RECLAMATION

Managing Water in the West

Scoping Report: Public Safety of Low-Head Hydraulic Structures

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Low-head hydraulic structures may create dangerous currents, hydraulic forces, and other hazardous conditions to someone trapped downstream of the structure because of localized hydraulic conditions. This scoping-level study determines the hydraulic characteristics of submerged hydraulic jumps, hazards associated with submerged hydraulic jumps, common characteristics of potentially dangerous hydraulic structures, types of low-head hydraulic structures that may cause public safety concerns, and structural modifications or other design techniques that can be used to mitigate risk for existing structures and new construction. A discussion of potential technical and non-technical paths forward is provided.

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Cover Photograph

Bureau of Reclamation's Huntley Diversion Dam on the Yellowstone River was modified to enhance public safety during rehabilitation after the 1997 spring flood.

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Introduction

After the failure of several large dams in the 1970s, concerns about dam safety in the United States increased. Forty-nine states and all federal agencies with dam oversight responsibility have established dam safety programs to regulate the design, construction, operation, inspection, and maintenance of dams (FEMA 2004, Tschantz and Wright 2011).

The National Inventory of Dams is a congressionally authorized database documenting dams in the United States and its territories (http://nid.usace.army.mil/). It is maintained and published by the U.S. Army Corps of Engineers. It contains information about a dam's location, size, purpose, type, last inspection, and regulatory facts. The database includes dams that meet at least one of the following criteria:

1) High hazard potential classification – loss of human life is likely if the dam fails
2) Significant hazard potential classification – no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns
3) Equal or exceed 25 feet in height and exceed 15 acre-feet in storage
4) Equal or exceed 50 acre-feet storage and exceed 6 feet in height

Low-head hydraulic diversion structures are typically not captured in the National Inventory of Dams database because they do not impound water and would not cause life loss or property loss upon failure. However, low-head hydraulic structures may create dangerous currents, hydraulic forces, and other hazardous conditions to someone trapped downstream of the structure because of localized hydraulic conditions.

The Bureau of Reclamation (Reclamation) manages both an Operation and Maintenance (O&M) program and a Safety of Dams Program. Submerged hydraulic jumps that can be generated by low-head hydraulic structures generally fall outside of the responsibilities of both O&M and Safety of Dams programs. Properly operating structures can create dangerous hydraulic conditions that are not necessarily identified or addressed under current programs.

Tschantz (2014) shows that the number of dam failure fatalities has decreased from 1960 to 2014 while the number of low-head dam fatalities has increased over the same time period. Since 1980, forty people have died from dam failures while 278 drowning deaths have occurred at low-head dams (Tschantz 2014). Two-thirds of the fatalities at low-head dams have occurred over the last 15 years. Kayakers, swimmers, boaters, anglers, and other river recreationalists are most likely to encounter these types of structures.

A database of fatalities at low-head dams in the United States was created by Kern (2014) for the purpose of increasing public awareness and generating support to remediate dangerous structures (http://krcproject.groups.et.byu.net). The American Whitewater Association also maintains a database of all types of river-related accidents (https://www.americanwhitewater.org/content/Accident/view/).

Public awareness, signage, buoys, lighting, and portage opportunities can minimize risk, but dangers from hydraulic forces remain. Tschantz (2014) states "Hydraulic engineers are aware of the forces created by moving water and have a professional responsibility to design safe structures to control and contain these forces."

There is momentum in the engineering community to examine public safety at low-head dams including new research and laboratory studies (Olsen 2013, Kern 2014) and professional articles (Tschantz 2014, Tschantz and Wright 2011, Schweiger 2011). The Association of State Dam Safety Officials (ASDSO) conducted a survey in 2014 to estimate the extent of low-head dams in the United States and determine the level of state regulation or policy that requires dam owners to warn the public of the inherent dangers of these structures (Tschantz 2014). ASDSO has initiated a technical committee within the professional organization to look specifically at the issue of safety at low-head dams (Bruce Tschantz, personal communication, 2016). The National Dam Safety Review Board has formed a task group to determine what future actions should be taken to improve public safety around dams, including the possibility of developing national standards and guidelines. There are also a number of national, state, and local organizations and departments that are educating the public about the dangers of low-head dams and promoting safe practices near low-head dams (e.g., American Whitewater Association, American Canoe Association, ASDSO, Department of Natural Resources for multiple states, Federal Energy Regulatory Commission, Federal Emergency Management Agency, Canadian Dam Association, Indiana Silver Jackets, The Pelorus Project).

In an effort to increase public safety, the State of Illinois evaluated 25 run-of-river dams as part of their Illinois Statewide Program (CTE|AECOM 2007). Existing conditions and public safety measures were evaluated at each of the 25 run-of-river dams. Non-structural (e.g., signage, fences, buoys, lighting) and structural (e.g., rock fill, riffle pool rock ramp, full bypass channel, in-stream bypass channel, dam face modification, dam removal) alternatives to enhance public safety at each of the run-of-river dams were discussed. Temporary and permanent structural modification options that would eliminate or lessen the public safety hazards posed by the dams and the estimated costs associated with the modifications were provided for future action.

In another statewide effort, a low-head dam public hazard program was established within the Iowa Department of Water Resources in 2008 to reduce fatalities at traditionally-designed low-head dams. "Solving Dam Problems: Iowa's 2010 Plan for Dam Mitigation" states that "The Iowa Department of Natural Resources (DNR) has a separate dam safety program tasked with assuring Iowa's dams are constructed and maintained per a hazard classification system based on risks downstream of the dam; however, this program does not specifically address the hazard posed by low head dams to recreational users. Reducing what to date have been more numerous Iowa deaths due to traditional "low-head" dam design was a main consideration in creating the newer public hazard program."

In 2010, Iowa Department of Water Resources created an inventory of low-head dams to document dams that are not reported in the National Inventory of Dams. Two hundred forty-six structures were found on major rivers in Iowa. The Iowa Legislature has appropriated funds for the development of dam mitigation projects. Dam owners and other eligible entities can apply for cost-share assistance and support for projects that reduce recreational hazards. Twelve low-head dams have been modified or removed in

Iowa from 2011-2015 using state, local, and private funds (http://www.desmoinesregister.com/story/news/investigations/2015/01/27/removing-lowhead-dams-making-parks/22441793/).

Purpose

The purpose of this scoping-level study is to determine:

- Hydraulic characteristics of submerged hydraulic jumps
- Hazards associated with submerged hydraulic jumps
- Common characteristics of potentially dangerous hydraulic structures
- Types of low-head hydraulic structures that may cause public safety concerns
- Structural modifications or other design techniques that can be used to mitigate risk for existing structures and new construction

This scoping-level study also identifies research gaps relating to public safety at low-head hydraulic structures and discusses possible future actions.

Methods

A literature review was conducted to find technical documents, guidelines, research studies, theses, and articles relating to public safety at low-head dams and other hydraulic structures. The literature review was used to determine the types of structures that may create dangerous conditions, the hydraulic and structural factors that increase risk of entrapment, and potential mitigation or retrofit alternatives. Prominent researchers interested in structure modifications were contacted by phone or email. Research gaps relating to public safety at low-head dams were identified.

There are several nonstructural ways to reduce the risk of drowning at hydraulic structures – signage, buoys, portage ramps, fences, and public communication (Bureau of Reclamation 2006, FERC 2001 and 1992, National Park Service 2004). This report focuses on structural modifications and retrofits to reduce or possibly eliminate the occurrence of potentially dangerous currents at the structures.

Dangers of Submerged Hydraulic Jumps

Hydraulic Conditions

Although low-head dams may not cause life loss or property loss upon failure, there are certain hydraulic conditions that can cause risk to the public. A hydraulic jump occurs when there is a rapid change from a low stage/high velocity condition (supercritical flow) to a high stage/low velocity condition (subcritical flow), resulting in an abrupt rise in the water surface elevation. Hydraulic jumps frequently occur at the end of spillways, downstream of regulating gates, or when a steep channel becomes flat. The depth upstream of the hydraulic jump is called the initial depth and the depth downstream of the hydraulic jump is called the sequent depth (y_2) (Figure 1).

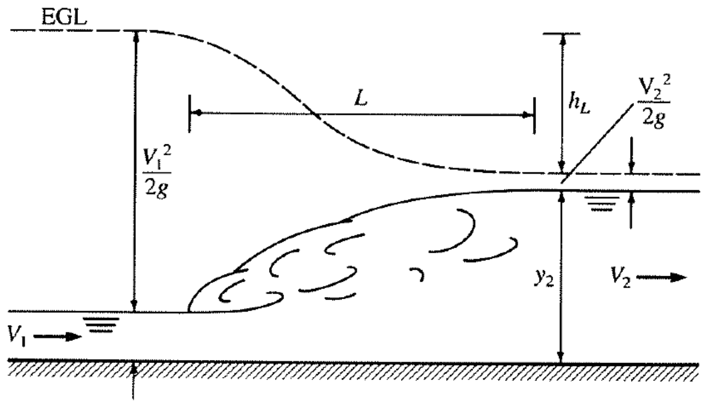

Figure 1. Schematic of hydraulic jump where the initial depth (left side of schematic) is measured at the V_1 location and the sequent depth (y_2) is measured downstream of the hydraulic jump (Roberson et al. 1995).

Flow over a vertical drop structure such as a low-head dam can produce four possible flow conditions based on the sequent depth and tailwater depth. In the case of a "swept-out hydraulic jump", a hydraulic jump is formed but is pushed downstream because of the low tailwater depth (Figure 2, Case A). With an "optimal hydraulic jump", a fully developed hydraulic jump is formed directly downstream of the structure (Figure 2, Case B). A "submerged hydraulic jump" is formed when the tailwater depth exceeds the sequent (or downstream) depth of the hydraulic jump and the hydraulic jump becomes submerged (Figure 2, Case C). In this case with mild submergence, the upstream directed velocity is highest (Leutheusser and Fan, 2001). As the submergence or tailwater depth increases, the countercurrent velocity decreases (Leutheusser and Fan 2001). In this "drowned-out hydraulic jump" condition, the tailwater depth well exceeds the sequent depth of the hydraulic jump such that the hydraulic jump is completely drowned out and only an undulating water surface exists (Figure 2, Case D).

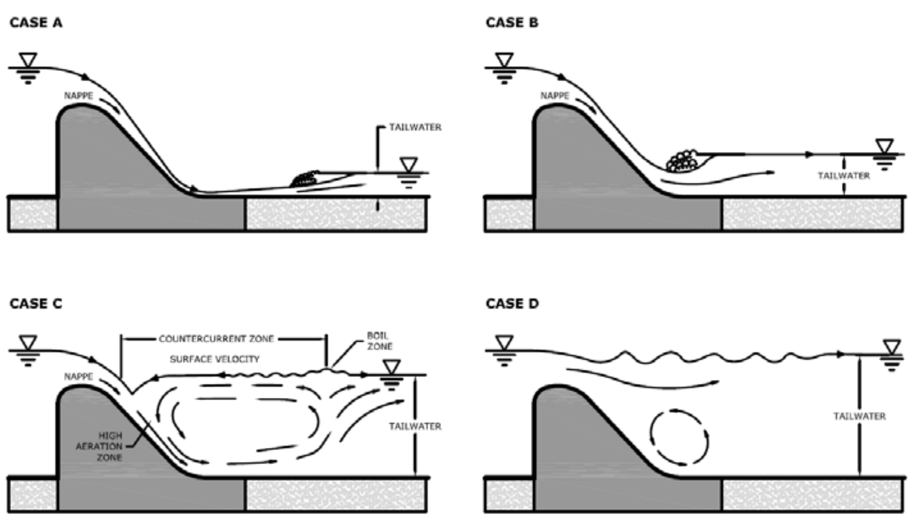

Figure 2. Four possible flow conditions over a low-head hydraulic structure: Case A – Swept-out Hydraulic Jump, Case B – Optimal Hydraulic Jump, Case C – Submerged Hydraulic Jump, Case D – Drowned-out Hydraulic Jump (modified from Tschantz and Wright 2011).

Case C is the most dangerous flow condition for recreationalists (Leutheusser and Birk 1991, Tschantz and Wright 2001). Submerged hydraulic jumps produce strong rotational currents toward the dam face (Figure 2, Case C). The point where downstream-directed velocities become upstream-directed velocities is called the “boil” point. Objects are submerged by the force of the plunging nappe, resurface upstream from the boil, and are swept upstream to the plunging nappe again by the upstream-directed surface velocities to repeat the process (Wright et al. 1995). The calm appearance of submerged hydraulic jumps make low-head dams deceptively dangerous (Tschantz and Wright 2011).

Leutheusser (1988) found that only about 50% of the general public can swim and as many as 85% are considered poor swimmers. Hydraulic jump velocities may exceed normal human swimming capabilities, making it difficult or impossible to escape the rotational currents. Life jackets do not eliminate risk. Air bubbles mixing in the water from the plunging nappe decrease buoyancy, so the victim can have a hard time staying afloat even with a life jacket or the life jacket may be ripped off in the turbulence (Tschantz and Wright 2011). Of 112 low-head dam fatalities where information about life jackets was reported, 44% of victims had worn life jackets and 56% had not (Tschantz 2014).

Structures of Concern

It is important to define which type of structures may create dangerous hydraulic conditions for the public. There is no universal definition of “low-head dam”, but it is generally accepted to be a hydraulic drop structure of about 15 ft or less in height (Schweiger 2011, Tschantz and Wright 2011).

Many different types of structures can produce hazardous hydraulic conditions. Any structure capable of producing a submerged hydraulic jump over some range of operational conditions poses a risk. A submerged hydraulic jump occurs when the tailwater depth exceeds the sequent (downstream) depth of the hydraulic jump causing strong rotational currents toward the dam face. Structures can be designed to increase the range of flow conditions for which a swept-out or optimal hydraulic jump will occur; however, there may be times when hydraulic conditions still create a submerged hydraulic jump. Flow rate and head on the dam are a function of hydrologic conditions in the watershed, and tailwater depth is determined by the characteristics of the channel (Leutheusser and Birk 1991).

For a certain hydraulic structure, small changes in flow can affect the degree of hazard produced by the submerged hydraulic jump (Tschantz 2014). Olsen et al. (2013) present a method for using easily-measured parameters to distinguish between high-risk and low-risk states of flow for ogee-crested and flat-topped dams of 2.0, 5.0, and 10.0 ft height. Dam height (P), upstream water surface elevation (hu), and downstream water surface elevation (hd) are used to define a risk factor = (hu-hd)/P. Numerical model results show that the most dangerous flow conditions occur when an ogee-crested dam has a risk factor from 0.093 to 0.798 and a flat-topped dam has a risk factor from 0.343 to 0.708.

Kern’s interactive database of fatalities at submerged hydraulic jumps shows a broad range of structure types that have caused fatalities (Kern 2014). Examples include ungated sharp-crested weirs (e.g., sheet pile weirs), ungated broad-crested weirs (e.g., ogee-crest and flat topped crests), gated structures (e.g., gated low-head dams), and drop structures (e.g., grade control and fish passage). In the laboratory, Kern (2014) tested a wedge-shaped, sloped spillway. Olsen et al. (2013) examined both ogee-crested and flat-topped weirs. Klumpp et al. (1989) and Freeman and Garcia (1994) tested physical models with modified ogee-crest dams in a hydraulics laboratory.

Low overflow structures that span the full width of the river or stream are of most concern. Full-spanning hydraulic structures create a uniform countercurrent across the channel width, so it is difficult for an entrained object or person to be ejected from the current laterally. Channel width-spanning structures of all types can create these hydraulic conditions.

Potentially dangerous low-head hydraulic structures typically have the following characteristics:

1. Continuous overflow from bank-to-bank
2. Not designed for storage, often for flow diversion
3. Generally without hydraulic structures such as gates, pipes, penstocks
4. Typically less than 15 ft high
5. Located on natural river systems where recreationalists are found

Since the largest concern is for structures that are located on rivers with recreationalists, this scoping-level report focuses on structures located in places where the public is legally allowed to be. Canals or locations with restricted access are outside of the scope of this study.

Hydraulic structures that meet the above criteria include, but may not be limited to: low-head run-of-river dams (ogee-crest or flat-top weirs), low-head diversion structures, channel-wide vertical drop structures and check structures, fish barriers, grade control structures, and low-head dams with fully-open floodgates.

Structural Remediation Options for Existing Structures

Many possible options have been recommended in literature to remediate existing structures. Leuthesser and Birk (1991) recommended the use of a baffled chute spillway (based on Reclamation's Type IX basin) because these structures produce continuous energy dissipation, function over a wide range of operating conditions, and are independent of tailwater conditions. Hotchkiss and Comstock (1991) countered this recommendation with the claim that baffles will introduce another mechanism of injury that could prevent safe passage over the structure.

Placement of large boulders or grout bags immediately downstream of the dam face to dissipate energy at the chute has been used successfully in many situations. Schweiger (2011) claims that this method is most popular because placement can occur in the wet during low flow periods. The city of Columbus, Ohio has placed large boulders at the base of low overflow structures to produce a rough incline with a slope of 3:1 to 4:1 (Emily K. King, personal communication, October 11, 1988 as cited in Leutheusser and Birk 1991). Schweiger (2011) shows another example of large boulder placement at Twolick Dam on the West Fork River in Clarksburg, West Virginia.

Another possible remediation technique is the installation of a stepped spillway or large concrete steps on downstream face of dam to create a rough incline of 4:1 or flatter (Schweiger 2011). This structural modification can be placed along the entire downstream face or at an appropriate spacing to break up downstream hydraulics. Schweiger (2011) shows an example at Island Farm Dam on Raritan River in New Jersey where the downstream face was stepped following four drowning deaths. Freeman and Garcia (1996) recommended a 4-step spillway with concrete blocks starting below the ogee curvature of dam face to remediate the Yorkville Dam in Illinois.

Klumpp et al. (1989) describe the installation of boat chutes on the South Platte River in Englewood, Colorado at an 18.5-ft-high reinforced concrete diversion dam that provides water supply for the city. The boat chutes were created with a lesser slope than the dam face to eliminate dangerous hydraulics. Boat chutes with head drops of 2.0 – 3.5 ft create artificial rapids and still pools for canoers and kayakers to navigate. Schweiger (2011) suggests, however, that boat chutes may become an open invitation or destination for canoers and kayakers to visit the site and may convey a measure of safety that may not exist.

Leutheusser and Birk (1991) suggest eliminating dangerous hydraulic conditions by raising the height of the overflow structure to promote formation of a proper hydraulic jump. The authors recognized that this may be deemed unacceptable in many situations. Depending on the purpose of the structure, dam removal is another option which may or may not be considered desirable.

Olsen et. al (2014) discuss possible remediation options for flat-top and ogee-crested weirs found through computational fluid dynamics and physical modeling. They found two promising approaches: upstream-facing ramps spaced along the channel width and spaced horizontal platforms protruding from the downstream dam face. The spaced protruding platforms produced the lowest overall entrapment time for an object for both flat-top and ogee-crested structures. The upstream-facing ramps also improved flow conditions for the flat-top weirs, but concern was raised over the possibility for physical injury to recreationalists passing over structure.

Two cost-effective retrofit options were examined in the thesis of Edward W. Kern (2014). He examined a channel-wide horizontal flow deflector and staggered flow deflectors on the downstream face of a 2H:1V spillway (Kern 2014). The channel-wide horizontal deflector placed at 0.7 times the dam height produced uniform downstream-directed velocities for a narrow range of tailwater elevations. The staggered flow deflector consisted of partial-width deflectors at multiple elevations to break up the uniformity of the countercurrent enough to allow a trapped object to be ejected. Staggered flow deflectors placed at six elevations from the floor to 0.87 times the dam height prevented uniform countercurrents over a wide range of tailwater elevations.

Schweiger (2011) suggests the installation of moveable crest dams (e.g., hydraulically operated steel gates, inflatable rubber dams, gates with an inflatable rubber bladder) when existing dams are replaced. Because the crest elevation of the dam can be varied from fully up to fully down, they should be able to reduce or eliminate the presence of dangerous hydraulics. Gate position could be changed automatically based on hydrologic conditions or time of the day. Research on the use of moveable crest dams for public safety has not yet been conducted (Schweiger 2011).

The combination of enhanced public safety and fish passage needs may provide a multi-faceted solution. Nature-like rock ramp fishways are installed with natural materials to a maximum slope of 20H:1V from the bed of the channel to the top of the structure. Aadland (2010) proposes rock arch rapids which add boulder weirs to rock ramps to add stability to the rapids. Both of these approaches reduce velocities and eliminate dangerous hydraulics.

Hauser et al. (1991, 1992) discuss two options for safer overflow structures. The first option is a timber crib weir with rock-fill and heavy steel grating over the fill. This structure is a wide (upstream to downstream), porous structure that steps down gradually, allowing flow to move through the weir rather than flowing rapidly over the weir. The second option is a labyrinth weir designed to create safe plunge pool conditions with lower unit discharges than low-head weirs. Labyrinth weirs pass a thinner sheet of water over the length of the weir and produce minimal downstream turbulence and recirculation. A field test showed that around 2 cfs/ft may be a threshold value for swimmer safety downstream of a labyrinth weir.

Examples of Hydraulic Structures Remediated by Reclamation

Drowning deaths have occurred at low-head hydraulic structures in the United States (Tschantz 2014). Reclamation owns structures that fall into the category of low-head hydraulic structures with submerged hydraulic jumps. Two diversion dams have been modified by Reclamation to minimize or eliminate the occurrence of a submerged hydraulic jump over the operational range of the structure.

The Roosevelt Power Canal and Diversion Dam upstream of Theodore Roosevelt Dam on the Salt River were constructed from 1904 and 1906 as an integral part of the Salt River Project to provide power during the construction of Roosevelt Dam. The Power Canal is no longer functional, but the Power Canal Diversion Dam is currently used to divert water into an irrigation ditch on river right. The Power Canal Diversion Dam is a transferred work to Tonto National Forest for operation and maintenance.

The Power Canal Diversion Dam was modified in 1989 to improve recreational safety while maintaining the fish barrier effect of the original weir (Figure 3). The original 7.25-ft-high ogee-shaped weir was retrofitted with steps on the downstream face of the spillway in 1989 to improve safety issues. A 1:35 Froude-scaled physical hydraulic model of Roosevelt Diversion Dam showed that a combination of a 3.25-ft step at the dam crest elevation followed by a series of 1-ft steps with differing tread length provided the best hydraulic conditions for recreational safety while preserving the fish barrier characteristics to prevent migration of non-native fish into the Salt River (Dodge 1989).


Figure 3. – Reclamation's Roosevelt Diversion Dam at the Power Canal upstream of Roosevelt Dam in the original design (left) and safer design retrofitted in 1989 (right).

Constructed in 1933, the original design of Reclamation's Huntley Diversion Dam on the Yellowstone River included a concrete gravity structure with a structural height of 10 to 11 ft and a crest length of about 250 ft. The structure was used to meet agricultural and municipal water demands for the Huntley Project and it was transferred to the Huntley Project Irrigation District for operation and maintenance. After the record spring runoff of 1997, Huntley Diversion Dam was modified to repair the dam, but also provide fish passage and enhance public safety (Figure 4). Along with a left abutment fish passage channel, heavy riprap was placed at a 4H:1V slope from the crest of the dam to the river bottom with a natural rock basin at the toe of the riprap slope. The top 6 inches of the riprap was grouted (Womack & Associates, Inc. 1999).

Figure 4. Huntley Diversion Dam was modified to enhance public safety during rehabilitation after the 1997 spring flood.

Possible Technical Future Actions

A number of viable options have been discussed in literature to remediate existing channel-spanning, run-of-river hydraulic drop structures depending on site conditions and resources available. Remediation of a specific hydraulic structure can be examined in a physical model to ensure that the preferred remediation alternative is effective and does not cause downstream erosion. Physical and/or computational modeling can also be used to determine if there are additional cost-effective options for new construction of low-head hydraulic structures that should be considered in the design phase. Specifically, research on the use of moveable crest dams for public safety has not yet been conducted.

Development of remediation options or alternatives for construction of safer new hydraulic structures that are outside of the scope of this report, such as canal check structures and pipe crossings, should be considered. When structures in access-restricted locations reach the end of their service life, these structures should be replaced with safer structures with design guidance from research studies.

This scoping-level paper focuses on low-head dams less than 15 ft high, but similar hydraulic conditions can occur at taller dams. Taller dams tend to be more formidable for the public than low-head dams, so public interaction is limited. However, possible remediation alternatives for taller dams could be examined in models to reduce risk at these structures.

Possible Non-Technical Future Actions

Many Reclamation offices and groups were contacted about this topic. Representatives from the Dam Safety Office; Safety, Security, and Law Enforcement Office; Safety and Occupational Health Office; Policy and Administration – Asset Management Division; Research and Development Office; and the Reclamation Design, Construction, and Coordination Team have assisted in providing input on this topic and/or reviewing this document.

Opinions of how Reclamation could move forward with addressing public safety of low-head hydraulic structures vary and sometimes contradict each other. Ideas range from broad-scale programmatic solutions to very specific solutions that address part of the overall issue. These ideas have been captured in the list below. They have not been vetted or prioritized and are not formal recommendations, but they are included here for documentation and further consideration.

- Present findings of this report to Facilities Operation and Maintenance (FAC O&M) Team to raise awareness of the issue and develop a plan for future action.
- Create an Issue Paper for review and action by the Reclamation Leadership Team. Several vetted options/alternatives would be listed for consideration and future discussion.
- Perform a legal review of Reclamation's responsibilities with respect to public safety at low-head hydraulic structures.
- Collect additional information during routine Review of Operation and Maintenance (RO&M) examinations performed in accordance with Reclamation Manual Directive

and Standard FAC 01-04 (www.usbr.gov/recman/fac/fac01-04.pdf) to better understand whether a hydraulic structure is a structure of concern.
    - Develop standardized criteria and checklist for O&M inspectors to uniformly collect information related to public safety of hydraulic structures.
    - Identify structures that have certain physical characteristics (e.g., type of structure, type of crest, height, width) along with known safety issues/incidents, safety features in place (e.g., signage, buoys, portage opportunities), volume/type of recreationalists, and visual evidence of a submerged hydraulic jump.
- Conduct a hydraulic analysis to determine the range of flow conditions that generate submerged hydraulic jumps for specific structures of concern. Create a list of field measurements and calculations that are needed for a hydraulic analysis.
- Create a centralized database or inventory of Reclamation's low-head hydraulic structures that meet the characteristics of a potentially dangerous structure to determine the extent of the problem within Reclamation. This database could be managed by Policy and Administration's Asset Management Division.
- Assess structures with known public safety incidents prior to collecting information on all hydraulic structures throughout Reclamation.
- Determine how to address findings of a potentially dangerous hydraulic structure if the structure is a transferred work.
- Create a new program for public safety of low-head hydraulic structures that assesses existing structures, prioritizes structures based on risk, and modifies structures as needed. This new program could be placed under the existing RO&M program.
- Ensure that public safety is incorporated at the design level of new low-head structures.
    - Coordinate with "Safe by Design" effort.
    - Implement safe design of structures or features when replacement is needed.
- Develop a reference guide on safe design of low-head hydraulic structures for new structures or retrofits to existing structures.

Conclusions

In order to increase awareness of this issue, several next steps are recommended. The findings of this report will be presented in a project close-out meeting with Reclamation's Research and Development Office. Results will also be presented to Reclamation's Dam Safety Office; Safety, Security, and Law Enforcement Office; Safety and Occupational Health Office; and Policy and Administration – Asset Management Division. It is also recommended that Reclamation continue coordination with technical committees and task committees for public safety at dams within the National Dam Safety Review Board, ASDSO, and United States Society on Dams (USSD).

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