Safety measures to prevent the new system from issuing false alarms only add to the system's complexity.

The past unplanned soundings were caused by many different things including computer problems, water infiltration, maintenance (short circuit), confusion with a separate nearby siren system, human error, and operator ergonomics (unreadable display panel). Sound problems including too loud/too soft and garbled words have also plagued the system (see Appendix D).

The system complexity, commissioning problems, and multiple unplanned soundings and false alarms lead the Review Team to believe that it would be nearly impossible to prevent new mis-soundings and false alarms were the system to be put back in operation without significant simplifying modifications.

2.3 – Given modern warning technologies that are currently in place, the need for the siren system is questionable.

The sirens associated with the Tolt Early Warning System are currently turned off. Other warning methods that are currently in place (such as ALERT King County) would be used in an actual event. These methods include wireless emergency alerts (text messages), radio and television broadcast, tone alert and weather radio, reverse 911 phone calls, social media, and potential route alerting and loudspeakers by King County deputies or other first responders.

These non-siren warning methods are considered to be a diverse and effective collection of warning channels, though special efforts need to be made to ensure residents who live the furthest upstream in the inundation zone where cell coverage is limited can be contacted.

There are no federal regulations regarding early warning systems for dams. In a few instances, FERC has required a warning system to be installed where residences or other facilities are near the dam and response time is limited. This is not the case for Tolt Dam where the leading edge of a dam failure flood wave would take at least 1.5 hours to reach the City of Carnation. However, given the decades long history of the siren system's existence and testing, some public officials and residents in and around Carnation believe that the sirens are necessary to protect the community.

Sirens provide a more rapid initial warning than other available methods. However, given at least 1.5 hours before a dam failure flood would arrive, research shows that other methods would likely provide adequate warning without the sirens.

3. Roles, Responsibilities, and Teamwork

3.1 – There is confusion about who is responsible for warning and evacuation.

For many decades, the City of Seattle has maintained and operated the siren system to warn people in and around the City of Carnation to evacuate in the remote event of a Tolt Dam incident or failure. While the City of Seattle does not provide on-the-ground response during an evacuation, the siren system instructs residents to evacuate, which implies that the City of Seattle has assumed decision making responsibilities for both warning and issuing evacuation recommendations. Within the United States, dam owners do not typically have any responsibility for evacuation or warning of the public. The Federal Guidelines for Dam Safety (FEMA, 2013) and FERC Engineering Guidelines (FERC, 2015) stipulate that, "Dam owners should not assume or usurp the responsibility of government entities for evacuation of people" except in cases where response time is extremely limited (which is not the case for Tolt Dam).

The City of Seattle has for decades assumed some of the warning and evacuation responsibilities (with the siren system), which may have contributed to an overreliance on the siren system and a weaker state of readiness by the City of Carnation, which is still developing its own plan for evacuating people at risk. This unique situation has created confusion. Many stakeholders including public safety officials are not clear about who has the authority to issue an evacuation recommendation for the City of Carnation.

3.2 – Under state law, King County and the City of Carnation are responsible for warning and evacuation.

The State of Washington delegates emergency management responsibilities to local (i.e., county or city) governments. Under the Washington Administrative Code (WAC 118-30) and the Revised Code of Washington (RCW 38.52), political subdivisions are directed to establish local organizations for emergency management which prepare and implement comprehensive emergency management plans for pertinent hazards that could impact local residents. These plans include warning and evacuation responsibilities.

By law, the City of Carnation is responsible for emergency management within its incorporated limits. The City of Carnation has limited avenues to share information or warn its residents of a hazard apart from the Tolt Early Warning System. A community Facebook page and city website can be used to post information. In an actual emergency, the City of Carnation would rely on King County OEM and other regional partners to communicate warning information. They would rely on limited contract support from the King County Sheriff and Eastside Fire and Rescue to implement traffic control or evacuation.

By law, King County is responsible for emergency management in unincorporated areas that would be impacted by a dam failure. This includes areas around the incorporated limits of Carnation including those residences that are furthest upstream and would be the first impacted in a dam failure scenario. In an emergency at Tolt Dam, the county would activate ALERT King

County upon being notified by City of Seattle that there is a confirmed incident or failure of the dam.

3.3– Current emergency management coordination efforts need improvement.

Collaboration and coordination between local emergency managers and other stakeholders appear to have improved over the last few years. King County OEM regularly facilitates Zone 1 Coordination and Tolt Dam Regional Work Group Meetings. However, some participants in these coordination meetings indicate frustration with a lack of accountability and results. Participation in the meetings is voluntary, and while King County OEM facilitates the meetings, they do not have authority to enforce actions or deadlines.

3.4 – Local emergency planning is improving but still needs work.

The City of Carnation's Comprehensive Emergency Management Plan is being actively updated and improved. This plan provides an important framework for the City of Carnation to develop the tools and capacities it needs to effectively respond to an emergency. The City of Carnation also hired a part-time emergency manager in 2023 and developed Hazard Mitigation Plan Annex to the King County Hazard Mitigation Plan in 2025. The Annex was approved by Carnation City Council in June 2025.

The latest version of the City of Carnation's Comprehensive Emergency Management Plan does not include a detailed evacuation plan for any of the identified hazards. The City of Carnation has developed a pedestrian evacuation concept to move people to higher ground as well as evacuation driving routes within City limits, but more detailed and comprehensive evacuation planning is needed to come up with optimum strategies and plans for implementing those strategies.

While the Comprehensive Emergency Management Plan is intended to address all hazards that could occur in the City of Carnation (e.g., wildland fires, riverine flooding, and earthquakes), the Review Team observed that the City of Carnation and its residents have placed a considerable focus on dam failure even though its risk ranking is lower than severe weather, flood, and earthquake hazards (City of Carnation, 2025). This is understandable given the attention, fear, and distrust that the recent Tolt Early Warning System false alarms have created.

The responses of residents and staff during past false alarm events suggest that the City of Carnation lacks the resources and capacity to implement their plan, support emergency response, or issue warnings during an actual emergency. They would be heavily reliant on King County OEM, King County Sheriff, Eastside Fire and Rescue, and other regional partners.

B. Summary Recommendations

Given the key findings summarized in the previous section, the Review Team provides the following recommendations or path forward for the City of Seattle and other stakeholders. The

recommendations are focused on what to do with the Tolt Early Warning System sirens and how to improve emergency planning and preparedness within the community should the need arise to respond to an incident at Tolt Dam.

1. Establish Emergency Management Roles and Responsibilities in Accordance with Washington State Law

In order to establish a path forward for the Tolt Early Warning System and general emergency management in the region, local emergency managers and public safety officials must establish a unified understanding of agency roles and responsibilities. Both King County and the City of Carnation should acknowledge and coordinate responsibility for emergency management within their jurisdictions as required by law (see Summary Finding 3.2). This includes warning and evacuation responsibilities unless formally delegated to and accepted by the City of Seattle. The City of Seattle should focus its dam owner efforts on the safe operation and maintenance of the dam and transfer its warning activities in a responsible and deliberate manner to King County and the City of Carnation unless otherwise agreed upon. The City of Seattle retains the responsibility to assess the condition of the dam and provide notification and evacuation recommendations to King County, the City of Carnation, and other relevant emergency management agencies as outlined in the Emergency Action Plan for Tolt Dam.

Given this lack of alignment as well as past grievances, it may be difficult for all parties to implement the transfer of responsibilities and agree upon specific emergency management roles and responsibilities amongst themselves. The Review Team recommends that the City of Seattle engage an independent mediator experienced in government policies and law to help address these issues and lay the groundwork for improved coordination. Possible mediators include the State of Washington Emergency Management Division which provides planning assistance to local governments and emergency planners or the William D. Ruckelshaus Center, a joint effort of Washington State University and the University of Washington, which helps parties involved in complex public policy challenges work together to develop shared solutions. At a minimum, participants should include the City of Seattle, King County OEM, and the City of Carnation.

The outcome of these mediation efforts should be a formal written agreement between all parties that outlines emergency management roles, responsibilities, and areas of collaboration in the region in accordance with state and local laws. Regional coordination meetings that are currently being facilitated by King County OEM should also continue with a greater commitment by all parties to accountability and action.

2. Invest in Local Emergency Planning and Preparedness during a Transition Period

While recent efforts have been made by the City of Carnation to improve emergency planning, additional work is needed. The City of Carnation currently lacks the resources and capacity to implement their Comprehensive Emergency Management Plan, support emergency response, or issue warnings during an actual emergency. As noted in Summary Finding 3.1, the City of

Carnation appears to be in a weaker state of readiness in part due to the City of Seattle's long-term assumption of warning and evacuation responsibilities.

To facilitate the orderly transfer of warning responsibility to local authorities, the City of Seattle should provide short-term support to the City of Carnation in the form of financial or other resources. The intent of this support is to allow the City of Carnation an opportunity to develop additional emergency management capabilities to warn and evacuate its residents.

Specifically, the City of Seattle should assist the City of Carnation in improving their Comprehensive Emergency Management Plan and developing:

- Evacuation Plan. More detailed evacuation planning is needed to come up with optimum strategies and plans for implementing those strategies. This should include a traffic study to guide the development of evacuation zones and routes and gain an understanding of the time needed to evacuate the area. Furthermore, evacuation plans should be developed based on an all-hazard approach. The current pedestrian evacuation plans focused only on dam failure are not a comprehensive strategy.
- Communication Plan. A communication plan and strategy is needed to keep affected residents informed and educated. In the event that another warning occurs, there should be multiple official sources where residents can go to obtain timely, consistent information about the emergency.

It would also be appropriate for the City of Seattle to support the addition of a full-time, professionally trained emergency manager to City of Carnation staff for multiple years, the extent to be negotiated during mediation. While it is not the City of Seattle's long-term responsibility to finance or support emergency planning and management within the City of Carnation, this temporary support can accelerate the improvement of the City of Carnation's capabilities and preparedness, thereby reducing the dependence that has been created by decades of reliance on the City of Seattle's siren system.

As new and improved emergency plans are developed, the City of Carnation should request the participation and technical assistance of King County OEM in order to strengthen collaboration and mutual support. Joint exercises should also be conducted to validate the City of Carnation's emergency plans and identify opportunities for improvement.

In addition to obtaining technical and financial support from others, the City of Carnation should explore other opportunities to enhance its internal emergency communication and management capacity. The City of Carnation ultimately holds legal responsibility for supporting its residents, and strengthening local capability in a manner that will endure without continued external support is essential for effective, long-term emergency preparedness and response.

3. Modify or Remove the Siren System

Changes to the Tolt Early Warning System are needed to reduce the complexity of system and address the loss of confidence. The detection elements of the Tolt Early Warning System have

performed well and should be maintained by the City of Seattle, including the dam failure and incident detection equipment at Tolt Dam and the communication network which allows continuous remote monitoring of the dam. Problematic elements include the indoor and outdoor siren system in and around the City of Carnation as well as the complex and frequently exercised testing protocols.

At present, the decision whether to remove or retain the siren system lies with the owner and operator of the system: the City of Seattle. If the City of Seattle elects to decommission the siren system, there is justification for such an approach as outlined below. However, there is also justification to retain the siren system if the City of Carnation and/or King County were willing to accept ownership and operation as entities who are legally responsible for warning and evacuation of the public. It would be best if this decision was made after the City of Carnation has had time to develop more mature emergency management capabilities as described in Recommendation #2. While that capacity is being developed, it is recommended that the siren system remain disconnected and only non-siren warning methods be used.

When King County OEM and the City of Carnation are prepared to move forward, they should make a collaborative decision whether or not to adopt the siren component of the Tolt Early Warning System. In deciding which option to choose, the benefits of a siren system must be weighed against the cost of maintaining the sirens and the negative impacts of potential future false alarms on members of the community. The Review Team recommends that one of two options be implemented to improve reliability and decrease the complexity of the system:

- Option 1: Remove the Siren Component of the System – There is justification to remove the siren part of the system given that there are no regulatory requirements for such a system, a diverse and effective collection of modern warning channels is already in place, a minimum of 1.5 hours is available to implement those warning channels should a dam incident occur, and there is potential for negative impacts on warning-weary residents should future false alarms occur. Removal of the siren component of the system would greatly simplify the Tolt Early Warning System, eliminate siren soundings, and significantly reduce the potential for future false alarms.

  If this siren removal option is selected, improvements to the existing network of warning channels should be considered. One primary way to enhance the effectiveness of existing channels would be to increase the number of people opting in to King County's warning service (ALERT King County). This would require a fairly intense and collaborative effort, going beyond mere public information. Various community events as well as outreach by the Carnation-Duvall Citizen Corps could be utilized to encourage people to sign up. A coordinated effort with the School District could also be employed to educate students on the need for opting in.

  Physical improvements to improve early warning could include installing electronic highway signs for use with all hazards (not just dam failure) and distributing NOAA weather alert radios to residents who do not have cell phones or wireless network coverage at their

place of residence. One other possibility would be to construct cell phone towers to provide service to areas that don't currently have reception.

- Option 2: Retain and Simplify the Siren System – If the City of Carnation and/or King County decide to retain and take ownership of the siren part of the system, then it needs to be simplified to ensure greater reliability (See Summary Finding 2.2). The siren system is the most rapid means of warning and would add an additional layer of redundancy to existing warning channels. Public officials and residents in and around Carnation appear to have mixed feelings about the siren system. Some feel it is necessary to protect the community, while others experience stress and anxiety during routine siren tests.

  If the siren system is retained and recommissioned, the design should be simplified in a variety of ways. This could include decoupling the siren system from the dam monitoring system and satellite connection so that sirens must be manually activated. Another suggestion would be to eliminate the voice capability of the sirens which has caused confusion and frustration. A single siren signal pattern could be adopted for both testing and warning situations, and residents could be directed to seek additional information from pre-determined official sources when they hear the sirens go off rather than immediately evacuate.

  Regardless of the selected modifications, it is also recommended to dramatically reduce the frequency of live testing of the sirens. The established approach of weekly testing creates several problems including alienating the public and diminishing public trust in the system. The Review Team recommends either a yearly or twice-yearly testing of the sirens, preferably in conjunction with a hazard preparedness event.

As noted, there is justification for either approach. Neither option will be without controversy in the community given the troubled history of the system. Mediation may be required to address the potential transfer of ownership if the City of Carnation or King County decides to retain the system either individually or under a joint agreement. If the siren system is removed, mediation may also be helpful in determining what additional physical improvements (if any) should be installed and who will be responsible for initial costs and long-term maintenance. The City of Seattle should remain engaged in the project until the siren system is either fully decommissioned and other alternative methods of warning have been improved; or the siren system is simplified and fully commissioned, and ownership is transferred to local authorities.

4. Bolster Community Outreach Efforts

Regardless of whether or not the siren system is retained, additional outreach and education are necessary to inform residents about the various hazards that could impact the City of Carnation and the surrounding areas, including the potential for dam failure. There is a significant amount of mistrust within the community that is directed towards any government authorities that are perceived to be associated with Tolt Dam or the Early Warning System, and long-term efforts are required to rebuild that trust. Both on an individual and collaborative basis, the City of Seattle, City of Carnation, and King County OEM should continue to administer and improve community

engagement, education, and preparedness outreach efforts within their respective spheres. It would best serve the community if an all-hazard emergency management approach is implemented and emphasized among residents. The Carnation-Duvall Citizen Corps and other local organizations may be helpful partners in these efforts. Residents should opt in to ALERT King County to be promptly notified in the event of an emergency.

Specific to the City of Seattle's efforts, a reset on community engagement and outreach regarding Tolt Dam is warranted and would be facilitated by creating a community advisory group. This would consist of a group of local residents who are active in emergency preparedness who meet at least quarterly with dam safety engineers, information officers, and emergency managers from the City of Seattle and King County. This group would work to identify opportunities for better engagement with and education of community members. The City of Seattle should develop a Communications Plan that includes continuing involvement in community education and outreach activities such as annual tours of the dam for residents and participation in the "Be Dam Ready" community event. This plan should also clarify coordination between SPU and SCL.

Consistent with newer practices within the dam safety industry, City of Seattle should publicly release the complete set of dam breach inundation maps from the Tolt Dam Emergency Action Plan. This increases transparency and will help communities and their residents make more informed decisions about protective action planning.

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LIST OF INTERVIEWS

Carnation-Duvall Citizen Corps

Ben Thompson (Member) – In person on March 17, 2025
Kathy Brasch (President) – In person on March 17, 2025

City of Carnation

Adair Hawkins (Mayor) – In person on January 8, 2025
Ashlyn Farnworth (Public Information Officer) – In person on March 17, 2025
Jim Ribail (Deputy Mayor) – Virtual on January 8, 2025
Lora Wilmes (Public Works Director) – In person on January 8, 2025
Rachael Fluhrer (Emergency Manager) – In person on January 8, 2025
Rhonda Ender (City Manager) – In person on January 8, 2025
Ryan Burrell (Council Member) – Virtual on March 17, 2025

City of Duvall

Cynthia McNabb (City Administrator) – In person on January 9, 2025
Luke Eckert (Emergency Management Coordinator) – In person on January 9, 2025
Steven Leniszewski (Public Works Director) – In person on January 9, 2025

City of Seattle (SPU, SCL, Mayor's Office)

Alex Chen (SPU Deputy Director, Water Line of Business) – In person on March 19, 2025
Ali Firoozfar (SCL Chief Dam Safety Engineer) – In person on March 19, 2025
Andre Ball (SPU Dam Safety Supervisor) – In person on March 19, 2025
Andrew Lee (SPU General Manager and CEO) – Virtual on April 4, 2025
Andrew Strong (SCL Engineering and Project Delivery Officer) – In person on March 19, 2025
Chad Buechler (SPU Emergency Management Manager) – In person on March 19, 2025
Dawn Lindell (SCL General Manager and CEO) – Virtual on April 4, 2025
Eric Autry (SPU Training and Exercise Coordinator) – In person on March 19, 2025
Josh Campbell (SPU Project Manager) – In person on March 19, 2025
Keri Burchard-Juarez (SPU Deputy Director, Project Delivery) – In person on March 19, 2025
Marco Lowe (City of Seattle Mayor's Office COO) Virtual on April 4, 2025
Mike Haynes (SCL Chief Operating Officer) – In person on March 19, 2025
Tom Walker (SPU Operations Supervisor) – In person on March 19, 2025
Taryn Sass (SPU Engineering Manager) – In person on March 19, 2025

Eastside Fire & Rescue

Cat Robinson (Emergency Coordinator) – In person on January 8, 2025
Catherine Breault (Public Information Officer) – In person on January 8, 2025
Greg Bawden (Emergency Manager) – In person on January 8, 2025

EnviroIssues

Laura Peña (Senior Associate) – Virtual on April 10, 2025

Federal Signal

Brent Gambrel (Vice President) – Correspondence dated April 4, 2025

Federal Energy Regulatory Commission

Doug Johnson (Regional Engineer) – Virtual on February 4, 2025

King County OEM

Andy Dixon (Dam Safety Specialist) – In person on January 9, 2025
Brendan McCluskey (Director) – In person on March 18, 2025
Edan Edmonson (Crisis Management) – In person on January 9, 2025
Sheri Badger (Public Information Officer) – In person on January 9, 2025
Sunita Hall (Zone 1 Liaison) – Virtual on March 21, 2025

King County Sheriff's Office

Captain Peter Horvath (Operations Captain) – In person on January 9, 2025
Deputy Riley Tollefson (Carnation Duty Officer) – In person on January 9, 2025

National Weather Service

Brent Bower (Senior Service Hydrologist) – In person on March 18, 2025

NORCOM

Cory James (Fire and EMS Liaison) – In person on March 18, 2025

Remlinger Farms

Cheryl Paquette (Manager) – In person on March 17, 2025
Nathan Sherfey (Co-founder and President) – In person on March 17, 2025

Riverview School District

Aaron De Folo (Safety Supervisor/Emergency Manager) – In person on March 17, 2025
Meisha Robertson (Assistant Superintendent) – In person on March 17, 2025
Shaun Tozer (Maintenance Supervisor) – In person on March 17, 2025
Steve Mills (Transportation Supervisor) – In person on March 17, 2025
Dr. Susan Leach (Superintendent) – In person on March 17, 2025

Sno-Valley Senior Center

Kira Avery (Executive Director) – In person on March 17, 2025

APPENDICES

A. List of Acronyms
B. Dams and Dam Safety Basics
C. Dam Breach Inundation Mapping for Tolt Dam
D. Timeline of Tolt Early Warning System Incidents
E. Listing of Known Siren Installations Downstream of Dams
F. Summary of Recent Tolt Dam Safety Assessments
G. Emergency Management Best Practices

APPENDIX A – List of Acronyms

ASDSO	Association of State Dam Safety Officials
BIA	Bureau of Indian Affairs
CA	Comprehensive Assessment
CAP	Common Alerting Protocol
CEMP	Comprehensive Emergency Management Plan
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
DSP	Dam Safety Program
DWR	Department of Water Resources
EAP	Emergency Action Plan
EAS	Emergency Alert System
EMA	Emergency Management Agency
EOC	Emergency Operations Center
EOP	Emergency Operations Plan
EPCRA	Emergency Planning and Community Right-to-Know Act
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FW	Fair Weather
HEC	Hydrologic Engineering Center
IC	Independent Consultant
IDF	Inflow Design Flood
IPAWS	Integrated Public Alert & Warning System
L2RA	Level 2 Risk Assessment
MCE	Maximum Credible Earthquake

MOU	Memorandum of Understanding
NASEM	National Academies of Sciences, Engineering, and Medicine
NIMS	National Incident Management System
NOAA	National Oceanic & Atmospheric Administration
NORCOM	Northeast Regional Communications Center
NPS	National Park Service
NRC	National Research Council
NWR	NOAA Weather Radio
NWS	National Weather Service
NWWS	National Weather Wire Service
ODSP	Owner Dam Safety Program
OEM	Office of Emergency Management
O&M	Operations and Maintenance
PFM	Potential Failure Mode
PFMA	Potential Failure Mode Analysis
PMF	Probable Maximum Flood
RCW	Revised Code of Washington
SCL	Seattle City Light
SOP	Standard Operating Procedure
SPU	Seattle Public Utilities
TEWS	Tolt Early Warning System
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
VoIP	Voice over Internet Protocol
WAC	Washington Administrative Code
WEA	Wireless Emergency Alert

APPENDIX B – Dams and Dam Safety Basics

This appendix explains dams, how they function, how they are cared for, and how they are kept safe. Supplementing each section below are links to short, professionally produced videos with additional explanations and graphics to increase understanding of each topic.

Learn More about dams at these websites:

- *Association of State Dam Safety Officials (Dam Safety Awareness Center)*
- *Association of State Dam Safety Officials (Dam Safety Toolbox)*
- *U.S. Army Corps of Engineers (National Inventory of Dams)*
- *Washington State Dam Safety Office (State Regulators and Resources)*
- *Federal Energy Regulatory Commission (Federal Regulations and Resources)*

A. What is a dam?

Like bridges and roads, dams are a type of manmade infrastructure. A dam is a structure that is built across a river or body of water to hold, divert, or regulate water. The body of water stored behind a dam is referred to as the reservoir or lake. Dams are not levees - dams lie across the watercourse, whereas levees are along a watercourse to keep the water, especially during a flood, from inundating areas.

Dams are sized based on their height. Small dams are those 25 feet high or less. Intermediate dams are between 25 and 50 feet high. Large dams are those higher than 50 feet or more. There are over 92,000 dams in the United States.

Dams were constructed to fulfill one or more purposes, including:

- Water storage for irrigation or water supply
- Generation of hydro-electric power
- Recreation
- Fish and Wildlife habitat
- Flood risk reduction
- Navigation
- Storage of mine waste

See the Dams 101 video from the Association of State Dam Safety Officials (ASDSO) to learn generally about dams and dam safety.

B. How do dams fail?

Dam failure is usually defined as any unplanned or uncontrolled release of the reservoir. Dams can fail during a flood by waters eroding the spillway, sides of the dam (the abutments) or the dam itself. Dams can fail in an earthquake. And dams can fail at normal reservoir levels from seeps that grow into increasing internal erosion. There are 10 to 20 dam failures in the U.S. each year, however most dam failures are of small dams. Every failure occurs due to a unique combination of factors and environmental conditions. Some reasons why more failures of smaller dams occur may include generally poor design and construction practices, inadequate maintenance, lack of regulation and inspection, inadequate spillway capacity, and the fact that small dams are much more numerous than large dams within the U.S.

See the Learning from Dam Failures video for more information.

C. How many dams are there in Washington State and King County?

Washington state government manages the safety of 1,100 dams (small, medium and large dams). The national inventory of dams includes 866 dams (medium and large dams) in Washington. While many large hydropower dams are owned by federal agencies (e.g., U.S. Army Corps of Engineers or the Bureau of Reclamation), there are 57 hydropower dams in Washington that are owned by non-federal agencies. In Washington State 13% of dams are concrete and 87% are embankment dams. There are 123 dams in King County: the most dams of any county in Washington.

D. Spillways and outlet works: How is water released from dams?

Normally, water is released though a dam through the outlet works. The outlet works consists of an inlet to the reservoir, a pipe through the dam and a plunge pool to carry fast moving water away from the dam without causing erosion of the stream. To control water through the outlet works there is a gate or valve (usually at the upstream end of the pipe).

During floods, the outlet works does not have the capacity to pass the very large inflows into the reservoir. The designers of the dam incorporate one or more spillways to carry the water over or through the dam without damaging the dam. Spillways have hardened surfaces such as concrete chutes, or pipes so the flood water doesn't erode into the adjacent dam.

For more information see the Spillways and Outlet Works video.

E. Caring for the dam: Operations and Maintenance

The dam owner is responsible for operating and maintaining (O&M) the dam. The owner should have an O&M plan. The owner should perform regular surveillance and informal inspections to look for problems such as slide, seeps, cracks, and animal burrows.

Many dams have instruments that can warn of potential problems. Dam O&M staff take periodic readings of the instruments and if measurements indicate problems the staff can contact an engineer to respond.

Operations include opening or closing of valves/gates to raise or lower the reservoir and maintaining flows in the downstream watercourse.

Maintenance includes repair of erosion, removal of burrowing animals, and control/removal of vegetation. Mechanical equipment maintenance includes lubrication, exercising and painting.

See the Operations and Maintenance of Dams video.

F. Just in case – Emergency Planning for Dams

When a dam fails, the resulting flood can cause loss of life and damage downstream. A dam owner needs to plan to respond to problems at their dams or dam failures in advance so that they can respond efficiently. Most dam regulators, including FERC (the regulator for Tolt Dam) require their dam owners to develop an Emergency Action Plan (EAP).

The EAP includes:

- Roles and Responsible of Key personnel including nights, weekends and holidays
- How to identify of problems at the dam
- Actions to take to intervene to keep the dam from failing
- How to classify the severity of the problem such as
- Level 1: Watch condition
- Level 2: Developing problem
- Level 3: Dam failure is imminent or has occurred

Each severity level has corresponding notifications that require contacting appropriate entities such as downstream public safety officials, the National Weather Service, the dam owner's management, and engineers.

A dam failure inundation map to show where people would be impacted if the dam were to fail.

The planning for a dam emergency does not end with the creation of an EAP. The EAP should be exercised so that people are familiar with the plan and their duties.

For more information on dam emergency planning see ASDSO's Emergency Planning video.

G. What other actions are taken to keep dam safe?

To ensure that their dams are in good condition, dam owners:

- Hire experienced engineers to inspect and analyze the risks of their dams
- Design and construct repairs to their dams
- Train and educate their dam staff on dam incidents, failures, operations and maintenance

APPENDIX C – Dam Breach Inundation Mapping for Tolt Dam

This appendix includes inundation maps for Tolt Dam that have been created using King County's Dam Emergency Preparedness website and interactive online mapping tool. This information is based on dam breach analyses which have been prepared in support of the City of Seattle's Emergency Action Plan.

A. Description and Background

Dam breach inundation analyses provide estimates of flood inundation extents, velocities, depths, and travel times for two hypothetical failure scenarios of Tolt Dam (Northwest Hydraulic Consultants, 2019). The Fair Weather Failure corresponds to a dam failure during a typical sunny day with normal operating conditions and stream flows in downstream reaches. The Inflow Design Flood Failure corresponds to dam failure during an extreme flood event with significant floods occurring downstream prior to failure of the dam. The maps provided herein correspond to the Inflow Design Flood Failure scenario, which is the more conservative of the two.

In addition to the dam breach analyses, more detailed maps were prepared by Northwest Hydraulic Consultants in August 2019 and are included in the Tolt Dam Emergency Action Plan to assist emergency management authorities in notifying and evacuating areas that could be affected by a dam failure in a timely manner. Per FERC engineering guidelines, "if there are significant changes to downstream development (e.g., new streets, bridges, subdivisions) that are not shown on the inundation maps and more-current base map information is available, the inundation maps should be updated. At a minimum, maps should be updated and reprinted during the [Emergency Action Plan] reprint cycle every five years" (FERC, 2015).

Note that these flood wave travel time and inundation estimates are based on hydraulic modeling that is intentionally conservative to provide worst-case conditions for emergency planning purposes. Additionally, any advance notice that a failure is about to occur would provide additional response time beyond the flood wave travel time indicated on the maps. Given the level of instrumentation and monitoring at Tolt Dam, it is highly likely that problems at the dam would be observed well in advance of dam failure and that advance notification could be given to downstream areas to prepare for a potential evacuation.

APPENDIX D – Timeline of Tolt Early Warning System Incidents

This appendix provides a summary of early warning system false alarms, mistimed soundings, missed weekly tests, siren system commissioning soundings, and other related incidents. It is based on available information reviewed by the Review Team including summary documents, news articles, public surveys, correspondence, root cause analyses, and after action reports. Significant incidents prior to 2020 are included, though it is noted that additional maintenance or other undocumented issues are likely to have occurred during this timeframe. Even after 2020 when additional scrutiny was given to the early warning system, it is likely that there were incidents that have not been identified and documented herein. Accordingly, this list should not be viewed as a comprehensive history but as a representative timeline of pertinent issues that have occurred.

Timeline of Tolt Early Warning System

DECEMBER 20, 1986 (SATURDAY)

DESCRIPTION:

A single siren was activated at low volume multiple times for durations of 10 to 15 seconds. The mother of a student heard the siren, assumed the dam had breached, got her children out of class, and headed for high ground. The teacher informed the principal about the classroom incident, and the principal informed the school district superintendent that the siren had gone off. The district treated the alert as genuine and sought confirmation of the breach from the Seattle Water Department Operations Center. The Operations Center staff were unaware of siren testing but were able to check conditions on site and confirm that the dam was intact.

ROOT CAUSE:

Electronic technicians were working on the siren units which caused the unplanned sounding. The sound generating part of the unit was activated, but the compressed air sound amplifier was not.

FOLLOW UP:

Correspondence took place between the school district and the City of Seattle. The City established communication protocols to provide advance notice to the school district and residents regarding periodic maintenance and testing. While not officially documented, this may also have contributed to the eventual installation of indoor warning devices at schools within Carnation.

APRIL 19, 2011 (TUESDAY)

DESCRIPTION:
Weekly noontime test was sounded on a Tuesday rather than Wednesday.

ROOT CAUSE:
Human error. A City of Seattle worker covered a shift for another worker and got confused about which day of the week it was. The worker sounded the weekly test a day early.

FOLLOW UP:
City of Seattle established protocol to confirm day/time prior to sounding weekly test.

JULY 28, 2020 (TUESDAY)

DESCRIPTION:
Old system (Whelen sirens) sounded for 38 minutes. The system did not provide notification of the alert to the Operations Center as designed. The sirens would not respond to controls at the SPU Operations Center. Significant confusion and trauma occurred within Carnation as residents tried to evacuate.

ROOT CAUSE:
Evidence suggests that the false alarm was caused by a short circuit in a backup controller unit. During maintenance activities near the controller, a hole was drilled in the panel and it is believed that metal shavings shorted out the system. This caused the sirens to sound and the controls to become unresponsive until the short was cleared.

FOLLOW UP:
City of Seattle activated their Emergency Action Plan to notify stakeholders that it was a false alarm. This major event initiated coordination efforts between the City of Seattle, local government agencies, and the public. Emergency Action Plan notification charts were analyzed and improved. King County OEM added pre-scripted false alarm community messages to their alert system and translated them into Spanish. King County Sheriff's Office also drafted a Standard Operating Procedure for dam failure that applies to all dam assets within the County.

The City of Seattle expedited the early warning system modernization project to replace the aging Whelen sirens with new Federal Signal sirens. In the interim, additional fail-safes were incorporated into the new system to ensure operator control of the system. Spare parts for the siren system were also ordered to augment repair capability.

SEPTEMBER 9, 2020 (WEDNESDAY)

DESCRIPTION:
Old system missed weekly test.

ROOT CAUSE:
Human error. Operator did not know how to use improved testing protocol that was put in place following the July 2020 false alarm.

FOLLOW UP:
City of Seattle Emergency Action Plan activated to notify stakeholders. Additional operator training performed.

JANUARY 13, 2021 (WEDNESDAY)

DESCRIPTION:
Old system missed weekly test.

ROOT CAUSE:
A power outage occurred, and the backup communications microwave system did not allow the test to occur.

FOLLOW UP:
City of Seattle called City of Carnation in advance to let them know the test would not sound. City of Seattle Emergency Action Plan activated to notify stakeholders.

JULY 22, 2021 (THURSDAY)

DESCRIPTION:
King County Dispatch reported to City of Seattle that a caller had heard the siren sounding.

ROOT CAUSE:
Dispatch later reported that the caller had been mistaken.

FOLLOW UP:
None.

JUNE 8, 2022 (WEDNESDAY)

DESCRIPTION:
New system indoor annunciators sounded at Riverview School District's transportation facility, Tolt Middle School, and Carnation Elementary School.

ROOT CAUSE:
This was an unplanned sounding that occurred as part of the contractor's work to commission the new system.

FOLLOW UP:
Unknown.

SEPTEMBER 12, 2022 (MONDAY)

DESCRIPTION:
Old system Siren #4 in downtown Carnation missed the first wail sound as part of the weekly test sequence.

ROOT CAUSE:
Unknown.

FOLLOW UP:
Unknown.

NOVEMBER 9, 2022 (WEDNESDAY)

DESCRIPTION:
Old system Sirens #2 and #3 along Tolt River Road missed the second wail sound as part of the weekly test sequence.

ROOT CAUSE:
Unknown.

FOLLOW UP:
Unknown.

FEBRUARY 23, 2023 (THURSDAY)

DESCRIPTION:
Resident reported false alarm.

ROOT CAUSE:
Unknown.

FOLLOW UP:
City of Seattle was unable to verify that the false alarm occurred.

MARCH 22, 2023 (WEDNESDAY)

DESCRIPTION:
New system missed weekly test. Testing still occurred on the old system.

ROOT CAUSE:
The new system test was cancelled due to testing issues as part of the contractor's work to commission the new system.

FOLLOW UP:
Unknown.

MAY 3, 2023 (WEDNESDAY)

DESCRIPTION:
Old system Siren #4 in downtown Carnation did not sound as part of the weekly test sequence.

ROOT CAUSE:
Unknown.

FOLLOW UP:
Unknown.

MAY 10, 2023 (WEDNESDAY)

DESCRIPTION:
Old system Siren #4 in downtown Carnation missed wail and voice message as part of the weekly test sequence. New system also did not sound.

ROOT CAUSE:
Unknown.

FOLLOW UP:
Public reports of missed soundings communicated to City of Seattle by Carnation City Manager.

JUNE 14, 2023 (WEDNESDAY)

DESCRIPTION:
Old system Siren #4 in downtown Carnation missed wail as part of the weekly test sequence. New system only provided message in Spanish.

ROOT CAUSE:
The new system was mis-programmed as part of the contractor's work to commission the new system.

FOLLOW UP:
Siren programming was corrected by the contractor after the incident.

JUNE 19, 2023 (MONDAY)

DESCRIPTION:
Multiple soundings were heard throughout the day. This included:

- A possible siren alert from the new system in East Carnation at 10:17 AM
- Multiple reports of audible clicks and garbled or glitchy tones from the old system in downtown Carnation at 10:27 AM
- A possible siren alert from the new system in East Carnation at 5:25 PM

ROOT CAUSE:
A separate, local siren is located at and operated by Camp River Ranch (owned by the Girl Scouts of Western Washington). This siren is used by the camp to warn recreationists on Tolt River of thunderstorms or other hazardous conditions and is unrelated to the Tolt Early Warning System. During the Camp's summer programs, they sounded the siren as part of their training. It is believed that the siren sounding initially reported at 10:17 AM was the Camp's siren. When the City of Seattle received initial reports of siren soundings, operators sent a precautionary stop command to the old system. It is believed that this command inadvertently resulted in a public address broadcast of the tones that were set to cancel the alerts. These tones would be like fax/modem sounds, and are believed to be the source of the soundings that were reported at 10:27 AM. These sounds were a result of the manufacturer's incorrect programming which was used to try to cancel all alerts in the old system. There is no indication that the new system sounded.

FOLLOW UP:
City of Seattle operators sent a stop command to the old siren system. The Emergency Action Plan was also activated to notify stakeholders. Public officials erroneously reported a false alarm of the Tolt Early Warning System. City of Seattle and the contractor for the commissioning of the new system investigated the incident.

While the incident was being investigated, the speakers for the new system were physically disconnected except for a short period during each weekly test. Independent continuous audio monitoring devices were also installed at all new siren locations.

JULY 3, 2023 (MONDAY)

DESCRIPTION:
Resident reported false alarm.

ROOT CAUSE:
Sounding attributed to Girl Scout Camp River Ranch siren system.

FOLLOW UP:
Unknown.

AUGUST 9, 2023 (WEDNESDAY)

DESCRIPTION:
Old system Siren #4 missed second wail sound as part of the weekly test sequence.

ROOT CAUSE:
Unknown.

FOLLOW UP:
Unknown.

AUGUST 22-23, 2023 (TUESDAY & WEDNESDAY)

DESCRIPTION:
Old system Siren #4 in downtown Carnation made alert sound (no voice) on Tuesday, August 22. Old system Siren #4 missed weekly test on August 23.

ROOT CAUSE:
Human error. A technician was onsite doing routine maintenance and accidentally pressed a button which caused the siren to sound for approximately four seconds. The following day, City of Seattle disconnected speakers due to ongoing maintenance to ensure no unusual sounds were heard during weekly testing period.

FOLLOW UP:
City of Seattle Emergency Action Plan activated to notify stakeholders of the unplanned sounding on August 22. City of Seattle called City of Carnation in advance on August 23 to let them know the test would not sound. After this incident, the decision was made to fully disable and decommission the old siren system in October 2023 at which time the new system would be fully functional. The Federal Energy Regulatory Commission (FERC) was also informed of the incident.

DECEMBER 20, 2023 (WEDNESDAY)

DESCRIPTION:
New system indoor annunciator sounded at Eastside Fire and Rescue Station 85.

ROOT CAUSE:
Human error. This was an unplanned sounding that occurred as part of the contractor's work to commission the new system. Contractor did not communicate that a new

connection to the speaker had been installed. Technician was unaware of new connection and did not fully disconnect the speaker prior to test.

FOLLOW UP:
Unknown.

MARCH 27, 2024 (WEDNESDAY)

DESCRIPTION:
At least one siren of the new system sounded the weekly test at 10 AM (two hours early). This caused significant confusion among City of Carnation residents and staff, and it prompted some to begin evacuating.

ROOT CAUSE:
Human error. Contractor (Federal Signal) did not follow company protocol and accidentally set off the test alert while doing remote work on the system. While accessing the City of Seattle's warning system control interface to develop user guidance, a Federal Signal employee in Illinois was unknowingly connected to the siren system's satellite communication channel. The system software includes automatic activation of the weekly test sounding and it was scheduled to run at 12 PM Pacific Time that day. The software erroneously referenced the time of the remote worker's computer (12 PM Central Time) without regard to the time zone which led to activation of the test exactly two hours early.

It was noted that not all sirens in the system were activated. Each siren's programming includes a time encryption code which should instruct the siren to ignore an activation request that is from outside the Pacific time zone. The contractor determined that the time encryption option was not activated for the affected siren(s).

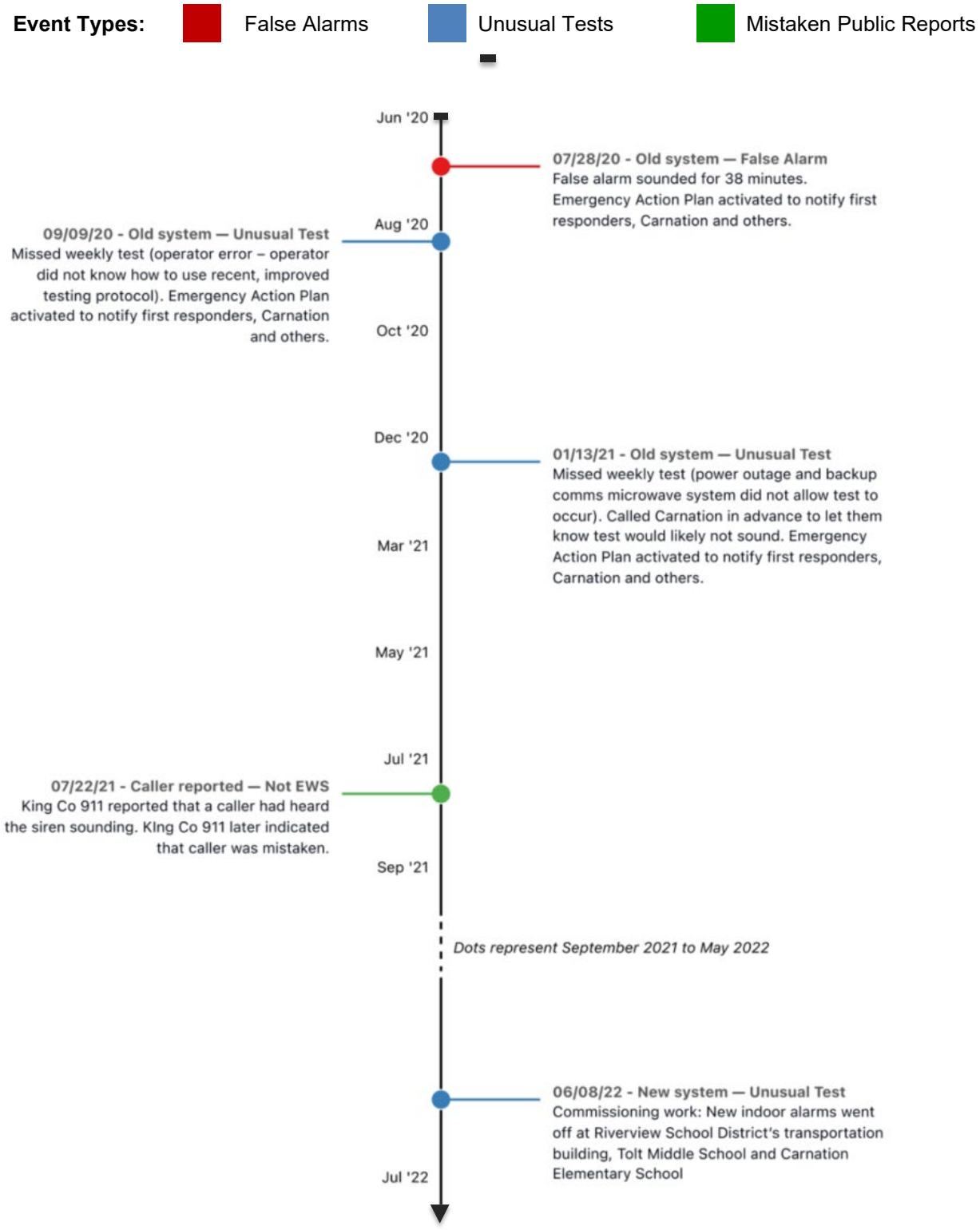
FOLLOW UP:
The Emergency Action Plan was activated to notify stakeholders of the false alarm. City of Seattle sent "all clear" tone and message at 10:21 AM after verifying the dam was safe and the test was activated in error. At 10:37 AM, King County OEM sent an email to subscribers notifying them of the unplanned sounding. At the request of the City of Carnation, the regularly scheduled noontime siren test was cancelled.

On Thursday, March 28, 2024, the City of Seattle (at the request of the City of Carnation) decided to temporarily deactivate and isolate the siren system, requiring manual activation by a human operator to sound an alert. Initial revisions were also made to the Emergency Action Plan to reflect the deactivation and expedite emergency alerts through King County OEM if necessary. The City of Seattle also established an electronic survey, hotline, email, and mailers to collect information from the public.

The City of Seattle and Federal Signal performed a root cause analysis. A silent test was performed in April 2024 to confirm that time encryption programming was the cause of the mistimed sounding. As a result of the assessment, Federal Signal updated training and implementation protocols. They also deleted City of Seattle's security and encryption keys for all technicians' laptops and drives to eliminate the possibility of a repeat occurrence.

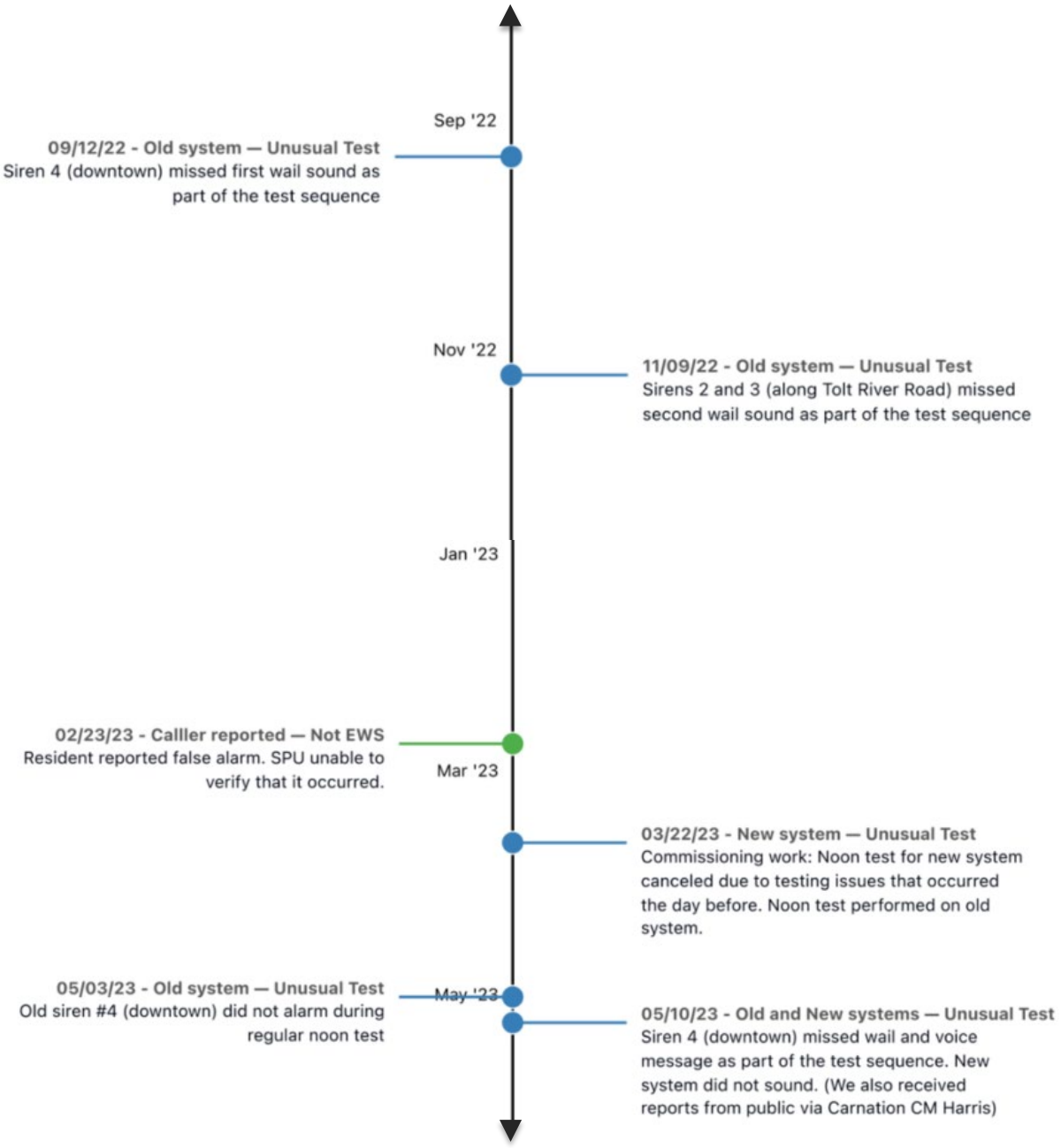
City of Seattle met with representatives from the FERC about the early warning system. FERC noted that the system "has clearly become detrimental instead of beneficial to public safety" and requested that the City of Seattle develop a plan and schedule to evaluate and implement alternatives. The City of Seattle proposed to fully disconnect the Early Warning System while an independent evaluation be performed by industry experts.

Tolt Early Warning System Incident Timeline (Page 1 of 3)



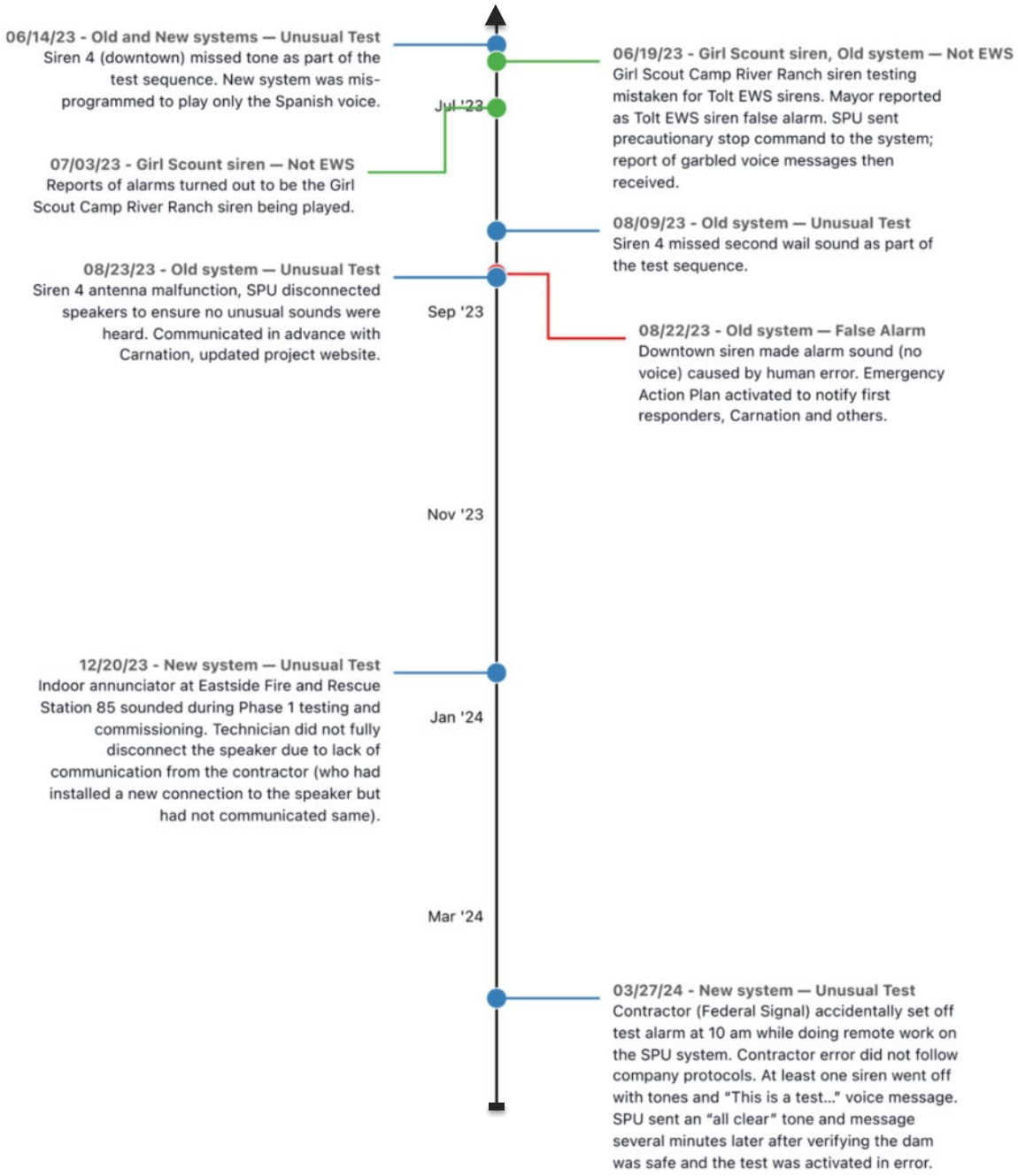
Tolt Early Warning System Incident Timeline (Page 2 of 3)

Event Types: False Alarms | Unusual Tests | Mistaken Public Reports



Tolt Early Warning System Incident Timeline (Page 3 of 3)

Event Types: False Alarms | Unusual Tests | Mistaken Public Reports



APPENDIX E – Listing of Known Siren Installations Downstream of Dams

This appendix includes a listing of known siren installations downstream of dams within the United States. Currently, there are no federal regulations regarding siren systems for dams. In a few instances, FERC has required a warning system to be installed where residences or other facilities are near the dam and response time is limited. In other cases, downstream communities have worked with dam owners to install sirens in the community. Most instances of sirens being installed downstream of dams can be categorized in three groups: 1) individual sirens immediately downstream of a dam or spillway to warn fishermen or other recreationists of a pending release from the opening of a gate or valve, 2) siren systems in communities downstream of a dam where response time during a dam failure would be extremely limited (less than 15 minutes), or 3) siren systems in areas with significant transient populations (e.g., campgrounds, recreation areas) and limited response time. Overall, only a limited number of the 92,000 dams nationwide have siren-based warning systems.

Table E.1: Listing of Known Siren Installations Downstream of Dams

Dam Owner	Project Name	Location
Brookfield Renewable	Chilhowee Dam	Tallassee, TN,
Bureau of Reclamation	Casitas Dam[1]	Oak View, CA
City of Ashland	Hosler Dam	Ashland, OR
Consumers Energy	Rogers, Hardy and Croton Hydroelectric Generating Plants	Newaygo County, MI
Consumers Energy	Tippy and Hodenpyl Dams	Wellston, MI
Coos Bay-North Bend Water Board	Pony Creek Dam	North Bend, OR
Dakota County	Lake Byllesby Dam	Dakota County, MN
Fairfax Water	Occoquan Dam	Occoquan, VA

Dam Owner	Project Name	Location
Georgia Power	Tallulah Falls Dam	Tallulah Falls, GA
Green Mountain Power	Chittenden Hydro Substation	Chittenden, VT
Lansing Board of Water and Light	Moores Park Dam	Lansing, MI
Osage Energy	Bagnell Dam	Miller County, MO
PacifiCorp	Cutler Dam	Box Elder County, UT
PacifiCorp	Lewis River Project	Cowlitz and Clark Counties, WA
PacifiCorp	Oneida Dam	Franklin County, ID
Pennsylvania DCNR	George B. Stevenson Dam	Cameron County, PA
Puget Sound Energy	Baker River Dam[2]	Concrete, WA
Santee Cooper	Lakes Moultrie and Marion[3]	Berkeley County, SC
Seattle City Light	Skagit River Project	Whatcom County, WA
Tacoma Power and Light	Mayfield / Mossyrock Dam	Lewis County, WA
Tennessee Valley Authority	Blue Ridge Dam	Blue Ridge, GA
U.S. Army Corps of Engineers	Isabella Dam	Lake Isabella, CA
Xcel Energy	Cabin Creek or Georgetown Hydroelectric Plants	Georgetown, CO

Dam Owner	Project Name	Location
Xcel Energy	Trego Hydroelectric Dam	Trego, WI
Xcel Energy	Winter Dam	Sawyer County, WI

[1] In January 2000, a false alarm of the Casitas Dam emergency siren system occurred that resulted in panic among downstream residents, not unlike what occurred in July 2020 with the Tolt Early Warning System. Ownership of the Casitas siren system was ultimately transferred to local governments. In 2010, local authorities decided to decommission the system which was degraded due to age, lack of maintenance, theft and vandalism.

[2] False alarms of the siren system downstream of Baker River Dam have occurred in November 2024 (single siren) and May 2025 (entire system). Both alarms resulted in evacuation of residents in Concrete, WA and other downstream areas.

[3] Periodic false alarms and unplanned soundings of an old siren system downstream of Lakes Moultrie and Marion have been reported. Because of these and other issues, this system was recently replaced.

APPENDIX F – Summary of Recent Tolt Dam Safety Assessments

This appendix includes significant findings and excerpts from the most recent dam safety assessments that are available for Tolt Dam and the City of Seattle's dam safety program. Summaries of the following assessments are included:

- Audit of the City of Seattle's dam safety program
- Most recent FERC engineering inspection of Tolt Dam
- Most recent Comprehensive Assessment of Tolt Dam

A. City of Seattle Dam Safety Program Audit (August 2021)

Summary

FERC requires each of its licensees to have an independent review/audit of their dam safety program every five years to ensure that it is working well, and any areas of concern are identified for improvement. The FERC-required audit meets and exceeds current dam safety industry regulator practices in the U.S.

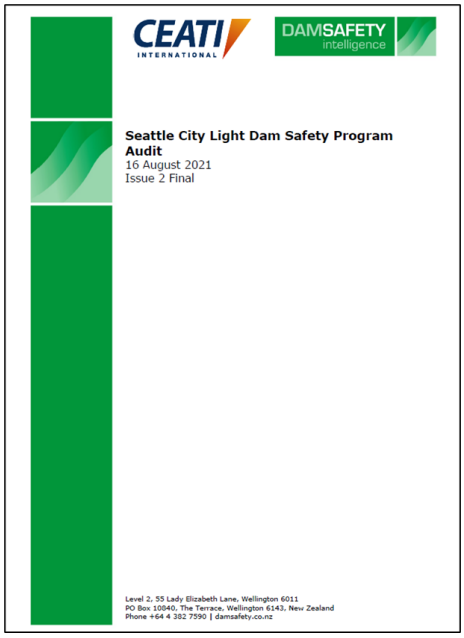


Figure F.1 – Cover of the 2021 Dam Safety Program Audit of the Seattle City Light Dam Safety Program (77 pages).

The latest audit of the City of Seattle's dam safety program happened in 2021. The audit found that the City of Seattle's "safe management of dams and reservoirs is guided by their well-established Standard Operating Procedure SOP I-604 Owners Dam Safety Program (DSP), approved by [the City of Seattle's] Chief Operating Officer".

"At SCL's request, the audit team used a maturity matrix to review their program. The maturity matrix shows how well SCL's is meeting current dam safety program industry practices for each of their dam safety program elements. The audit found that SCL is achieving 'Good Industry Practice' or 'Best Industry Practice' partially or fully across all program elements. At a high level, the results indicate that SCL's DSP has significant strengths in the Dam Surveillance, Audits and Reviews, and Governance elements. There were no elements of the dam safety program with an 'intermediate', 'needing development', or 'leading edge' rating."

Specific Positive Findings/Conclusions/Recommendations

"The Panel was impressed by the quality and commitment of SCL's people accountable and responsible for delivering the Dam Safety Program (DSP). The Panel commends SCL on the many examples of Good and Best Industry Practice that were evident. It was very clear that dam safety is well understood and prioritized across the organization, largely due to strong safety culture, relationships, capability, and communication."

"SCL's Chief Dam Safety Engineer has effective line of communication directly to the Executive Team."

"SCL has a learning culture that fosters high levels of leadership, collaboration, motivation and commitment toward the safety of people, its dam systems and the environment."

SCL is participating with many national and international dam safety and hydropower associations.

SCL staff conduct daily visual inspections of the dam.

Specific Findings/Conclusions/Recommendations for Improvement

"... [formalize] the organizational systems, processes and documentation that support engagement and timely discussions. Identify key people or groups that have decision making responsibility."

"... plan for the replacement of existing staff when they leave the organization."

"... formalize roles and responsibilities."

"Dam safety information needs to be more centralized and available to all SCL employees."

"Formalizing briefings by the Chief Dam Safety Officer to the executive team."

"[the City of Seattle] should develop formal documented processes for dam safety issue and risk management."

"[the City of Seattle] should use more staff cross training, centralize record keeping, and train staff at key times (for example when staff changes occur)."

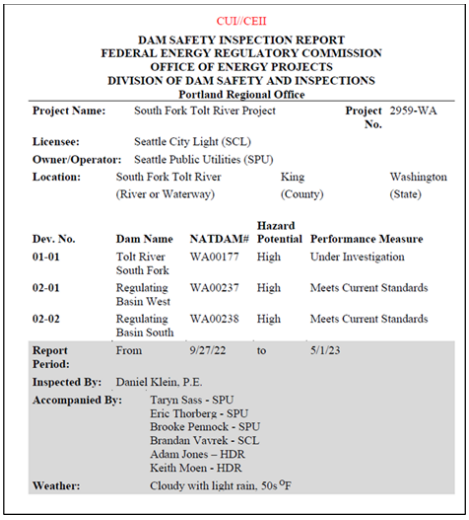
B. FERC Annual Inspection Report

Background

As dam safety regulator, the Federal Energy Regulatory Commission (FERC) performs an annual engineering inspection of Tolt Dam. The most recent inspection report available for review for Tolt Dam was dated May 24, 2023.

The annual FERC annual engineering inspection meets and exceeds current dam safety industry regulatory practices.

This engineering inspection report addressed the visual inspection and overall condition of the dam, ongoing investigations and assessments, performance monitoring, and other aspects of the City of Seattle's work to keep the dam safe.



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DAM SAFETY INSPECTION REPORT
FEDERAL ENERGY REGULATORY COMMISSION
OFFICE OF ENERGY PROJECTS
DIVISION OF DAM SAFETY AND INSPECTIONS
Portland Regional Office

Project Name:	South Fork Tolt River Project	**Project No.**	2959-WA
Licensee:	Seattle City Light (SCL)		
Owner/Operator:	Seattle Public Utilities (SPU)		
Location:	South Fork Tolt River (River or Waterway)	King (County)	Washington (State)

Dev. No.	Dam Name	NATDAM#	Hazard Potential	Performance Measure
01-01	Tolt River South Fork	WA00177	High	Under Investigation
02-01	Regulating Basin West	WA00237	High	Meets Current Standards
02-02	Regulating Basin South	WA00238	High	Meets Current Standards

Report Period:	From	9/27/22	to	5/1/23
Inspected By:	Daniel Klein, P.E.			
Accompanied By:	Taryn Sass - SPU Eric Thorberg - SPU Brooke Pennock - SPU Brandan Vavrek - SCL Adam Jones – HDR Keith Moen - HDR			
Weather:	Cloudy with light rain, 50s °F			

Figure F.2 – Cover of the FERC 2023 Annual Dam Safety Inspection Report (90 pages).

Overall Condition

"On the day of the inspection the South Fork Tolt Dam, West Regulating Basin Dam, and South Regulating Basin Dam were in satisfactory condition."

"The inspection did not identify any conditions which indicated an imminent threat to dam safety or required immediate follow-up action by the licensee."

"South Fork Tolt Dam was in satisfactory condition. The spillway is in fair condition with concrete deterioration. The spillway [chute] also has issues with joints and its drainage system. The City of Seattle has completed a comprehensive assessment of the spillway and will lead to a spillway rehabilitation (repair) project."

"There were no field observations or instrument readings that indicate development of a Potential Failure Mode (PFM). There was no observed evidence of instability that would indicate a dam safety problem was developing."

Investigations

At the time of the inspection, the South Fork Tolt Dam had three ongoing or outstanding investigations including: (1) spillway chute design and condition assessment, (2) a seismic hazard assessment, and (3) an internal erosion study. These investigations have since been completed.

Performance Monitoring Program

"All observations are documented in the daily/weekly and monthly inspection forms. This documentation includes daily visual inspections by Tolt Crew Members. City of Seattle dam safety engineers conduct an annual inspection."

"The current Performance Monitoring Program contains adequate instrumentation and inspection procedures to identify potential failure modes and to monitor the general health of the project. There were no visual observations or instrumentation readings that suggest a critical dam safety issue."

Potential Failure Mode Development

"There were no field observations or instrument readings that indicate development of a Potential Failure Mode (PFM). There was no observed evidence of instability that would indicate a dam safety problem was developing".

Emergency Action Plan (EAP)

"The EAP document and testing procedures are adequate."

"City of Seattle staff are knowledgeable about EAP procedures and their responsibilities. Updated EAP flowcharts were observed in the SPU operations center. Communication methods discussed with City of Seattle staff are consistent with methods described in the EAP. The licensee's EAP training is considered sufficient. Equipment and materials needed for a response to an emergency are readily available and in acceptable condition."

Summary of FERC Inspection Results

"[The City of Seattle is] implementing the Owner's Dam Safety Program appropriately with respect to the South Fork Tolt River Project. The dam is in satisfactory condition. The spillway is in fair condition. No conditions indicated a threat to the dam or required immediate attention of the owner. No dam safety problem was developing. The dam's Emergency Action Plan is updated and functional exercises are being performed."

C. Independent Consultant's Part 12D Comprehensive Assessment

Requirements of the FERC-Required Comprehensive Assessment

The FERC requires their dam licensees to perform a thorough assessment of their dam's safety and risk every 10 years. The City of Seattle volunteered to be one of the first dam owners in the country to perform a FERC Comprehensive Assessment. The 2023 comprehensive assessment included:

- Hiring of a FERC-approved dam engineering Independent Consultant (IC) with extensive dam safety experience,
- The review of available reports including original design/construction, monitoring reports, and inspection reports,
- Visual inspection of the dam by the Independent Consultant,
- Review of monitoring data and instrumentation,
- Test operation of operable equipment,
- Performing new or review of existing engineering analyses,
- Review of the Emergency Action Plan,
- A multi-day workshop to identify ways the dam could fail (i.e., Potential Failure Mode Analysis), and
- A multi-day workshop to estimate the risks associated with Potential Failure Modes. This is referred to as a Level 2 Risk Assessment (L2RA).

The 2023 Comprehensive Assessment and inspection of the safety of Tolt Dam by engineering consultants was performed by HDR, Inc. Based on review of the 2023 Comprehensive Assessment Report, the Review Team found that the assessment meets current dam safety industry practices.

General Findings of the 2023 Comprehensive Assessment of Tolt Dam

Seven Part 12 inspections have been performed since the dam was constructed. The latest assessment for Tolt Dam was performed in 2023 by HDR, Inc., a FERC-approved engineering consulting firm which is respected in the dam safety industry. In the Comprehensive Assessment Report the Independent Consultants made the following statements about Tolt Dam:

"[The] Part 12D field inspection for the Comprehensive report was conducted on May 1, 2023, by the Independent Consultants, City of Seattle personnel, and FERC engineers. The primary water-retaining structures were inspected with no significant unusual observations or adverse indications noted. Conditions appeared to be consistent with previously reported observations. No developing PFMs were observed, and the Project overall is well maintained and there were no observations indicating loss of capacity to meet design intent."

“The Project structures, including Tolt Dam, the Tolt Dam spillway, and abutments; the Regulating Basin embankments and spillway; and the conveyances were in FAIR condition due to questions over the performance of the spillway under infrequent seismic and flood loading conditions.”

“There have been no significant earthquakes or floods that have affected the site.”

“The history of instrumentation data available for the Project was reviewed and there is no indication of concerning adverse trends or abnormal behaviors that indicate dam safety issues.”

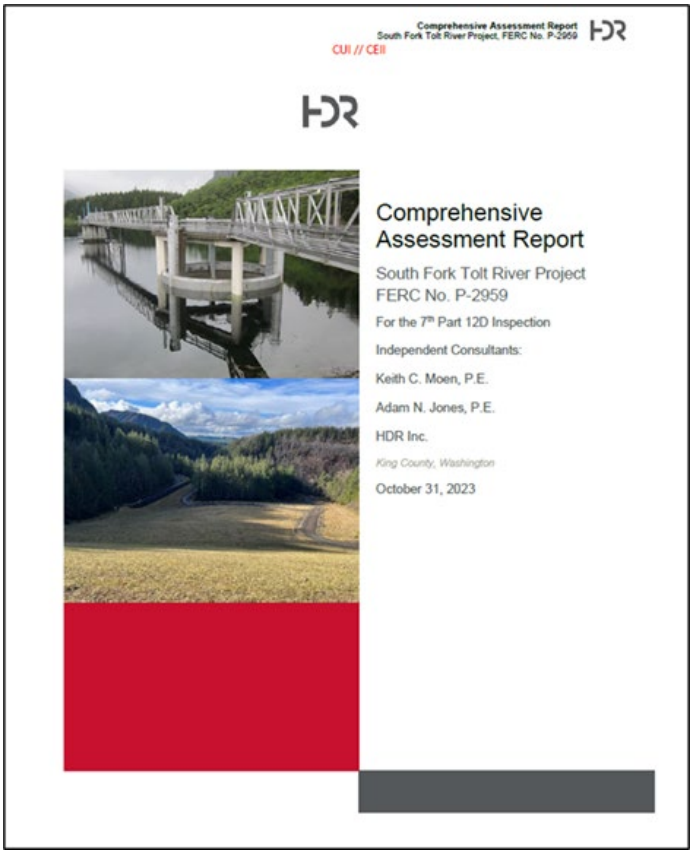

Figure F.3 – Cover of the 2023 Tolt Dam Comprehensive Assessment Report (1,427 pages).

“The current surveillance procedures are judged to adequately monitor both the identified credible Potential Failure Modes described in the Dam Safety Surveillance and Monitoring Plan and those identified during the Level 2 Risk Analysis (L2RA), and to monitor the general health of Project features. Observations are recorded on daily, weekly, and monthly field inspection forms as well as the Daily Visual Inspection Checklist.”

“No observations were made that caused concern about public safety, the current condition of the dam and other Project features, or continued operation of the Project.”

“The Independent Consultants consider the Operations and Maintenance programs sufficient for safe and reliable operation of the Project.”

“The South Fork Tolt River Dam (Tolt Dam) was observed to be in satisfactory condition, Minor concrete surface erosion was noted throughout the stilling basin and sidewalls. One area was found with significant spalling and exposed reinforcing on the bottom slab. The condition of the spillway chute is considered to be Fair.”

“The visible portions of the intake tower and outlet works was observed to be in satisfactory condition”

“The city has completed two repair projects for Tolt Dam in the past 8 years.”

“The zoned earthfill embankment at Tolt Dam generally conforms to modern standards”

"The morning glory spillway intake tower and horseshoe conduit have sufficient capacity to pass the Probable Maximum Flood (PMF). However, later modeling indicates that overtopping of the spillway chute walls may occur at or below the PMF. The extent of the chute wall overtopping is currently being evaluated by the City with an ongoing physical spillway model study at the United States Bureau of Reclamation (USBR)."

"Review of the structural design indicates the spillway tower structure was not designed for current maximum credible earthquake (MCE) seismic loading and is generally under-reinforced with splicing details that do not meet modern standards."

"The original intake tower was found to be under-designed for modern seismic loading and is generally under-reinforced with splicing details that do not meet modern standards. The intake tower has since undergone a seismic upgrade that consists of the installation of six post-tensioned tendons into the foundation rock and was completed from 1997 to 1998."

"SCL and SPU have developed and maintained a strong positive dam safety culture focused on maintaining the safety of their projects."

"Key instrumentation is monitored by an automated data acquisition system (ADAS) which is transmitted continuously to SPU's Operations Control Center (OCC) which is staffed 24 hours per day, 7 days a week."

"SPU has field crews dedicated to the Project that visit both the Tolt Reservoir and Regulating Basin seven days a week."

A total of 268 candidate Potential Failure Modes were brainstormed during the 2023 Level 2 Risk Assessment for the Project, with 201 PFMs brainstormed for Tolt Dam and 67 for the Regulating Basin. Of the brainstormed PFMs, only 17 were found to be credible and estimated as part of the risk assessment.

There were no observations or findings that indicated that a Potential Failure Mode was developing or in progress. No urgent or insufficient information Potential Failure Modes were identified during the Potential Failure Mode Analysis.

Probability of Failure

The total estimated probability of failure of Tolt Dam by the Comprehensive Assessment team is one in 10,000-chance-per-year.

Risk Classification

The Independent Consultants recommend a Dam Safety Risk Classification (DSRC) of III-Moderate. The visual inspection of the dam found it to be in satisfactory condition, with no significant adverse conditions observed. Surveillance of the dam is effective, with daily inspections by a well-trained crew, supported by senior dam safety personnel. Instrumentation data review did not identify any significant adverse trends. Several spurious readings in the last

5 years were observed, attributed to the effects of recent or seasonal rainfall, or issues with sealing of piezometer caps. Seismic performance of the spillway tower and of the embankment dams under severe seismic loading, for which there is little precedent, were identified as key risk drivers during the L2RA and actions have been identified to better understand or reduce risks. There have been no significant seismic events in the history of the Project, therefore, past operational history cannot be used to assess Project reliability under these severe loadings. Confidence in risk estimates was generally at least moderate, with some PFMs estimated at low confidence that could potentially be increased with further study or confirmation of assumptions.

Elements of Dam Safety Risk Classification (DSRC) III-Moderate

The following summarizes the general description, characteristics, and potential actions for a DSRC III-Moderate classification as described in FERC guidelines. Not all of these elements need apply to a specific dam classified as DSRC III-Moderate.

Description – Potential failure mode(s) appear to be dam safety deficiencies that pose a significant risk of failure and actions are needed to better define risks or to reduce risks.

Characteristics – MODERATE TO HIGH RISK: Confidence in the risk estimates is generally at least moderate but can include facilities with low confidence if there is a reasonable chance that risk estimates will be confirmed or potentially increase with further study.

Potential Actions –

- Implement Interim Risk Reduction Measures, including operational restrictions, as warranted
- Ensure that the Emergency Action Plan is current and functionally tested
- Conduct heightened monitoring and evaluation
- Prioritize investigations and actions to support long-term risk reduction
- Prioritize confirmation of classification as appropriate

Specific to Tolt Dam, the Independent Consultants did not identify a need for Interim Risk Reduction Measures or heightened monitoring of the dam. The Independent Consultants' recommendations were to conduct investigations to better define and understand risk. The City of Seattle has provided a plan and schedule to the FERC to complete these investigations.

Emergency Action Plan (EAP)

"The Independent Consultants consider the EAP to be adequate". They made the following recommendations:

1) "Consider developing a Standard Operating Procedure (SOP) to address site access, monitoring, video surveillance, communication, alarm, and siren to remain functional in the event of a dam safety incident resulting from a significant flood or high magnitude earthquake. Address vulnerabilities that are identified. The SOP should be available

for the next L2RA [Comprehensive Assessment] to be considered in the updated consequence estimates."

2) "Consider developing a Standard Operating Procedure that defines actions to be taken at various reservoir water levels, spillway flow, loss of function, and the appropriate steps Define actions at various water levels, spillway flow, loss of function and the appropriate operational steps."

Note that at the time of the Part 12D Comprehensive Assessment, the Tolt Early Warning System sirens were still active, hence the reference for the sirens to remain functional during a significant flood or earthquake. This recommendation from the Part 12D report and the recommendations of this Independent Review of the Tolt Early Warning System are different in nature and scope and should not be confused. The scope of the Part 12D Comprehensive Assessment did not include an evaluation of the need for the siren system.

5. Comprehensive Assessment Conclusion of the Safety/Risk of Tolt Dam

"Based on the findings of the CA, the Independent Consultants (ICs) judge the Project to be suitable for continued safe and reliable operation. No immediate actions are required to ensure the safety, stability, and/or structural integrity of the Project. No potential failure modes (PFMs) identified during the PFMA and L2RA are judged to be active or developing."

The City of Seattle has provided a plan and schedule to the FERC to address all recommendations from the Independent Consultants within the Part 12D Comprehensive Assessment Report.

APPENDIX G – Emergency Management Best Practices

This appendix summarizes key factors pertaining to both organizational performance and warning system performance during emergencies.

A. Organization Performance in Emergencies

Studies of organizational performance in emergencies have led to the identification of three categories or factors that differentiate good from poor performance. These factors are:

1. Having written plans and procedures,
2. Practicing the plans and procedures, and
3. Avoiding communication breakdowns.

In addition to these three factors, a key aspect of the performance of the Tolt Early Warning System is the false alarms and unplanned soundings which have plagued both the old and new siren systems since 2020. These events have had a significant impact on organizational and operational performance on many levels.

Write Plans and Procedures

Emergency response organizations that have thought through the warning decision process and prepared plans, procedures and the relevant tools for arriving at rapid decisions will perform better than those organizations who have left warning decisions to be made in an ad-hoc manner. Important elements include:

- Standard Warning Plan is written down
- Standard Operating Procedures (SOP) are written down
- Warning thresholds are in place (Matrix)

FEMA has published guidelines for comprehensive community emergency plans. The basic structure of an Emergency Operations Plan (EOP) written to FEMA specifications is depicted in Figure G.1.

Emergency Support Function EOP Format

1. Basic Plan

a) Introductory Material
   (i) Promulgation Document/Signatures
   (ii) Approval and Implementation
   (iii) Record of Changes
   (iv) Record of Distribution
   (v) Table of Contents

b) Purpose, Scope Situation Overview, and Assumptions
   (i) Purpose
   (ii) Scope
   (iii) Situation Overview
      (a) Hazard Analysis Summary
      (b) Capability Assessment
      (c) Mitigation Overview
   (iv) Planning Assumptions
c) Concept of Operations
d) Organization and Assignment of Responsibilities
e) Direction, Control, and Coordination
f) Information Collection, Analysis, and Dissemination
g) Communications
h) Administration, Finance, and Logistics
i) Plan Development and Maintenance
j) Authorities and References

2. Emergency Support Function Annexes

a) ESF #1 – Transportation
b) ESF #2 – Communications
c) ESF #3 – Public Works and Engineering
d) ESF #4 – Firefighting
e) ESF #5 – Emergency Management
f) ESF #6 – Mass Care, Emergency Assistance, Housing, and Human Services
g) ESF #7 – Logistics Management and Resource Support
h) ESF #8 – Public Health and Medical Services
i) ESF #9 – Search and Rescue
j) ESF #10 – Oil and Hazardous Materials Response
k) ESF #11 – Agriculture and Natural Resources
l) ESF #12 – Energy
m) ESF #13 – Public Safety and Security
n) ESF #14 – Long-Term Community Recovery
o) ESF #15 – External Affairs
p) Other ESFs as defined by the jurisdiction

3. Support Annexes

(Note: This is not a complete list. Each jurisdiction's support functions will vary.)

a) Continuity of Government/Operations
b) Warning
c) Population Protection
d) Financial Management
e) Mutual Aid/Multijurisdictional Coordination
f) Private Sector Coordination
g) Volunteer and Donations Management
h) Worker Safety and Health
i) Prevention and Protection

4. Hazard-, Threat-, or Incident-Specific Annexes

(Note: This is not a complete list. Each jurisdiction's annexes will vary based on their hazard analysis.)

a) Hurricane/Severe Storm
b) Earthquake
c) Tornado
d) Flood/Dam Failure
e) Hazardous Materials Incident
f) Radiological Incident
g) Biological Incident
h) Terrorism Incident

Figure G.1 – FEMA Recommended Emergency Operations Plan (EOP) Content

With respect to the City of Carnation, it is critical that a standard warning plan is written that covers all potential hazards that face the area. In addition, there should be a special annex specific to dam failures and resulting flash floods. It is also critical that SOPs are in place to implement the warning for specific hazards including dam failure. While plans lay out the general structure of issuing warnings, SOPs provide step by step guidance as how to implement the plan.

Another important element of planning is to develop pre-emergency decision criteria to determine whether to issue warnings. Usually this is in the form of a threat matrix or table which lists the factors that determine whether an emergency is in progress or about to occur. Having predefined conditions for issuing warnings eliminates uncertainty about whether to issue a warning.

Roles and responsibilities should be clearly outlined in the plan and operating procedures. There should be clearly defined authority as to who can initiate the warning. It is also important that plans are clear about succession of responsibilities. It is critical to have worked out who will be backup to key personnel if they are not available. Backup personnel should be trained to carry out their responsibilities if the primary is unavailable.

Communications between organizations involved in the warning should not be ad hoc. There should be clearly defined rules and procedures for communicating between critical parties. In addition to one way communication such as call down lists for the standard message, there should be guidelines for two-way communications between organizations. Interpersonal relationships are also very important to the communication process. Personnel from various organizations involved in the warning process should meet regularly to share ideas, identify problems, and work out solutions.

Practice

Providing training on the warning issuance process and exercising it on a periodic basis will improve the effectiveness and implementation of the warning decision process. Moreover, understanding the communications process and knowing the people one is communicating with will also reduce issuance time. Flexibility in adapting to new and unforeseen situations will also reduce delays.

FEMA defines the following types of exercises:

Tabletop Exercises (TTX)

A tabletop exercise is a facilitated analysis of an emergency situation in an informal, stress-free environment. There is minimal attempt at simulation in a tabletop exercise. Equipment is not used, resources are not deployed, and time pressures are not introduced. Tabletops are designed to elicit constructive discussion as participants examine and resolve problems based on existing operational plans and identify where those plans need to be refined. The success of the exercise is largely determined by group participation in the identification of problem areas.

Drills

A drill is a coordinated, supervised exercise activity, normally used to test a single specific operation or function. It can also be used to provide training with new equipment or to practice and maintain current skills. Its role is to practice and perfect one small part of a damage assessment program and help prepare for more extensive exercises, in which several functions will be coordinated and tested.

Functional Exercises (FE)

A functional exercise is a fully simulated interactive exercise that tests the capability of an organization to respond to a simulated event. It is similar to a full-scale exercise, but does not include equipment. It simulates an incident in the most realistic manner possible short of moving resources to an actual site. The exercise tests multiple functions of your damage assessment plan.

A functional exercise focuses on the coordination, integration, and interaction of an organization's policies, procedures, roles, and responsibilities before, during, or after the simulated event. Functional exercises make it possible to examine and/or validate the coordination, command, and control between various multi-agency coordination centers without incurring the cost of a full-scale exercise. A functional exercise is a prerequisite to a full-scale exercise.

Full-scale Exercises (FSE)

A full-scale exercise simulates a real event as closely as possible. It is multi-agency, multi-jurisdictional, multi-discipline exercise designed to evaluate the operational capability of emergency management systems in a highly stressful environment that simulates actual response conditions. To accomplish this realism, it requires the mobilization and actual movement of emergency personnel, equipment, and resources. Ideally, the full-scale exercise should test and evaluate most functions of a damage assessment plan on a regular basis.

Full-scale exercises are the ultimate in the testing of functions as "trial by fire." Because they are expensive and time consuming, it is important that they be reserved for the highest priority hazards and functions.

Tolt Dam Emergency Action Plan Exercise

To satisfy FERC requirements, the 2024 Tolt Dam exercise was conducted in two phases: a tabletop (September 5, 2024) and a functional exercise (October 2, 2024). For this exercise, a hypothetical Tolt dam failure scenario was simulated through a severe regional storm in December compounded by debris management challenges from a simulated wildfire in the watershed. This scenario culminated in activation of both the EAP notification Chart 2 (Potential Failure) and Chart 3 (Failure is Imminent or Has Occurred), allowing participants to collaborate in addressing pre-failure and post-failure challenges collaboratively.

While FERC requires that an Emergency Action Plan exercise be conducted every five years, it is recommended that more frequent drills and tabletop exercises be conducted. Ideally, several drills of warning system activation would occur each year as well as a tabletop exercise to evaluate communications.

Avoid Breakdowns

Having hardened and redundant communications can prevent technology failures from interfering with making decisions. Historically many ineffective warnings can be attributed to a breakdown in communications. Breakdowns occur from both equipment failure and procedural failures. Equipment failures can be minimized by having redundant means of communication. Procedural failures can be prevented by good planning and good exercising of roles and responsibilities. It is critical that one has backup communications technologies in place if the primary means of communication fails. Multiple backups are encouraged.

False Alarms

There are several different types of false alarms. This summary addresses three primary types:

- Warning during a near miss
- Malfunction of isolated parts of a warning system
- Malfunction of entire warning system

Warning during a Near Miss

The first type of false alarm is one that occurs during a near miss or an event in progress that never causes a dam failure. Warnings are sent out and evacuation is initiated due to a real hazard, but the incident never progresses to complete failure and there is no downstream damage. The best example of this type of event in recent memory is the Oroville Dam near failure.

The Oroville Dam had been part of the local Butte County landscape for nearly 50 years. During the winter of 2016-2017, northern California experienced its wettest winter in a century, and large amounts of water flowed from the Feather River into the dam's reservoir. In January, the California Department of Water Resources (DWR) opened the dam's concrete service spillway to release water into the downstream channel to keep a safe water level behind the dam.

An unusual flow of water on the spillway was detected on February 6th, which caused DWR employees to stop the release of water and inspect the spillway. It soon became a non-stop international media event. They discovered a large area of concrete erosion or hole on the spillway chute. The Butte County Sheriff's office was informed. On February 9th, the DWR decided to use an alternative emergency spillway made of earth to avoid more damage to the concrete spillway. The sheriff issued public bulletins on February 9th and again on the 11th to prime the Butte County public in communities along the Feather River to prepare in case an evacuation warning was issued.

On February 12, state officials alerted the Butte County Sheriff that unanticipated erosion could cause a failure of the emergency spillway, causing significant downstream flooding. Shortly thereafter, the first public warning evacuation message was issued at 4:21 PM on February 12, 2017 to people in Butte County. It stated the following:

> *This is an evacuation order. Immediate evacuation from the low levels of Oroville and areas downstream is ordered. A hazardous situation is developing with the Oroville Dam auxiliary spillway. Operation of the auxiliary spillway has led to severe erosion that could lead to a failure of the structure. Failure of the auxiliary spillway structure will result in an uncontrolled release of floodwaters from Lake Oroville. In response to this developing situation, DWR is increasing water releases to 100,000 cubic feet per second. Immediate evacuation from the low levels of Oroville and areas downstream is ordered. This is NOT A Drill. This is NOT A Drill. This is NOT A Drill.*

This message was disseminated to the public using social media, local radio and television, and the Blackboard Connect notification system, which disseminated it to government agencies and organizations. The Sheriff also ordered Butte County deputies to go to neighborhoods at risk and announce the evacuation order over the PA system in their police vehicles. The Sheriff also called the Sheriffs of Yuba and Sutter Counties to let them know that he was evacuating Butte County, and they should do the same in their counties. It is estimated that nearly 180,000 people evacuated the area. Had the spillway failed, it is possible that some would have perished in the flood waters. Fortunately, dam managers were able to control the situation, and a dam failure was averted.

Based on research of similar events, false alarms due to near misses such as Oroville do not erode the credibility of the warning systems.

Malfunction of Isolated Parts of a Warning System

The second type of false alarm is the inadvertent sounding of one element of the warning system such as a siren. This is a common occurrence in modern warning systems. It occurs because of technology failure (e.g., mechanical, electrical, or software issues) as well as human error. Research shows that this type of false alarm does not significantly affect the credibility and performance of a warning system. However, if it occurs regularly, then the public tends to ignore the sounding of the siren.

Malfunction of Entire Warning System

The third type of false alarm is the inadvertent sounding of the entire warning system when there is no event in progress. This occurred in 2000 in Ventura, CA when an emergency siren system used to notify residents of a collapse at Casitas Dam malfunctioned during testing and instead issued warnings to flee to higher ground. The warnings blared from speakers mounted throughout western Ventura at about 6 PM, and it was reported that hundreds of people who live off Ventura Avenue ran for their cars and tried to get away.

In a systematic study of this event, it was concluded that while false alarms may create frustrations for individuals, they do not reduce willingness to respond. Rather, they can provide opportunities to learn appropriate responses in future warnings. However, it has also been found that over-warning due to either frequent tests, unplanned soundings, or multiple false alarms have reduced the credibility of the siren system. This is likely the case of the Tolt Early Warning System. Through interviews with many stakeholders, the Review Team observed that residents, public officials, and City of Seattle staff have lost confidence in the Tolt Early Warning System sirens as a result of the many false alarms and unplanned or mistimed soundings.

In May 2003, a computer glitch at the Santee Dam on Lake Marion, SC set off sirens followed by a recorded message to evacuate to higher grounds. It was reported that the false alarm created some anxiety for downstream residents.

More recently, on May 30 ,2025, the early warning system for the Baker Dam on the Skagit River malfunctioned and set off sirens which included sounding an evacuation recommendation for downstream communities. The false alarm was quickly corrected. It is unclear how the public responded to this event, but it did not generate much media attention.

B. System Performance in Emergencies

The goal of an effective warning system is to rapidly alert and notify the public in the event of an impending emergency or disaster and to get them to take appropriate protective actions. *Alerting* is defined as signaling by audio or other means that something is out of the ordinary. *Notification* is defined as providing people with the information necessary to make a protective action decision. Social scientists have studied a variety of emergency warning situations over the past 75 years and have developed a collective knowledge about how to achieve those goals. In this section, we review some of those actions or characteristics that constitute an effective warning system.

Choice of Channels

Warnings can come from the formal local EMA system, from an outside organization, or through informal communication processes. It can be an alert (signal) or a notification (message). Formal alerts and warnings can come via several different communication channels involving both new technologies (e.g., cell phone, internet) and established technologies (e.g., TV, radio, sirens, route alert). Each channel has strengths and weaknesses such as the speed of dissemination, ability to convey information, and susceptibility to failure. An effective warning system will employ a diverse mix of both modern technologies such as text messaging, telephone ringdown systems and traditional technologies such as route alerting or television. The use of multiple and diverse channels to reach different areas and divergent population needs is extremely important. Single technologies or single channels are inadequate to reach everyone.

The National Weather Service administers several warning channels under FEMA's Integrated Public Alert & Warning System (IPAWS). IPAWS is a national system for local alerting that

provides authenticated emergency and life-saving information to the public through various technologies and channels. These official warning channels include:

- NOAA Weather Radios: The system is a reliable means of receiving information about life-threatening weather as well as emergency alerts about a range of hazard types including dam failures. It is a service provided by all National Weather Service offices, 24 hours a day, 7 days a week. Routine programming includes the latest weather conditions, weather summaries for the vicinity and surrounding areas, and short term forecasts of significant weather expected within the next several days.
- Weather Wire: The National Weather Wire Service (NWWS) provides warning notifications to television and radio broadcasters, emergency managers, commercial/private alerting services, and the general public. It is one of the fastest means of broadcasting the current weather information. Alerts and warnings are sent in text format from the local National Weather Service Forecast Offices and National Centers.
- Wireless Emergency Alerts: The National Weather Service utilizes the Wireless Emergency Alert (WEA) system to disseminate messages to cell phones about a variety of emergency situations. Messages are derived from templates that are part of the system. Messages can be 90 characters long for older cell phones and 360 characters long for more modern cell phones. Table G.1 shows FEMA-recommended templates for writing WEA messages for dam failures, including 90- and 360-character messages.
- Emergency Alert System: The Emergency Alert System (EAS) is a national public warning system commonly used by state and local authorities to deliver important emergency information, such as weather and AMBER alerts, to affected communities. EAS Participants – radio and television broadcasters, cable systems, satellite radio and television providers, and wireline video providers – deliver local alerts on a voluntary basis, but they are required to provide the capability for the President to address the public during a national emergency. Figure G.2 displays an actual EAS message a dam break in eastern Tennessee. In the end, the dam did not fail, but the associated property damage from the flooding was substantial.

In addition to these official channels, Table G.2 provides a comprehensive list of warning technologies and channels and some of their characteristics. In addition, messages need to be frequently repeated. People become information hungry in an emergency and will seek out information from non-official and perhaps erroneous sources if not provided with sufficient information.

Additionally, informal notification (i.e., receiving warning from friends, relatives, neighbors, or co-workers) occurs in every warning event. It often accounts for a large portion of the first alert in an emergency. It is an important social process because it reduces the overall time it takes to disseminate the warning.

Table G.1 – FEMA-recommended WEA message content and ordering during a dam failure.

Scenario	Dam/Levee Failure (About to Happen) *Be Ready/Prepare*	Dam/Levee Failure (Is Happening/Has Happened) *Immediate Evacuation*
90-Character Message	**ORGANIZATION NAME**: **[Dam/Levee]** failure in this area. Check local media. *(71 characters)*	**AGENCY NAME: [Dam/Levee]** failure in this area. LEAVE areas near **[LOCATION]. [WEBSITE]**. *(86 characters)*
360-Character Message	**[AGENCY NAME]: [DAM/LEVEE]** FAILURE in **[location]** possible. Potential for life threatening flooding to occur and catastrophic amounts of fast moving **[surge/water]**. BE READY to **[evacuate/leave] [location]** when advised by **[ORGANIZATION NAME/LOCAL OFFICIALS]**. CHECK **[source]** for **[updates/information]** at **[info]** LEAVE areas near **[location].** *(339 characters)*	**[AGENCY NAME]: [DAM/LEVEE]** FAILURE in **[location]** at **[time].** Potential for life threatening flooding to occur and catastrophic amounts of fast moving **[surge/water].** LEAVE areas near **[location].** AVOID area around **[location]** until further notice. DO NOT walk or drive through moving water. CHECK **[source]** for **[updates/information]** at **[info].** *(339 characters)*

BULLETIN - EAS ACTIVATION REQUESTED

Flash Flood Warning

National Weather Service Morristown TN

1135 PM EDT Fri Sep 27 2024

...FLASH FLOOD EMERGENCY FOR TOWNS AND CITIES IMMEDIATELY BELOW NOLICHUCKY DAM ON THE NOLICHUCKY RIVER...

The National Weather Service in Morristown has issued a

- Flash Flood Warning for... A Dam Break on the Nolichucky River below Nolichucky Dam in... North Central Cocke County in east Tennessee... Southwestern Greene County in east Tennessee... Southeastern Hamblen County in east Tennessee...
- Until 345 AM EDT.
- At 1135 PM EDT, dam operators reported the failure of Nolichucky Dam causing flash flooding downstream on the Nolichucky River. This is a FLASH FLOOD EMERGENCY for towns and cities immediately below Nolichucky Dam on the Nolichucky River. This is a PARTICULARLY DANGEROUS SITUATION. SEEK HIGHER GROUND NOW! HAZARD...Life threatening flash flooding from the failure of Nolichucky Dam. SOURCE...Dam operator. IMPACT... This is a PARTICULARLY DANGEROUS SITUATION. SEEK HIGHER GROUND NOW! IMMEDIATE EVACUATION for areas downstream from the Nolichucky Dam along the Nolichucky River.

Figure G.2 – Actual EAS message from a potential dam break in eastern Tennessee.

Table G.2 - Characteristics of emergency message dissemination channels.

Dissemination Channels	Speed of Alert[1]	Geographic Coverage of Alert[2]	Penetration of Initial Alert[3]	Message Comprehen-siveness[4]
Route alerting	Slow	Limited	Low	High
Loudspeakers and public address (PA) systems	Fast	Limited	Low	Medium
Wireless Emergency Alerts (WEA)	Very Fast	Disperse	Medium	Very Low
Wireless communications (SMS)	Very Fast	Disperse	Low	Very Low
Radio	Moderately Fast	Widespread	High to Low	High to Low
Television broadcast	Moderately Fast	Widespread	High to Low	Very High to Medium
Television message scrolls	Moderately Fast	Widespread	High to Low	Low
Newspaper	Very Slow	Disperse	Medium	Very High
Dedicated tone alert radios	Very Fast	Limited	High	High
Tone alert and NOAA Weather Radio	Fast	Disperse	Medium	High
Text Telephone (TTY)	Fast	Disperse	Low	Low
Telephone automatic dialers	Fast	Disperse	Medium to Low	High
Audio sirens and alarms	Fast	Limited	Medium	Very Low
Broadcast sirens	Fast	Very Limited	Medium	Medium
Message boards	Fast	Very Limited	Low	Low
Aircraft	Slow	Very Limited	Low	Low
Visual alerting	Fast	Very Limited	Low	Low
Internet protocol (IP) based technology	Fast	Disperse	Low	Very High to Medium
Social media	Fast	Disperse	Low	Low

1. *The rapidness of the system to reach their targeted audience, ranging from Very Fast (less than 10 minutes to Slow (greater than 60 minutes)*
2. *The geographic coverage including Very limited and Limited (only a small area covered); Disperse (greater number of people covered but widely distributed); and Widespread (larger areas covered).*
3. *The Penetration of Initial Alert (portion reached) ranging from Low (less than 25%) Medium (25 to 75 %); or High (greater than 75%). Entries with a range reflect variation due to time of day.*
4. *Message Comprehensiveness or the ability to convey the content needed for effective response including Very Low (alerting only); Low (very little information conveyed); Medium (Many but not all essential contents conveyed); High (all relevant content conveyed); Very High (all relevant content conveyed with enhanced graphics).*

Know Your Audience

The receipt of a first alert/warning is also influenced by the characteristics of people for whom the alert is intended. These include the activities that people are engaged in, where they are located, the time of day, reception impediments, and personal resources available when a first alert/warning is issued. For example, some people who are engaged in recreational activities may be difficult to warn. Also, nighttime notification is more difficult than daytime.

Some of the more difficult to warn based on activity and location include:

- Boaters downstream from a dam
- Campers
- Hikers
- Recreational users
- People shopping
- Attendees at special event venues
- Schools
- Agricultural workers in fields
- Visitors/Transients
- Homeless

Another set of factors that influence first alert penetration in a human population are receiver impediments to reception. These include sensory impairments such as being hearing or visually impaired, cognitive impairments that reduce the ability of some people to understand what may be said in a first alert message, and linguistic or cultural impairments such as not speaking the language used in a first alert message.

One additional category of constraints that can keep people from receiving a first alert is personal resources. Since many warning channels or distribution technologies rely on warning receivers to have a particular technology, not having it can constrain first alert penetration. For example, having a modern cell phone capable of receiving a Wireless Emergency Alert (WEA) message, which is our nation's most modern approach to distributing first alert messages, or participating in social media, which some EMAs use as a supplemental first alert dissemination channel is dependent on having a WEA or social media enabled cell phone. Finally, being of low socio-economic status (i.e. low education, income, or occupational status) isolates people from many communication channels that are more available to others. This is further accentuated for people who also are older, a member of a disenfranchised minority group, or are a female head of household, all of which have less access to resources, particularly financial ones.

Scientific Based Messaging

The characteristics of an alert/warning message influence whether people decide to take protective action as well as how much time people delay in initiating a protective action. These message characteristics include content, style, nature and frequency of delivery, and the type of recommended protective action contained in the message.

- Appropriate Content and Organization: The scientific research record provides repetitive evidence that public warning messages have a higher probability of motivating appropriate and timely public protective action-taking (which is how the objectives of public warnings can be achieved) if those warning messages contain information on five topics. These factors are typically referred to as warning or message content:

    - ***Guidance*** – Tell people exactly what to do to maximize their safety and how to do it. Tell them the factors to consider when making a stay or go decision.
    - ***Time*** – Tell people by when they should begin their protective action and by when they should have it completed For example, by what time they should begin evacuating if they decide to go and by when they should reach a safe area.
    - ***Location*** – Say exactly who should and who should not take action in terms that the public can readily understand. Tell them the physical geographical boundaries of the location where people who need to take action are located.
    - ***Hazard and Consequences*** – Tell about the impending hazard by describing the event and how its consequences pose a threat to people, and what they are being asked to do reduce those.
    - ***Source*** – Say who the message is from based on what constitutes the most credible/believable source for the at-risk population as a whole, which is typically a panel of mixed sources rather than a single source. Additionally, messages from official and familiar sources work best.

- Style: The research record also provides strong evidence that public warning messages with the following style elements work best. These factors are typically referred to as warning or message style:

    - ***Clarity*** – Simply worded, free of jargon, and in words that people can understand.
    - ***Specificity*** – Precise and non-ambiguous about the area at risk, what people should do, the character of the hazard, how much time people have to engage in protective actions before impact, and the source of the message. Tell people how high the flood waters could be when they reach them rather than use a word like “flood” that can be interpreted differently by different people. Even when things are known imprecisely, the warning message need not be nonspecific. For example, one can say we do not know exactly how high the flood waters will be when they reach your town, but we do know that people who live there should now begin taking protective action as if the flood will be 40 feet high on arrival.

- ***Accuracy*** – Timely, accurate and complete information that is free from errors to the extent possible. If people learn or suspect that they are not receiving the whole truth, they may well not believe the message, or they may consider its sources to be non-credible. Being fully open and honest with the public regarding a hazard enhances accuracy.
- ***Certainty*** – Messages should be stated authoritatively, confidently, and with certainty even in circumstances in which there is ambiguity about message content factors. This is especially important in speaking about the protective action the public is being asked to take. Messages should also explain that even though physical details are changing, experts agree on the protective actions people should take.
- ***Consistency*** – Messaging should be consistent across time and explain any changes from past messages. They also should be internally consistent by not saying things within the same message that contradict each other (e.g., the flood waters are headed for your town, but don't worry – since people should be worried in such a circumstance).
- ***Consistency in Messages from Multiple Sources*** – Besides being internally consistent, messages should be consistent from different message sources.
- ***Message Length Adequacy*** – Alert and warning messages used in practice vary widely in terms of message length. Recent research has provided clear evidence that message length plays a critical role in influencing people's understanding, belief, decision making, risk personalization, and the amount of time they delay initiating protective action. Short messages (e.g., 90 or 360 characters long Wireless Emergency Alerts and 140 characters long social media messages) foster milling behavior and delay initiating protective action taking as people seek to learn more about the event they face and what to do about it. However, more robust messages (e.g., 1,380 characters long messages) reduce milling and accelerate protective action initiation.
- ***Ordering information contained in messages*** – Studies have shown that the ordering of information is important in getting people to take protective actions. Furthermore, it differs for very short versus longer messages. As discussed above, there are five essential topics that must be included in an emergency alert or warning message and in other emergency public information like press releases. Short messages, for example those that are 90 or 140 characters, work best if the contents are presented in the following order: 1) source, 2) guidance, 3) hazard, 4) location, and 5) time. Longer messages such as those that may be embedded in a press release or a National Weather Service message work best if the message contents are presented in a different order: 1) source, 2) hazard, 3) location, 4) guidance, and 5) time.

- Delivery: There is clear evidence that the means of delivering warning messages to the public influences public warning message response. These are typically referred to as warning or message delivery factors. They are important because they help people to, for example, confirm the warning message and personalize risk, both of which are important

intervening factors between getting a message and taking a protective action. Certain types of channels are effective in some settings but not in others. This includes channels which are viewed as official, credible, have face-to-face delivery, or are familiar. Thus, using more channels is preferable, given that different people have access to different channels, and hearing the message over different channels motivates protective action by reducing the time people spend searching for confirming information (also referred to as milling). Hence, warning messages delivered over multiple channels reduces the time people delay taking protective actions.