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Managing Water in the West

Water Operation and Maintenance Bulletin

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In This Issue . . .

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This *Water Operation and Maintenance Bulletin* is published quarterly for the benefit of water supply system operators. Its principal purpose is to serve as a medium to exchange information for use by Bureau of Reclamation personnel and water user groups in operating and maintaining project facilities.

The *Water Operation and Maintenance Bulletin* and subject index may be accessed on the Internet at: <**http://www.usbr.gov/pmts/infrastructure/inspection/waterbulletin**>.

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***Cover photograph** –Stiff testing frame.*

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The New Materials Engineering and Research Laboratory

by Katie Bartojay, P.E.[1]

The Materials Engineering and Research Laboratory (MERL) is excited to announce the addition of soils and rock testing to our current expertise in concrete, concrete repair, paints and coatings, corrosion mitigation and cathodic protection, geosynthetics and plastics, and structural testing.

The MERL is located in the Bureau of Reclamation's (Reclamation) Technical Service Center (TSC) in Denver, Colorado. Our primary role as part of the Civil Engineering Division is to assist Reclamation in the construction and condition assessment of dams, spillways, bridges, and water conveyance structures. We have been providing services to Reclamation for the last 74 years. *Don't miss the 75th anniversary in 2006!*

The MERL provides a wide variety of services—dam safety research laboratory investigations, operation and maintenance (O&M) research investigations, expertise in state-of-the-art construction materials and practices, troubleshooting construction problems, specification preparation and review, material submittal approvals, research, and related training. The group is comprised of experts on the various materials, including concrete, protective coatings, corrodible metals, geosynthetics, and now soils and rocks that Reclamation uses to build and maintain its structures.

The MERL welcomes Tom Strauss, Doug Hurcomb, Zeynep Erdogan, and Les Shehorn into our mix of skilled professionals. These experts will perform studies related to soil, rock, and foundation materials for the MERL in order to provide technical advice on condition assessment, rehabilitation, and preservation of Reclamation projects. They will perform state-of-the-art studies and analyses for embankment dams and geotechnical aspects of other structures.

With collaboration of other MERL experts, the properties and performance of all Reclamation project materials can be evaluated under various environmental and service life conditions.

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Who are they and what do they do?

Thomas (Tom) Strauss, P.E., is a geotechnical engineer with 23 years of experience with Reclamation. He has extensive experience in all aspects of soil and rock testing, both in the laboratory and the field. Tom has been instrumental in developing new testing procedures, testing systems, and quality assurance plans for laboratory operations. Tom has been involved in numerous investigations with other Federal and State agencies, including the Environmental Protection Agency, General Services Administration, Federal Highways Administration, U.S. Geological Survey, Department of Energy, and the State of North Dakota.

Doug Hurcomb is a petrographer and engineering geologist who provides technical expertise and assistance in materials evaluation and problem solving associated with research, design, O&M, and construction activities for Reclamation. Doug joined Reclamation in 1986. He is a certified professional geologist and has advanced his skills using microscopy, x-ray diffraction, and scanning electron microscope techniques to evaluate rocks and concrete as well as other materials used on Reclamation projects.

Zeynep Erdogan has a Masters degree in geotechnical engineering and has worked at Reclamation for the last 5 years. Prior to joining Reclamation, Zeynep worked as a geotechnical engineer for several private consulting firms in Colorado and in her native country of Turkey. Zeynep has been involved with specialized soils and rock testing programs and has a great working knowledge of the geotechnical testing used at the TSC.

Leslie Shehorn (Les) has been a geotechnical technician at Reclamation for over 28 years. He is skilled in all aspects of laboratory soils testing, including Triaxial Shear, Direct Shear, Consolidation, Permeability, and other specialized testing methods. Les is also experienced in the maintenance and calibration of all equipment utilized in the laboratory. In addition, Les has extensive field experience, performing field testing and quality control tasks at various Reclamation construction projects and site investigations.

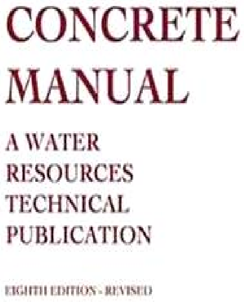
The MERL is changing with the needs of Reclamation. Some of the services are tried and true, and some are revolutionary. Besides the addition of geotechnical and geologic expertise, the concrete, coatings, corrosion, and plastics specialists at the MERL have been transforming over the years as well.

What's new in concrete and concrete repair?

The concrete and concrete repair experts at the MERL are knowledgeable in both old and new concrete technologies relating to Reclamation projects. They also serve as Reclamation's concrete repair and preservation specialists, providing technical advice on condition assessment, repair, rehabilitation, and preservation. This expertise has been invaluable in their research to design quality concrete for innovative but practical applications. They keep up to date with industry advances in cement, pozzolans, aggregate, and chemical admixture production.

These experts can be called on to assess the structural condition of cultural and historic facilities through laboratory testing and field investigations. This assessment includes evaluating site conditions, determining causes of damages, and assisting in repair procedures and material selection. For any new construction or restoration work, they prepare or review specifications to ensure only quality materials and processes are being used on Reclamation projects.

The MERL is known for publishing the *Concrete Manual*, Reclamation's one-stop guide for concrete construction. They are also responsible for the recently published *Guide to Concrete Repair* that is being used throughout the concrete industry.



CONCRETE
MANUAL
A WATER
RESOURCES
TECHNICAL
PUBLICATION

EIGHTH EDITION - REVISED

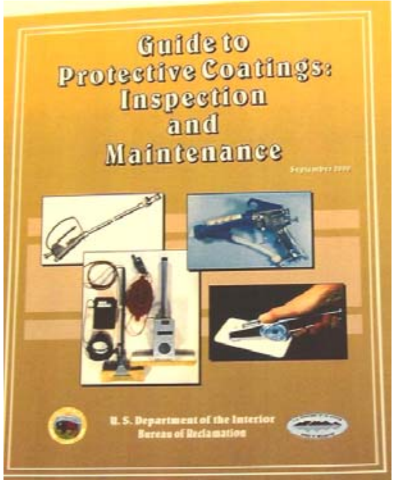
Guide to
Concrete Repair

What's new in coatings?

With recent advances in chemistry and stricter environmental legislation against pollutants, our experts work hard to stay on top of the always evolving coatings industry. The coatings experts at the MERL are called on to research and recommend environmentally acceptable, low-cost, durable coating systems and processes. This is particularly challenging when it comes to repairing or replacing existing coatings on many of Reclamation's aging projects.

Our coatings experts prepare guide specifications and provide technical advice on selecting, applying, monitoring, and inspecting paints and protective coatings. They also prepare guidelines for removing deteriorated coatings safely and in an environmentally acceptable way while complying with Reclamation and industry standard worker safety regulations. They perform laboratory exposure testing to evaluate current and new coating materials and are currently working on a research program to evaluate the remaining service life of protective coatings using Electrochemical Impedance Spectroscopy (EIS).

The coating experts at the MERL recently published the *Guide to Protective Coatings: Inspection and Maintenance* that is being used on many Reclamation projects.



Guide to
Protective Coatings:
Inspection
and
Maintenance

U.S. Department of the Interior
Bureau of Reclamation

What's new in corrosion?

The corrosion technology experts at the MERL offer advice and troubleshooting services for corrosion prevention, control, and mitigation for Reclamation's facilities. They determine materials selection for corrosion control on new facilities as well as develop corrosion monitoring and cathodic protection system designs and specifications. They also perform corrosion surveys on existing structures to determine the causes of corrosion and formulate methods for mitigation.

The corrosion experts specify testing and review test data for proper system performance. They also provide training to field personnel on testing and operating corrosion monitoring and cathodic protection systems.

What's new in plastics (geosynthetics/polymers)?

The MERL has specialists dedicated to providing technical expertise on design, construction, and maintenance of polymeric (plastic) construction materials, including geosynthetics, sealants, waterstop, roofing, rubber gaskets, and plastic pipe. These experts recommend environmentally safe applications to use in aquatic and wildlife habitat enhancement as well as seepage, erosion, and pollution control on many types of Reclamation projects.

Our experts are knowledgeable of geosynthetic-polymeric materials, including geomembranes, geotextiles, and geodrains. They also provide technical and troubleshooting expertise on material submittals and specifications for operation and maintenance.

These experts direct quality control testing for polymeric, elastomeric, asphaltic, and petrochemical materials, including complex or unusual applications. They conduct applied research to evaluate new or improved materials and methods for more economical construction, lower maintenance, and improved repair or design approaches.

So, how do they do that?

The testing capabilities of the MERL are unlike any testing lab you have seen. We use a combination of old (if it's not broken, don't fix it) and new equipment coupled with data acquisition systems to evaluate a multitude of test specimens. A wide range of standard American Society for Testing and Materials (ASTM) and American Concrete Institute (ACI) tests can be performed. Research and Reclamation project conditions also lead to unique MERL engineered testing apparatus and specialized testing programs.

Compression and tension testing machines range from 10 pounds to 5 million pounds. The 5-million-pound machine reaches three stories and can handle specimens up to 50 feet high.

Full-scale, substructure, or model testing can be performed both in static and dynamic conditions. An 8- by 10-foot 1-D shake table can handle payloads in the 25,000 pound range.

Soils and Rock Testing Equipment

Geotechnical testing and analysis are being facilitated by the use of a half-million-pound stiff testing frame capable of testing rock in triaxial compression with pore pressure measurements at elevated temperatures. We also use a large triaxial shear facility for soils capable of testing up to 9- by 22-inch specimens, large direct-shear machines for testing up to 10-inch-diameter rock and concrete specimens, 12- by 12-inch soil direct shear, various permeability and filer testing apparatus, along with most soil and rock testing services.

Stiff testing frame.

Large direct shear machine.

Flexible wall permiameter.

Other services include specialized petrographic analysis utilizing stereo-microscopes, an X-ray diffractometer, and a scanning electronic microscope.

X-ray diffractometer.

Scanning electron microscope.

If you would like to talk to one of the professionals at Reclamation's MERL, please contact one of the following individuals. They would love to hear from you!

Concrete	Bill Kepler	303-445-2386
Concrete Repair	Kurt von Fay	303-445-2399
Coatings	Tom Bortak	303-445-2376
Corrosion	Roger Turcotte	303-445-2383
Plastics/Geosynthetics	Jay Swihart	303-445-2397
Geotechnical/Geological	Tom Strauss	303-445-2343

Early Warning System Phase I Design – Prairie Dam No. 1 and Standing Rock Dam No. 1

Purpose and Justification

The Bureau of Indian Affairs (BIA) Safety of Dams (SOD) Program has been directed to implement Early Warning Systems (EWS) at all high and significant hazard dams in their inventory as authorized by the Indian Affairs Manual, Part 55, Chapter 2.5E, which states, “EWS instrumentation will be installed, operated, and maintained at High or Significant Hazard dams and in the upstream basin when early detection of hydrologic events would provide additional time needed for emergency management activities.” EWS maintenance activities were authorized by the 1994 Indian Safety of Dams Act.

In consultation with the BIA Regional SOD Officer, it is expected that an EWS at Prairie Dam No. 1 and Standing Rock Dam No. 1 will provide the following benefits:

Emergency Management

- Early detection of rainfall-induced flood events. This will provide the BIA Agency and Tribal staff with a better detection and measurement of hydrometeorological events in the drainages.

- Early detection of potentially hazardous operational spillway releases. The safe channel capacity downstream of Standing Rock Dam No. 1 is less than the dam’s combined spillway capacity. The EWS will notify dam operations staff and allow time for them to use the Emergency Action Plan (EAP) to notify public safety officials downstream to warn and evacuate affected populations at risk.

- Floods that exceed 11 percent of the Probable Maximum Flood (PMF) will overtop and likely fail Prairie Dam No. 1. Standing Rock Dam No. 1 also overtops by floods exceeding 60 percent of the PMF. Through dam reservoir monitoring, the EWS will detect a rising reservoir (both elevation and rate of rise) and notify dam operations personnel that a potentially threatening event could occur.

- A siren warning device is in place to warn the residents downstream from the dam in Bullhead, South Dakota, of a potential hazard at the dam.

Dam Operations

- Since reservoir data will be directly available to the BIA and Tribal staff, the BIA's SOD staff on the Standing Rock Reservation can better operate and maintain the dams, and responsible staff may not need to travel out to the dams as frequently.

- Some dams may have reservoir restrictions. Having an EWS allows the operations staff and their management confidence that these water surface restrictions are in compliance.

- The dam Visual Inspection Checklist requires that the dams be visited more often during periods of higher reservoir elevations. EWS reservoir elevation data allow for accurate dam visitation frequency.

Dam Safety

- The EWS can be designed to provide for detection of a hydrologic failure event due to overtopping.

- The EWS can be designed to provide for detection of other failure modes (static or seismic) after the breach or piping throat has developed enough to cause float switches downstream from the dam to be lifted.

Prairie Dam No. 1

Background

Prairie Dam No. 1 is located on the Standing Rock Sioux Reservation approximately 13 miles north of Fort Yates, North Dakota, and about 1 mile south of the Prairie Knights Casino on State Highway 24. For a general location map, see figure 1. The dam was constructed in 1966 on the north tributary to Bone Creek, which drains into Lake Oahe on the Missouri River about 6 stream miles below the dam (figure 2). The drainage area above the dam is 1.7 mi^2 and has an average elevation near 1900 feet. The dam embankment is approximately 385 feet long. The reservoir impounded by the dam has been reported to have a storage capacity varying from about 66 acre-feet to 164 acre-feet with the water surface elevation at the inlet to the service spillway (reference 1).

Prairie Dam No. 1 was modified by the Tribe in 2002. The changes included extending the up- and downstream embankment faces to flatten the slopes, filling in the uneven dam crest to a uniform elevation, installing a geotextile membrane covered with riprap on the upstream face, filling the original service spillway corrugated metal pipe (CMP) with concrete, and constructing a new service spillway (reference 1).

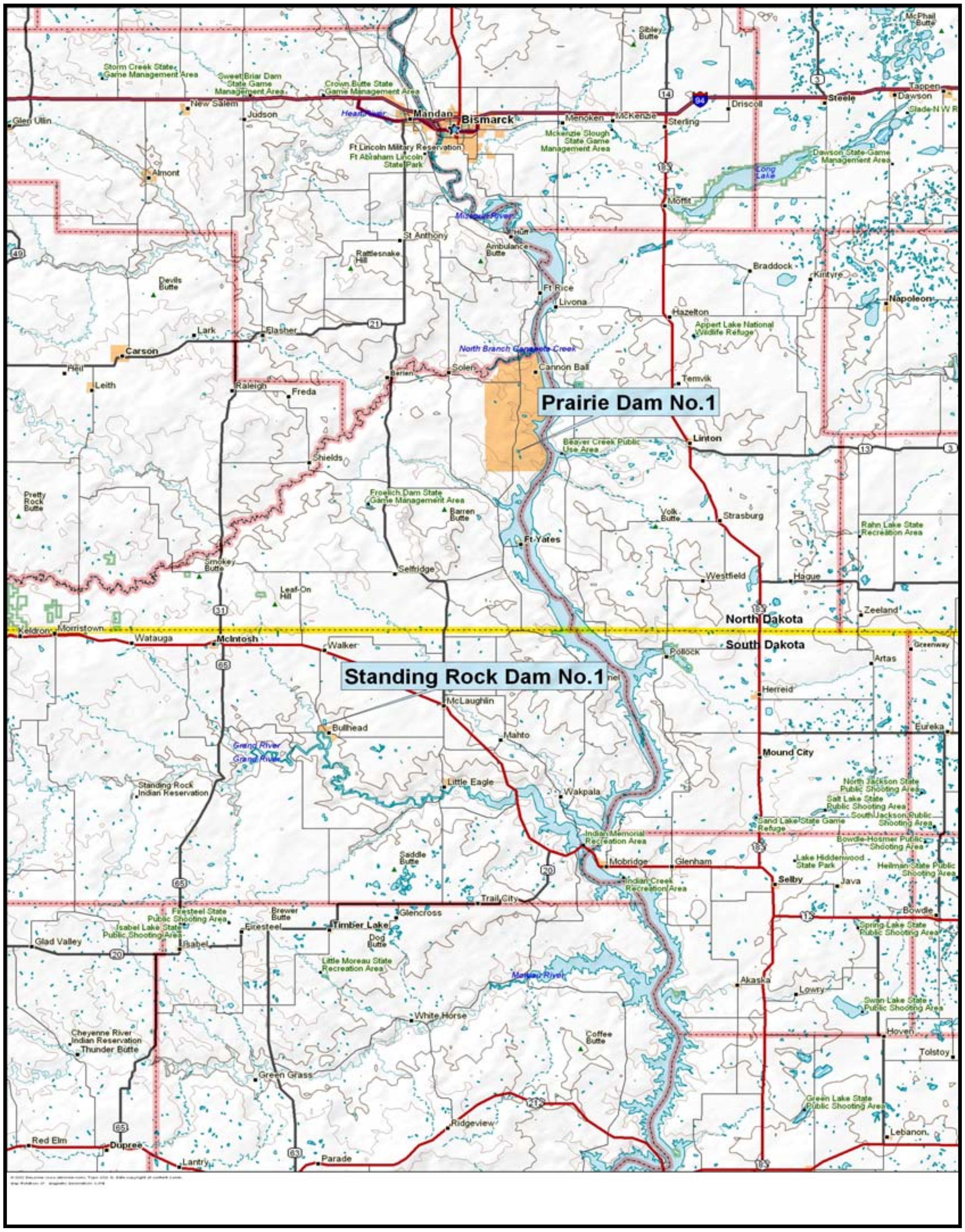


Figure 1.—Vicinity map of Prairie Dam No. 1 and Standing Rock Dam No. 1.

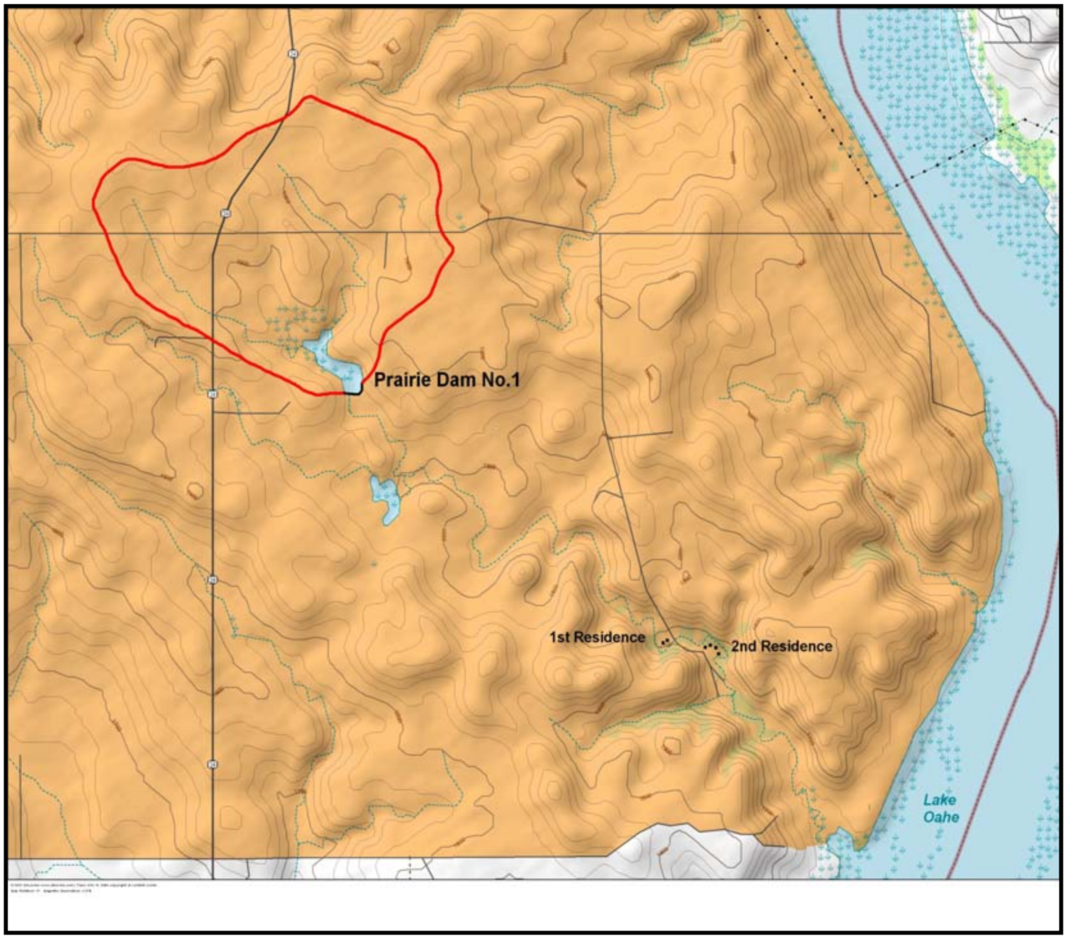


Figure 2.—Location map of Prairie Dam No. 1 and Reservoir, North Dakota.

The new service spillway is an ungated, 24-inch-diameter, double-walled, high-density polyethylene (HDPE) corrugated pipe that extends through the embankment at a location about 120 feet from the left end of the dam. It is connected with a 36-inch-diameter drop inlet structure whose crest is about 4.8 feet below the top of the dam. The new service spillway has never operated, and its discharge capacity is unknown (reference 1).

During the 2002 modification, fill material for the embankment was excavated from the emergency spillway channel located in a shallow natural depression on the left abutment. Field measurements in 2003 indicated the modified spillway is now about 220 feet wide and the lowest spot on its crest is about 4.7 feet below the top of the dam. The original spillway was about 190 feet wide and approximately 3 feet lower than the dam crest. The discharge capacity was estimated to be 1,170 ft^3/s, with the reservoir approximately 1 foot below the current dam crest elevation. Hydraulic characteristics of the modified emergency spillway are currently unknown (reference 1).

There are no low level outlet works for the dam.

Downstream Hazards and Dam Failure Inundation Study

The Bureau of Reclamation (Reclamation) completed a Downstream Hazard Classification for Prairie Dam No. 1 in 1994 (reference 2). The study identified the structure as being a significant hazard. Residences identified that are at risk from potential dam failure flows are located 3.4 and 3.7 miles downstream from the dam. A subsequent Safety Evaluation of Existing Dams (SEED) analysis of the structure concluded the dam had an overall safety classification of conditionally poor due to the potential for overtopping during a flood and because of other structural issues. The maximum safe downstream channel capacity was estimated to be between 2,500 and 10,000 ft^3/s.

A dam failure inundation study was completed for Prairie Dam in 1997. The study area included the 6 stream miles from the dam to Lake Oahe. Two dam breach simulations were conducted: (1) a sunny day failure assuming the reservoir was at the inlet elevation of the service spillway and (2) a hydrologic failure that assumed the dam was being overtopped by 1 foot when failure occurred.

The peak breach outflow discharge for the sunny day failure was 5,160 ft^3/s. The travel time for the leading edge of the flood wave to reach the first residence was 78 minutes, but neither residence was inundated by the flood. The first residence is about 14 feet above the streambed, and the second residence is about 8.5 feet above the streambed. The hydrologic failure produced a peak outflow discharge of 17,300 ft^3/s. The flood wave's leading edge took 48 minutes to reach the first residence, while the maximum flood stage took 1 hour.

Hydrology Studies and Warning Time

The PMF Study for Prairie Dam No. 1 was completed in 1996. The study computed general storm PMFs that were based on Probable Maximum Precipitation (PMP) from Hydrometeorological Report (HMR) Nos. 51 and 52. A 100-year, 3-day volume flood hydrograph was used as the antecedent flood that could occur prior to the PMFs. The results from that study are still considered valid. Table 1 gives the PMF and antecedent flood values.

The envelope curve value for the 1.7 mi^2 drainage is 7,000 ft^3/s.

Reservoir routings of the antecedent flood and the two PMFs were completed in 1996 (reference 3). They indicated that Prairie Dam No. 1 would overtop for floods greater than 11 percent of the standard arrangement general storm PMF and 13 percent for the front-end loaded general storm PMF. The initial water

Table 1.—Prairie Dam No. 1 probable maximum and antecedent floods

PMF	Peak inflow (ft^3/s)	Volume (acre-feet)
100-year, 3-day volume antecedent flood	1,280	6,200 (15-day)
General storm – standard arrangement	10,300	8,300 (15-day)
General storm – front end loaded	9,300	8,300 (15-day)

surface elevation was taken at the crest of the emergency spillway (97.0 feet), and the service spillway CMP was assumed to be plugged with debris. The dam crest was assumed to be 99.0 feet. The area capacity values used were the smaller estimates (i.e., 66 acre-feet) (see "Background" section above). The routing results for all three floods are shown in table 2.

Table 2.—Prairie Dam No. 1 flood routing results[1]

PMF	Initial water surface elevation (feet)	Maximum water surface[2] (freeboard) (feet)	Duration of overtopping (hours)
100-year, 3-day volume antecedent flood	97.0	99.06 (-0.06)	~0.5
General storm – standard arrangement with 100-year antecedent flood	97.0	102.8 (-3.8)	6
General storm – front-end load with 100-year antecedent flood	97.0	102.5 (-3.5)	6

[1] Results for old dam configuration (before 2002 modifications).
[2] Dam crest elevation – 99.0 feet.

Flood routings have not been done for the modified dam and spillway configuration. Some estimates of a substantially increased spillway capacity have been made; however, a site visit and advice from the BIA Regional SOD Officer raise doubt as to the accuracy of such estimates. It is unknown how much updated routing results would differ from those shown in table 2; however, one should expect lower maximum water surface elevations and decreased overtopping durations with the larger spillway.

Calculations were made of the warning times that would be available based on the routing of the antecedent flood with the two PMFs. Warning time is defined as the time it takes for the reservoir water surface to rise from the emergency spillway crest (97.0 feet) to the dam crest (99.0 feet). Table 3 gives these warning time values in hours for the old dam configuration. With a larger spillway and slightly higher dam, these times would be expected to slightly increase.

Table 3.—Prairie Dam No. 1 available warning times[1]

PMF	Available warning time from emergency spillway crest[2] to dam crest[3] (hours)
100-year volume antecedent flood	180
General storm – standard arrangement with antecedent flood	7.0
General storm – front-end loaded with antecedent flood	0.5

[1] Results for old dam configuration (before 2002 modifications).
[2] Emergency spillway crest – 97.0 feet.
[3] Dam crest – 99.0 feet.

Potential Failure Modes

The Comprehensive Dam Review (CDR) for Prairie Dam No. 1 discussed several potential failure modes (reference 1). During normal operations, piping and internal erosion due to seepage through the embankment and/or the foundation could breach the structure and release the reservoir catastrophically. This is most likely to occur along the old and the new service spillway pipes. The old abandoned service spillway was plugged, but details regarding the method used and the CMP's condition are unknown. This, plus its lower location in the embankment, suggests the old CMP is the more likely piping location.

During flood-related operations, a higher reservoir pool would result in higher internal pressures and could instigate increased potential for the piping and internal erosion failure mode discussed above. The most likely locations would be the same, and the dam's abutments may also experience seepage that would normally not occur. Even though the emergency spillway discharge capacity has been increased somewhat and the dam has been raised since the last flood routings were done, the threshold flood is unknown, and the dam would still be overtopped by large floods (i.e., those more rare than approximately the 100-year flood). Additionally, the transition area between the left end of the embankment and the emergency spillway channel has no slope protection and is sparsely vegetated; therefore, erosion could be problematic for lower magnitude floods that require use of the spillway.

Seismic failure modes are considered unlikely because the predicted magnitude of an earthquake event in the area is small.

EWS Design and Cost Estimates

A simple but effective EWS design for Prairie Dam No. 1 includes a method for monitoring the reservoir level in real-time with a backup indicator of a high reservoir level that threatens embankment overtopping and signals high spillway discharges. This includes an SDX 1100 satellite telemetry station with a system data logger, a pressure transducer to measure the reservoir elevation and elevation rate of change, and one float switch set at an elevation to be determined, but in the neighborhood of 0.5–1 foot below the dam crest.

A second float switch site with two switches could be installed just downstream from the embankment near the original streambed and near the present seepage area. This would provide monitoring of potential piping or breaching flows from the area of the old plugged service spillway CMP located in the right half of the embankment. A training berm on the right side of the new service spillway outlet will likely direct flows away from the proposed float switch location, so it would not be capable of detecting piping or breach flows from the extreme left side of the dam. If the SDX site is installed on the right portion of the dam, the downstream float switches could be hard-wired to the SDX enclosure for minimal cost.

EWS data would be transmitted to the BIA National Monitoring Center (NMC) in Ronan, Montana, which would provide the full-time warning and monitoring capability for the dam. Decision criteria using the EWS data would be developed and programmed in the NMC monitoring software. The NMC could disseminate the same data to Standing Rock SOD personnel via e-mail, phone, or fax, or the data could be accessed through a password-protected Web site.

Estimated costs for the EWS design as discussed are given in table 4. Costs include equipment; building, programming, and installing the EWS; and contractor travel.

Table 4.—Prairie Dam No. 1 EWS cost estimates

Item	Cost ($)
Equipment and installation: SDX 1100 transceiver, CR10X or equivalent data logger, comm. engine, one PT and cabling, one float switch in reservoir and cabling, solar charger, voltage regulator, battery, lightning arrestor, intrusion alarm, mounting pole, and NEMA enclosure, miscellaneous cabling, and assorted mounting hardware.	17,000
Downstream float switch site extension and installation: Two float switches and cabling, intrusion alarm, and enclosure.	7000
Setup programming and travel: EWS system build, EWS and NMC programming setup, equipment preparation, shipping, and travel.	3000
Total cost	27,000

Standing Rock Dam No. 1

Background

Standing Rock Dam No. 1 (also known as Bullhead Dam) is located on the Standing Rock Sioux Reservation about 1 mile north of the town of Bullhead in north-central South Dakota. For general and local vicinity maps, see figures 1 and 3. The dam was constructed in 1935 on an un-named tributary of Rock Creek and controls a drainage area of 3.7 mi^2. The dam overtopped and failed in September 1938 and was rebuilt and enlarged in 1941. In 1991, the dam underwent major rehabilitation that included new outlet works, rehabilitation of the principal, auxiliary, and emergency spillways, and raising the embankment 5 feet (reference 4).

The dam is an earthen structure 39 feet high (hydraulic height 32 feet) with a crest length of 604 feet and a crest width of 12 feet. The dam crest elevation is 1841.0 feet with about 6 inches of road grade material on top. The normal reservoir storage is 315 acre-feet at the principal spillway crest elevation of 1829.8 feet and approximately 890 acre-feet at the dam crest elevation. The maximum reservoir elevation reported to date is approximately 1833.5 feet, which occurred August 15, 1978 (reference 4).

The low-level outlet works for Standing Rock Dam No. 1 consist of an intake structure, a control tower gatehouse, an outlet conduit, and an outlet structure. The intake structure is located at the upstream end of the outlet works conduit and consists of a concrete box with the elevation of the top of its walls at 1810 feet. The control tower is located about 78 feet downstream and contains three concrete box chambers separated by two sluice gates located in tandem that control the flow through the outlet works. The upstream-most gate serves as the emergency gate, and the downstream gate is the regulating gate. The outlet conduit is a 36-inch-diameter concrete pipe that runs for 218 feet from the intake structure through the base of the control tower and dam embankment to the outlet structure, discharging into a downstream stilling basin and seepage pond located at the downstream toe of the dam. The estimated flow through the outlet works is 110 ft^3/s at a reservoir elevation of 1829 feet (reference 4).

There are three spillways at Standing Rock Dam No. 1. The principal spillway has two features: (1) an ungated overflow concrete box located near the left abutment that serves as the service spillway and (2) three overflow weir slots in the exterior walls of the outlet works control tower that discharge into the outlet works conduit. The service spillway concrete box connects with a 120-foot-long, 5- x 4-foot concrete culvert that extends through the embankment and discharges into the downstream stilling basin and seepage pond. The three overflow weirs discharge into the downstream-most concrete box chamber in the base of the control tower, then through the outlet works conduit, and into the downstream stilling basin and seepage pond. The rated discharge capacity of the principal

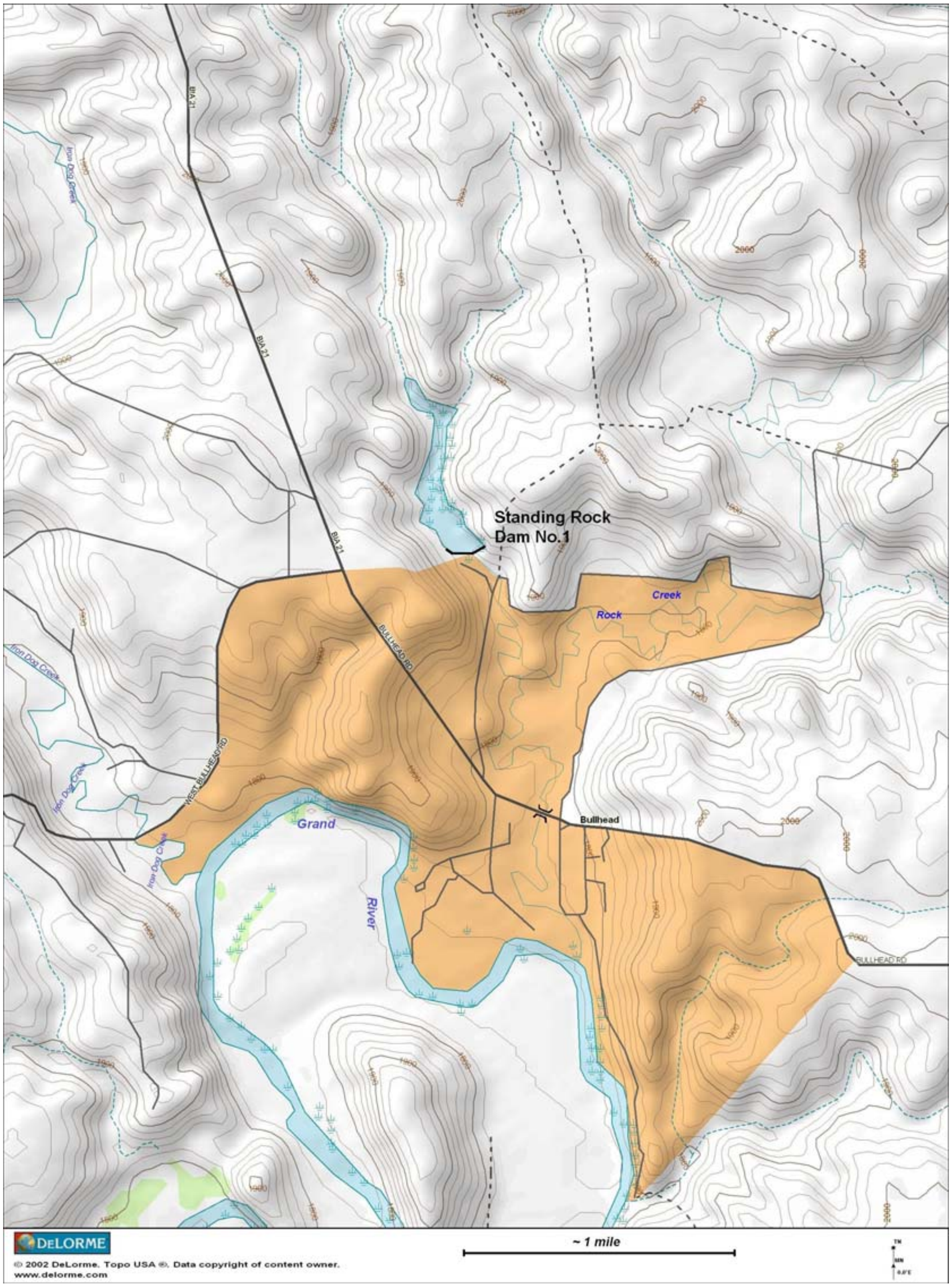


Figure 3.—Location map of Standing Rock Dam No. 1 and Reservoir, South Dakota.

spillway is 244 ft^3/s at the auxiliary spillway crest elevation (1831.5 feet) and 546 ft^3/s with the reservoir elevation 1 foot below the dam crest, or at 1840.0 feet (reference 4 and figure 4).

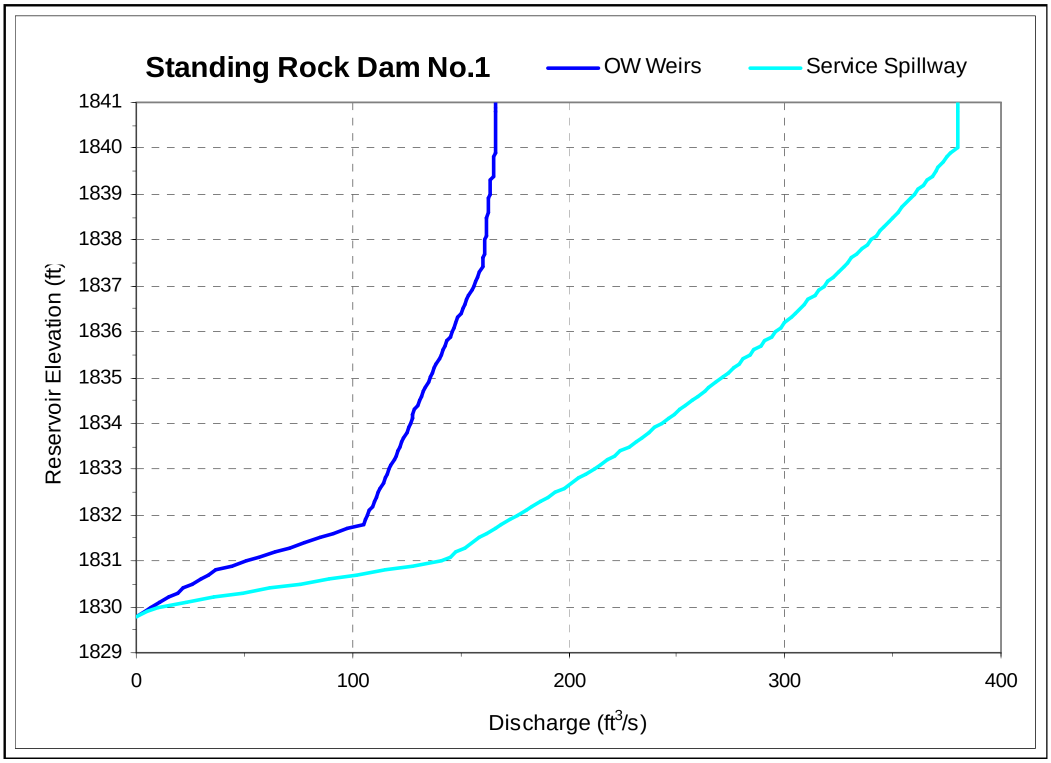


Figure 4.—Standing Rock Dam No. 1 principal spillway rating curves.

The auxiliary spillway is an uncontrolled, unlined, open-cut channel that extends around the left end of the dam. The channel has a bottom width of 165 feet, is 650 feet long, and has a crest elevation is 1831.5 feet. The rated discharge capacity is 9,052 ft^3/s, with the reservoir water surface at 1840.0 feet (figure 5).

A secondary or emergency spillway channel is similarly cut around the right abutment of the dam. The unlined channel's floor is 60 feet wide and 700 feet long with an uncontrolled crest elevation of 1832.0 feet. The rated discharge capacity is 3,923 ft^3/s, with the reservoir elevation at 1840.0 feet (figure 5).

The auxiliary and emergency spillway channels are separated from the dam embankment by training dikes with crest elevations of 1841.0 feet that direct any outflows several hundred feet downstream from the toe of the dam. The rated capacity of all the spillways with the reservoir at the dam crest (1841 feet) is 16,358 ft^3/s (figure 5).

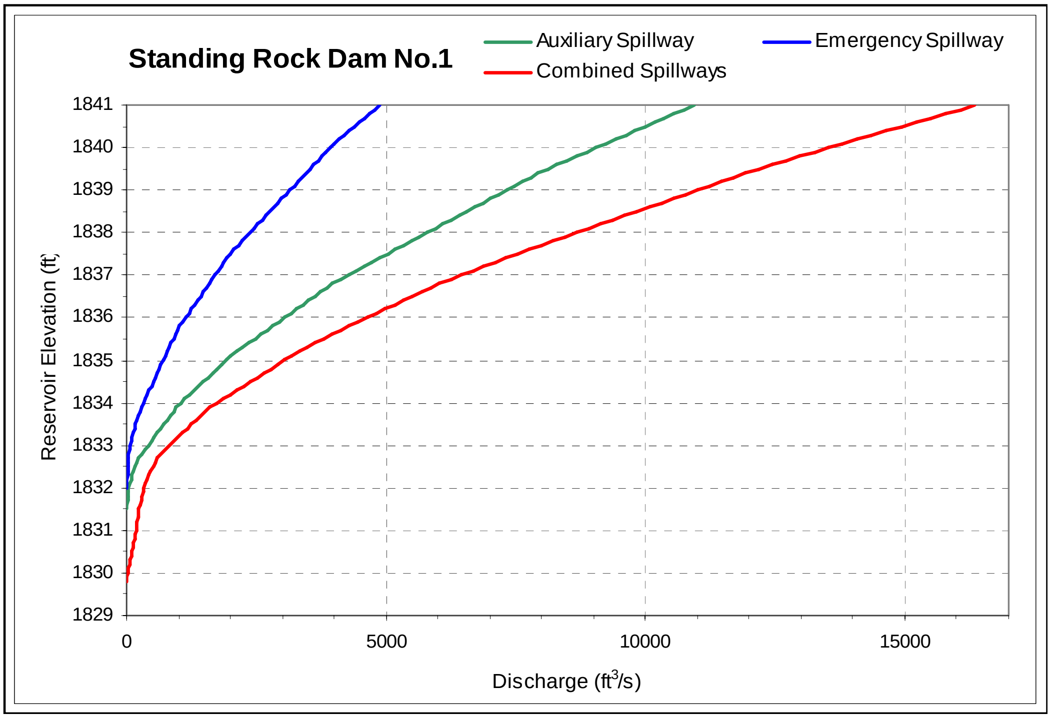


Figure 5.—Standing Rock Dam No. 1 spillway rating curves.

Downstream Hazards

Apparently, all the Population-At-Risk (PAR) exists just 1 mile downstream from Standing Rock Dam No. 1 in the town of Bullhead. Failure of the dam would cause catastrophic, life-threatening flooding in the town; therefore, the dam was assigned a downstream hazard classification of high. The safe channel capacity through Bullhead is unknown. On the south edge of town, the flood waters would empty into the Grand River and gradually dissipate.

Dam Failure Inundation Study

A dam failure inundation study was completed for Standing Rock Dam No. 1 in 1999 (reference 5). The study area included the 2 stream miles from the dam to the Grand River downstream from Bullhead. Two breach simulations were conducted: (1) a sunny day (piping) failure assuming the reservoir was at the inlet elevation of the service spillway (1829.8 feet) and (2) a hydrologic failure that used an inflow flood equal to 78 percent of the PMF to simulate an overtopping event.

The peak breach discharge for the sunny day failure was 15,193 ft^3/s. Travel time was 14 minutes for the leading edge of the flood wave to reach the edge of town and 35 minutes for the peak flow of 11,800 ft^3/s to arrive. Maximum water depth was 9.3 feet. Some homes in Bullhead are inundated, and the best estimate of the PAR is nine (references 4 and 5).

The hydrologic dam failure produced a peak outflow discharge of 46,100 ft^3/s. The flood wave's leading edge took about 6 minutes to reach the outskirts of Bullhead. The peak flood discharge was almost 36,000 ft^3/s and took 29 minutes to arrive. Maximum water depths ranged from 15 to 17 feet, which resulted in inundation of much of the town. The best estimate of PAR for this failure mode is 170 (references 4 and 5).

Hydrology Studies and Warning Time Discussion

A flood frequency and PMF study for Standing Rock Dam No. 1 was completed by Morrison-Maierle/CSSA, Inc., in 1989 (reference 6). A regional flood peak analysis was performed using the methodologies in Water Resources Bulletin 17-B. The study also computed a 24-hour general storm PMF based on 24-hour PMP from HMR Nos. 51 and 52. No antecedent flood was assumed prior to the PMF. The storm precipitation was arranged so that the most intense rainfall occurred at the 14th hour of the 24-hour storm. Table 5 gives flood frequency and the PMF peak and volume results. A timing-critical (front-end loaded) storm was not examined.

Table 5.—Standing Rock Dam No. 1 frequency and Probable Maximum Floods

Frequency flood/PMF	Peak inflow (ft^3/s)	Volume (acre-feet)
10-year peak discharge	3,300	Data unavailable
50-year peak discharge	6,500	Data unavailable
100-year peak discharge	8,200	Data unavailable
500-year peak discharge	13,500	Data unavailable
24-hour general storm	27,400	5,371 (15-hour)

No reservoir routings of the PMF were found in the consultant's reports. It was stated that the old Standing Rock Dam No. 1 could overtop by nearly 10 feet (reference 6). The consultant determined that the Inflow Design Flood (IDF) for the new dam configuration is 50 percent of the PMF, or 13,500 ft^3/s. One foot of freeboard is maintained when the IDF is passed through the rehabilitated dam. The new spillways were configured to pass 16,358 ft^3/s (60 percent of the PMF) without overtopping the dam. The 1999 dam failure inundation study (reference 5) routed a flood that was 78 percent of the PMF with the rehabilitated dam configuration (5 feet of surcharge and larger spillways). The report stated that the reservoir reached the crest of the dam before the simulated failure began. The CDR for Standing Rock Dam No. 1 (reference 4) states that the PMF will overtop the dam, but it is unknown to what height or for what duration. Since the combined spillway capacity is 16,358 ft^3/s and the safe downstream channel capacity through Bullhead is probably less than 5,000 ft^3/s, incipient flooding will occur in town at some unknown value of spillway discharge (i.e., reservoir elevation) before the dam is overtopped.

Flood travel times from Standing Rock Dam No. 1 to Bullhead range from 5–15 minutes for the flood’s leading edge and about 30–35 minutes for the peak discharge (references 4 and 5). If an EWS is installed, it must be accurate and reliable and must be used with an effective EAP.

The streambed below Standing Rock No. 1 Dam joins the channel of Rock Creek about halfway between the dam and town. The Rock Creek drainage is much larger than that of Standing Rock Dam and has been known to produce high runoff and come out of its banks on occasion, requiring some downstream evacuations. For comparison, the PMF peak discharge for Rock Creek is 152,000 ft^3/s, and the flood volume is 92,000 acre-feet (reference 6). If the Standing Rock Dam reservoir receives large inflows from an intense rain or snowmelt event, it is possible that Rock Creek will also experience high water, potentially exacerbating the effects of any dam releases downstream in Bullhead.

Potential Failure Modes

Potential failure modes at Standing Rock Dam No. 1 are discussed in the CDR for the dam (reference 4). During normal operations, piping and internal erosion due to seepage through the embankment and/or the foundation could breach the structure and release the reservoir. This is possible anywhere the embankment material is internally unstable to piping erosion. This is most likely to occur along the outlet works conduit or the principal spillway conduit. All other factors being equal, the outlet works conduit is the more likely of the two because of the greater reservoir head and seepage gradients that exist there. It is also remotely possible for piping to occur through the dam foundation, from the embankment into the foundation, and due to displacement at joints of the outlet works and spillway conduits.

Even though the dam has been rehabilitated to pass a flood of up to 60 percent of the PMF, overtopping from an extreme hydrologic event would likely result in catastrophic failure. Lesser magnitude floods that would require use of the auxiliary or emergency spillways could cause erosion of the training dike walls and/or the unlined channels of either spillway.

Lastly, seismic events, while not of sufficient energy in this area to threaten the embankment directly, could produce deformation and cracking of the embankment slope or displacement of the outlet works or principal spillway conduits to allow piping in either or both features. If seismic shaking of sufficient intensity occurred, the outlet works control tower and gates could be damaged, leading to failure and uncontrolled release (limited by the conduit discharge capacity) of the reservoir contents. This could lead to some downstream flooding.

EWS Design and Cost Estimates

An EWS was installed at Standing Rock Dam about 12 years ago. Apparently, there were persistent phone connection difficulties. It is presently reported to be inoperable; however, a Tribal staff member stated that it still occasionally autodials the Tribal SOD Office in Fort Yates, North Dakota. It appears that the original hardware is still installed in the gatehouse and wet well chamber. The EWS autodialer was designed to call the Tribal SOD Office when the reservoir elevation reached and exceeded the principal spillway crest elevation, 1829.8 feet. An AC power utility cable and telephone line are routed in the dam embankment out to the gatehouse. A siren was also installed on a 70-foot steel pole in Bullhead and is currently used as a community clock that operates at set times each day.

If a new EWS is installed at Standing Rock Dam No. 1, it is recommended that a method of monitoring the reservoir level in real-time be made a priority as it was for the existing inoperable system. There should also be redundant backup indicators for the occurrence of high operational spillway discharges that can cause downstream flooding and for reservoir levels that threaten overtopping of the embankment. The system would include a SDX satellite telemetry station at the dam with a data logger, a pressure transducer installed in the reservoir, and two float switches – one set at a reservoir elevation indicating a certain spillway discharge and the second set 1 foot or less below the dam crest.

A float switch site is recommended downstream from the dam beyond the discharge and seepage ponds. This site should have two float switches and would provide downstream monitoring of piping or breach flows from the embankment. If the downstream float switches are hard-wired to the SDX site at the dam, the cable run could be 200 feet or more, but there would be a slight cost savings over a stand-alone site using a radio frequency hop to the dam. However, a radio frequency site could be located further downstream if desired.

EWS data would be transmitted to the BIA NMC in Ronan, Montana, which would provide the full-time warning and monitoring capability for the dam. The same data could be routinely disseminated to Tribal and BIA SOD staff by way of e-mail, phone, fax, or by accessing a password-protected Web site.

The existing siren in Bullhead would add a valuable warning capability to the EWS. Experience shows that a completely automatic warning siren without any human interaction is a recipe for false alarms. Human-controlled remote activation could be achieved with a telephone or radio siren controller located in a facility staffed 24 hours a day, 7 days a week, such as a law enforcement and emergency medical dispatch center. There appears to be no round-the-clock facility in Bullhead, so the best location would probably be in Fort Yates, which is about 30 air miles from the siren location. A two-way controller that provides status reporting from the siren when polled would be the best configuration. A SCADA-type arrangement providing control by the NMC or Tribal staff through an SDX transceiver installed at the siren site is cost prohibitive.

Estimated costs for the EWS design as discussed are given in tables 6 and 7 for the two different downstream site options. Costs include equipment; building, programming and installing the EWS; and contractor travel. Estimates for the equipment, labor, and programming cost involved with a siren controller add-on are uncertain at this stage. We estimate it, generously we believe, at $10,000 and include this additional cost in tables 6 and 7. The total cost does not include Reclamation labor costs for project management and procurement support. These costs will be provided if the BIA requests Reclamation to provide a Phase 2 Project Plan for implementation of the EWS.

Table 6.—Standing Rock Dam cost estimates for EWS with hard-wired downstream site

Item	Cost ($)
Dam site equipment and installation: SDX 1100 transceiver, CR10X or equivalent data logger, comm. engine, one PT and cabling, two float switches and cabling, AC charger and battery, lightning arrestor, intrusion alarm, NEMA enclosure, miscellaneous cabling, and assorted mounting hardware.	18,000
Downstream site extension equipment and installation: Two float switches and cabling, intrusion alarm, and enclosure.	7,500
Setup, programming, and travel: EWS system build and programming, NMC interfacing, equipment preparation, shipping, and travel.	3,500
Siren automation	10,000
Total cost	39,000

Summary and Conclusions

The detection and warning systems recommended in this study should provide additional warning and evacuation times (where appropriate) in the event of extreme hydrologic or other failure modes for Prairie Dam No. 1 and Standing Rock Dam No. 1. At Prairie Dam No. 1, the recommended EWS design consists of (1) a reservoir elevation-monitoring sensor with one reservoir float switch near the dam crest, and (2) a float switch site with two float switches below the dam. With warning times of 1 hour or more (including the flood travel time), the EWS would provide SOD personnel and responsible local authorities at nearby Fort

Table 7.—Standing Rock Dam No. 1 cost estimates for EWS with radio hop downstream site

Item	Cost ($)
Dam site equipment and installation: SDX 1100 transceiver, CR10X or equivalent data logger, comm. engine, RF400, one PT and cabling, two float switches and cabling, AC charger and battery, lightning arrestor, intrusion alarm, NEMA enclosure, miscellaneous cabling, and assorted mounting hardware.	19,000
Radio hop downstream site equipment and installation: Two float switches and cabling, CR205, intrusion alarm, and enclosure.	8,000
Setup, programming, and travel: EWS system build and programming, NMC interfacing, equipment preparation, shipping, and travel.	4,000
Siren automation	10,000
Total cost	41,000

Yates, North Dakota, sufficient decisionmaking information to implement the actions specified in the EAP for notifying and protecting the inhabitants at the two downstream residences below the dam.

At Standing Rock Dam No. 1, the proximity of the town of Bullhead, South Dakota, 1 mile downstream, requires rapid notification of the PAR in case of hazardous operational spillway releases, embankment overtopping, or other failure modes. With continuous reservoir level monitoring, real-time detection of high inflows or piping-caused rapid drawdowns are possible. Two float switches installed in the reservoir, one at an elevation near the level of hazardous spillway discharges and the second near the dam crest, would provide redundant and specific alerting for these two critical points. A float switch site installed below the dam in a position to detect high flows from anywhere along the length of the embankment toe would provide direct measurement of breach or piping flows. The ability to activate the local siren system in Bullhead should be integrated into the EWS by adding a remote activation controller, probably best located in Fort Yates at an office or dispatch center staffed around the clock.

The BIA NMC’s 24-hour monitoring and notification capability is an essential component of both EWS designs. The data from each EWS would be transmitted through the SDX satellite system to the NMC, which would provide warning and notification to the responsible Standing Rock Reservation staff. If properly maintained, the systems should function reliably for an indefinite time. To be truly effective, the EWS must be incorporated as part of an overall Emergency Management System that includes an EAP and a Warning and Evacuation Plan.

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