RECLAMATION
Managing Water in the West

Water Operation and Maintenance Bulletin

No. 219

In This Issue . . .

U.S. Department of the Interior
Bureau of Reclamation

March 2007

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 *This embankment dam failed shortly after the reservoir was filled for the first time. Failure was attributed to internal erosion because of the short time required for seepage to develop and because the soils were not the type considered susceptible to backward erosion piping.*

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Identifying and Solving Problems with Embankment Dam Conduits: Best Practices

by Chuck R. Cooper[1]

Conduits through embankment dams are a potential source of failure and other serious incidents, particularly as they age and deteriorate. Knowing how these conduits were designed and built, as well as their potential failure modes and structural defects, can help owners identify and deal with potential problems.

Conduits that are part of an outlet works system provide controlled conveyance of water from a reservoir through, under, or around an embankment dam. Conduits can act as primary or service spillways, auxiliary or secondary spillways to help the primary spillway pass floods, or penstocks to generate electricity.

Tens of thousands of conduits through embankment dams in the U.S. are aging and deteriorating. Many of these conduits were built without the benefit of modern design and construction techniques and lacked proper quality control. As each year passes, deteriorating conduits pose a greater risk of developing defects that can lead to dam failure, with potential catastrophic results.

Case histories show that dam failures and accidents often are located near conduits. The contact area between a conduit and its surrounding earthfill and foundation is a potential pathway for seepage through the dam. During development of new dams, designers must consider the effect of the conduit and soil compaction around the conduit.

Various conduit materials have been used, including cast-in-place and precast concrete, thermoplastic and thermoset plastic, cast and ductile iron, steel, and aluminum. Water seeping through the embankment can enter the conduit if the conduit: is not pressurized and is damaged from loading, develops defects from corrosion, or experiences separation at joints. If the conduit is pressurized, water may escape under pressure and damage the surrounding embankment and foundation.

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How Conduit Design and Construction Affect Dam Stability

A conduit represents a discontinuity that can create differential settlement. Hydraulic fracture is common because conduits create differential strains and stresses in surrounding embankment soils. Hydraulic fracture often results in a separation in the soil mass, if the applied water pressure exceeds the lateral effective stress on the soil element. Soils that are compacted without optimum water content are more susceptible to hydraulic fracture. Hydraulic fracture can cause cracking of the earthfill and lead to dam failure.

Earthfill also may be compacted differently around a conduit than in the rest of the dam. This differential settlement may lead to arching and hydraulic fracture, which is the primary cause of cracks that can provide flow paths for internal erosion in earthen embankments. Internal erosion is a general term used to describe all of the various erosional processes where water moves internally through or adjacent to the soil zones of embankment dams and foundations, except for the specific process referred to as backward erosion piping. When paths develop through which water can flow and erode the earthfill, severe problems or breaching type failures often result. Because they are extremely erodible, dispersive clays have been responsible for failure of numerous embankments.

Until about the mid-1980s, the most common approaches for controlling seepage were antiseep (or cutoff) collars and careful compaction of backfill around conduits. Antiseep collars are impermeable diaphragms, usually sheet metal or concrete, constructed at intervals within the zone of saturation along the conduit to increase the length of the seepage path and minimize the potential for internal erosion or seepage along the conduit.

Antiseep collars were designed primarily to address intergranular seepage (flow through the pore spaces of intact soil). They do not fully address the often-more-serious mechanism of flow through cracks (internal erosion) in compacted earthfill near the conduits. In the 1980s, major dam design agencies – including the U.S. Department of the Interior's Bureau of Reclamation, Soil Conservation Service (now called the Natural Resources Conservation Service), and U.S. Army Corps of Engineers – stopped using antiseep collars.

Most modern dam designs include a zone of granular filter surrounding conduits that penetrate the embankment. Since these filter zones were adopted, few failures have occurred that can be attributed to internal erosion near conduits.

In addition to filter zones, cutoff measures are essential. Proper selection of backfill soils around the conduit, especially through the center zone of the dam, is important. Soils should be chosen based on plasticity and lack of dispersive character. Good construction practices, including control of placement water content, are essential for obtaining a high-quality contact between the conduit and the dam core. The type and configuration of the filter zone depend on site conditions and soils used in the dam.

Filters used in conjunction with conduits through embankment dams fall into three categories:

1. *Chimney filter*. This filter serves several functions, including lowering the phreatic line (planar surface between the zone of saturation and zone of aeration) and protecting the embankment from transverse cracks. Conduits through the embankment will intersect the chimney filter (often located immediately downstream from the dam's core), which serves as a filter for the conduit as well as functioning as a chimney filter and drainage zone for the entire embankment. Embankments with a chimney filter usually do not require additional protective filter zones for the conduit.

2. *Filter diaphragm*. This diaphragm is a zone of filter material constructed around a conduit. The filter diaphragm will intercept both intergranular flow through the earthen embankment and flow through cracks in the earthfill or along the conduit-earthfill interface. This zone can act as a drain to carry off water and as a filter to intercept soil particles in the water. Filter diaphragms are used in embankment designs that do not include a full chimney filter. (See Figure 1.)

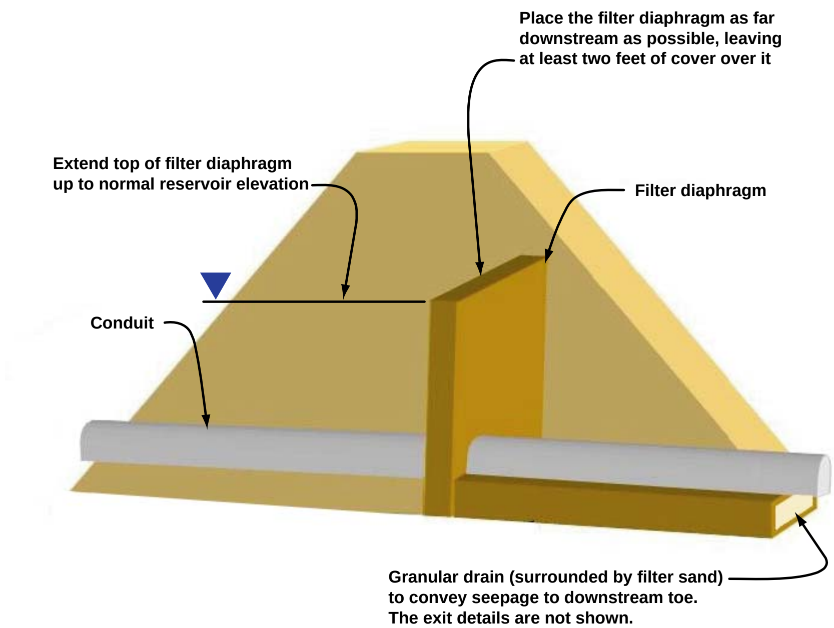

Figure 1.—For the typical configuration of a filter diaphragm used in an embankment dam, the filter diaphragm should be located as far downstream as possible, leaving adequate cover over it.

3. *Filter collar*. This collar consists of a zone of filter material (usually sand) that completely surrounds the conduit in an annulus shape. This type of filter most often is used for smaller embankment dams and levees. A filter collar is recommended only if the flow is likely to be solely along the contact between the conduit and the surrounding earthfill, and the embankment soils are not dispersive clays.

Potential Failure Modes

Each material used to build conduits reacts differently in buried applications. Structural defects can develop from abrasion, aging, cavitation, corrosion, poor design, and poor construction technique. For example, leakage can occur at bell and spigot joints in precast concrete pipe. For steel pipe, buckling collapse or pinhole leaks are possible.

Failure of this embankment dam resulted from internal erosion of earthfill near an outlet works conduit. The embankment soil contained dispersive clay fines, and the dam's design included antiseep collars, but no filter diaphragm.

Conduits can experience one of four failure modes:

1. *Backward erosion piping or internal erosion of soils into a nonpressurized conduit*. The interior pressure of the conduit is presumed to be lower than the seepage pressures in the surrounding soil. In this mode, the conduit is surrounded over at least part of its length by soil with low resistance to backward erosion piping or internal erosion. Backward erosion piping is characterized by the formation of an open tunnel that initiates at an unprotected downstream seepage exit point and progresses back upstream toward the reservoir. If the conduit develops a defect or a joint becomes open from movement, seepage forces in the surrounding soils may carry soil particles into the conduit. In other cases, the surrounding soils may hydraulically fracture, and internal erosion of particles into the conduit can occur.

This embankment dam failed shortly after the reservoir was filled for the first time. Failure was attributed to internal erosion because of the short time required for seepage to develop and because the soils were not the type considered susceptible to backward erosion piping.

2. *Backward erosion piping or internal erosion of soils by flow from a pressurized conduit*. When the conduit is flowing under pressure, interior pressure can exceed exterior pressure. The high-pressure flow can exit through defects in the conduit walls or at the joints. The pressurized water begins to exert hydraulic forces on the embankment soils. This is usually more serious than failure mode 1.

3. *Backward erosion piping or internal erosion of soils outside a conduit caused by hydrostatic forces from the reservoir*. Water flows along the interface between the conduit and surrounding earthfill. This failure mode usually is associated with embankment seepage through the soils surrounding the conduit. The seepage along the conduit-soil interface may be concentrated enough to result in backward erosion piping, if the soils are susceptible. This mode is similar to failure mode 2, except for the source of water.

4. *Internal erosion of hydraulic fracture cracks in the earthfill above, below, or adjacent to the conduit*. Conduits are one of the primary causes of differential settlement of an embankment dam that can result in hydraulic fracture. When a pathway is created along which water from the reservoir

can flow easily and erode the soil in contact with the crack, failure can occur. This mode differs from failure mode 3 because the seepage pathway for internal erosion forms at a location away from the soil-conduit interface.

Methods to Identify and Evaluate Conduit-Related Problems

To avoid catastrophic results from failure of a conduit, dam owners need to know methods that can identify defects before they cause irreversible damage. These include an inspection program, instrumentation and monitoring, and geophysical and non-destructive testing.

Inspection Program

Structural defects and deterioration develop over time, but situations can arise suddenly that cause serious damage quickly. An experienced inspector can identify defects and problems before conditions become serious. Periodic inspection may reveal trends that indicate more serious problems are developing. Situations that call for immediate inspection include times when the system is at full discharge capacity or seismic activity occurs.

Visual observations by the dam owner and/or the owner's engineer may be the most important method of monitoring the performance of a dam or an emergency situation. Personnel should visually inspect the dam at each site visit or when making

New Manual Available

A technical manual titled *Conduits through Embankment Dams — Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair* is available. The Federal Emergency Management Agency (FEMA) published the manual, with support from the National Dam Safety Program. Representatives from the Association of State Dam Safety Officials, U.S. Department of the Interior's Bureau of Reclamation, Federal Energy Regulatory Commission, Natural Resources Conservation Service, and the U.S. Army Corps of Engineers developed the contents of the manual.

The purpose of the manual is to condense and summarize the vast body of existing information, provide a clear and concise synopsis of this information, and present a recommended course of action. The manual is intended for use by personnel familiar with embankment dams and conduits, such as designers, inspectors, construction oversight personnel, and dam safety engineers.

The free manual – available in print copy (FEMA 484), CD-Rom (FEMA 484CD), and DVD (FEMA 484DVD) – contains more than 280 illustrative figures, 34 case histories, and an in-depth glossary.

The CD-Rom and DVD have built-in Adobe Acrobat Reader software, hyperlink, and search capabilities. The CD-Rom and DVD also contain pdf copies of all references cited within the manual that are available in the public domain or where reprint permission was obtained.

The DVD has a collection of more than 150 "additional reading" references in pdf format. These references are included to assist the user in furthering their understanding of conduits and embankments dams.

Copies of the manual may be obtained by calling FEMA's Publication Distribution Center at (1) 800-480-2520.

instrumentation readings. The results of the inspection should be properly documented, so any changes over time can be readily detected.

Selecting the most appropriate method for conduit inspection depends on accessibility, importance of the conduit, and degree of risk presented (i.e., threat to life, property, and environmental damage). Factors influencing accessibility include reservoir operations and water levels, confined spaces, or other limitations that may require specialized inspection services.

Specialized inspection services include:

- *Dive team.* Intake structures, conduits, and terminal structures that normally are submerged or inundated require underwater inspection. Factors to consider in any dive inspection include depth, altitude, access, leakage, currents, visibility, size, and length.

- *Remotely operated vehicle (ROV).* An ROV is a good alternative when conditions such as depth, diameter, or length restrict physical access to the conduit. The ROV can be used to inspect the submerged portions of intake structures, conduits, and terminal structures.

- *Closed circuit television (CCTV).* CCTV can be used to inspect the submerged portions of intake structures, conduits, and terminal structures. CCTV is an inspection alternative in situations where confined space entry issues may require Occupational Safety and Health Administration (OSHA) permitting.

Instrumentation and Monitoring

Instrumentation in a conduit or dam furnishes data to determine if the structure is functioning as intended and provides warning of developments that could signal problems for the structure. Instruments and procedures range from simple (e.g., strain gages) to complex (internal displacement monitoring systems consisting of baseplates, inclinometers, tiltmeters, and extensometers). The need for instrumentation for monitoring potential and/or existing dam deficiencies must consider the hazard classification, complexity of the conduit and dam, extent of the deficiency being monitored, and size of the reservoir.

Geophysical and Non-Destructive Testing

Geophysical and non-destructive testing techniques can be used to investigate the condition of a conduit and embankment dam. These techniques are used to detect flaws, defects, deterioration, and other anomalies that could lead to a dam failure, and they do not disturb the feature being tested. The most common techniques include: seismic tomography, self potential, electrical resistivity, ground-penetrating radar, sonar, ultrasonic pulse velocity, ultrasonic pulse echo, radiography, and mechanical and sonic calipers. Depending on the situation, some techniques are more effective than others.

Methods for Renovating, Repairing, Replacing, or Abandoning Conduits

If the condition of a conduit deteriorates, operational performance or safety of the dam may be compromised. Several corrective actions are available:

- *Renovation*. Renovation of the conduit using trenchless methods, rather than traditional removal and replacement, has become popular. Sliplining of existing conduits, which involves pulling or pushing a pipe of smaller diameter into the conduit and grouting the annulus, is the most common renovation method. Flexible plastic and steel pipe has been successfully used for sliplining.

Sliplining of existing conduits is the most common renovation method. At this dam, a high-density polyethylene plastic slipliner is being inserted into an existing corrugated metal pipe outlet works conduit.

- *Grouting around conduits*. Grout can be used to fill voids created by internal erosion and to reduce future settlements. However, grouting around conduits is not recommended as a long-term solution to prevent internal erosion. Grouting is seldom 100 percent effective in intercepting flow paths adjacent to the conduit, and seepage gradients in the "windows" in the grout may actually be higher than the gradients before grouting. A filter diaphragm or collar or other positive means should be used in conjunction with grouting to prevent internal erosion. Water often can penetrate cracks that cannot be grouted closed.

- *Remove and replace*. If the conduit is severely deteriorated, removal and replacement may be the only technically feasible solution. However, installing a new conduit can be time-consuming and expensive. Typically, costs for removal and replacement may be five to ten times higher than for the sliplining renovation method, depending on the height of the embankment dam. Construction costs rise rapidly as the height of the embankment increases. A filter diaphragm or collar around the downstream portion of the conduit should be used whenever a new conduit is installed.

- *Repair techniques*. Concrete used to build modern conduits is very durable and, if properly proportioned and placed, will provide a long service life. To ensure a successful repair, the cause and extent of the damage must be determined; the proper repair technique must be selected; and the proper preparation, application, and curing must be performed.

- *Abandonment of conduits*. Abandonment should be considered for badly deteriorated conduits that no longer serve their intended design purpose. The most common method used to close an abandoned conduit is by injection of grout or tremie concrete.

Conclusion

A conduit through an embankment dam serves a vital role in the successful operation of the facility. However, history has shown that conduits are often overlooked, due to their low visibility as a buried and submerged structure. If a conduit develops a problem, this can lead to an increased risk of dam failure and catastrophic consequences to populations living downstream. All personnel associated with the design and construction of new dams or the care and oversight of existing dams need to understand the varied aspects involved with conduits through embankment dams.

Reference

Conduits through Embankment Dams — Best Practices for Design, Construction, Problem Identification and Evaluation, Inspection, Maintenance, Renovation, and Repair, FEMA 484, Federal Emergency Management Agency, Washington, D.C., September 2005.

Water Production for Emergency Response – Expeditionary Unit Water Purifier Proven in Hurricane Duty

by Drew Downing[1] and Michelle Chapman[2]

During the summer of 2005, the Bureau of Reclamation (Reclamation) Water Treatment and Engineering Group (86-68230) was busy testing a brand new Expeditionary Unit Water Purifier (EUWP) when a call from the Office of Naval Research came in just before Labor Day to pick up the purifier and get it down to the Gulf Coast as quickly as possible. At the time, the team was conducting field work near Salt Lake City, but by Tuesday of the following week, we were enroute to Jackson, Mississippi.

The EUWP was born as a congressional add-on to the Office of Naval Research (ONR) budget in 2003. ONR's mandate was to develop a C-130 transportable water production unit capable of producing 100 kgal of potable water per day from most any source. The first criterion limits the size and weight of the equipment to 40' x 8' x 8' and less than 32,000 pounds. The criterion of treating any source of water includes the ability to purify water contaminated with chemical or biological toxins. ONR took advantage of the combined expertise of the Interagency Consortium for Desalination and Membrane Separation Research to identify state-of-the-art technology to pack maximum productivity into the minimum footprint. The key features of the unit are the innovative membrane configuration that reduced the number of modules needed; an energy recovery device to reduce the size of the high pressure pump; and incorporation of higher productivity ultrafiltration (UF) membranes. The unit was designed to the team's specifications and built by Village Marine Tec of Gardena, California, chosen for their proven track record of fitting high quality water treatment systems into small, irregular spaces in ships. Two units were built—one was signed over to Reclamation, while the second is kept at the Naval Facilities Engineering Service Center at Port Hueneme, California.

Reclamation received the first unit in June 2005 and was concluding a test period on groundwater at Alamogordo, New Mexico, when Hurricane Katrina hit the Gulf Coast. With the prompt assistance of Reclamation's Socorro Field

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Office to help with shipping, we were able to get the first unit to Biloxi, Mississippi, to mobilize within 1 week of the call. Operators from the Water Treatment and Engineering Group cleaned and packed the unit in record time.

Two Locations, One Mission

Meanwhile, the Jackson, Mississippi, Federal Emergency Management Agency (FEMA) team identified the Biloxi Regional Medical Center as the highest priority for water production capacity. The recognizance team, made up of representatives from Reclamation and the U.S. Army Tank Automotive Research and Development Engineering Command (TARDEC), visited potential sites for deployment. At that time, the medical center was operating with non-potable water from a municipal well at a cost of $100,000 per week, delivered by a convoy of water trucks that filled the streets and available parking areas. There was no water pressure in the lines, and no well within reach; however, the Mississippi Sound was right down the street. Without delay, the Reclamation unit was deployed 4 blocks south of the hospital at the Hard Rock Casino, located between Route 90 and the Mississippi Sound. The open intake system was deployed directly into the Sound, which had a salinity level ranging from 10,000 to 20,000 milligrams per liter of total dissolved solids (TDS) and a turbidity ranging from 8 to 16 nephelometric turbidity units (NTUs) depending on the tides. By the afternoon of September 10, the EUWP had 10,000 gallons of super-chlorinated potable water in a storage bag ready to pump to the hospital. With a bit more help from the Mississippi Department of Transportation in constructing an asphalt ramp over Route 90 to protect the distribution line, and from local plumbers in putting in the distribution line, the EUWP was ready to deliver the water to sanitize the hospital by September 12.

Operating 24 hours per day over the next several weeks, the EUWP met the 72,000-gallon-per-day demand of the Biloxi Regional Medical Hospital—even through the battering of Hurricane Rita. While operating from the Mississippi Sound, the EUWP maintained an average TDS rejection of 98.8 percent and produced approximately 700,000 gallons of potable water. The intake system and UF process used 2.3 kWh/kgal (270 gpm feed), and the reverse osmosis (RO) process used 7.44 kWh/kgal (160 gpm high pressure pump only). After Hurricane Rita, the unit was re-deployed in the Medical Center parking lot and operated on city water – available but still not certified – until October 6 when the unit was officially released by FEMA.

The TARDEC team brought the second EUWP along with three smaller military units from Warren, Michigan. After ensuring that the Biloxi EUWP site was operational, the TARDEC team turned their attention to setting up the second EUWP at the Port of Pascagoula. The mission in Pascagoula was to provide potable water to the Carnival Cruise Ship – The Holiday, which was scheduled to arrive at the port to assist in relief efforts. The ship was leased by FEMA with the intent to house displaced persons in Pascagoula, allowing them to be closer to their destroyed homes.

On September 11, the team met at the port and offloaded the EUWP onto an abandoned wharf. The port's water treatment system was not operational and was not expected to be running for 30–60 days. In order for the cruise ship get authorization to dock in Pascagoula, a potable water source had to be available. By September 12, TARDEC had setup the EUWP and had purified water in the EUWP's storage bags, using the Pascagoula River as the water source. The river, under a tidal influence at the EUWP location, had a salinity level ranging between 21,000 and 39,000 microSiemens per centimeter (µS/cm) during the operation. TARDEC used an open intake system that was dropped over the wharf's edge, which resulted in an average turbidity of five NTUs.

The Water Purifier

The EUWP is a mobile water purification system capable of purifying, storing, and dispensing water that meets the military's Tri-Service Field Water Quality Standards for short- or long-term consumption (up to 1 year) from any water source (fresh, brackish, saline and nuclear, biological, or chemical [NBC] warfare agent contaminated). The system is ideally suited to support civilian agencies during emergencies, disaster relief, humanitarian efforts, and nation building efforts. The EUWP can be deployed by a four-person team in 4 hours and can operate around the clock by two, two-person teams.

The EUWP can produce up to 200,000 gallons per day (GPD) of potable water from fresh water sources that contain less than 1,000 mg/L TDS and 100,000 GPD from sea or brackish water sources that contain less than 45,000 mg/L TDS. The EUWP, including all the equipment necessary to intake, produce, and store water, is configured on two 8' x 8' x 20' International Organization for Standardization (ISO) platforms. Each platform, also known as a skid, weighs approximately 15,200 pounds. The unit is equipped with a 60-kilowatt, diesel-powered generator and has a 40,000-gallon water storage and distribution system. There is an optional electrical conversion kit that allows the unit to be operated from a power distribution grid.

The Process

The purification process starts at the intake structure. An anchored floating strainer is used to maintain the intake above the bottom and below the surface of the water source. An electric pump delivers 300 gallons per minute (gpm) of raw water through an Amiad 200-micron backwashable strainer to a 3,000-gallon break tank. Optional ferric chloride injection can occur just before the break tank for enhanced filtration. The break tank is sized to allow for the necessary backwash volume while maintaining a minimum intake line and pump size. The electric UF pump then delivers 260 gpm of raw water to 16 Koch Membrane Systems Targa UF cartridges, which have a molecular weight cut-off of 100,000 Daltons. The UF polysulfone membranes, housed in 10-inch-diameter by 48-inch-length cartridge, are in a hollow fiber configuration (0.9 mm diameter inside-out flow). The UF process uses a cross-flow configuration and is designed for a normal operating flux of 40 gallons per square foot per day. Under the cross flow condition, 10 percent of the feed stream is wasted in order to reduce membrane fouling. Every 20 minutes, the UF system automatically backwashes for 3 minutes at a rate of 640 gpm to remove the solids and micro-organisms from the membrane. This backwash process reduces the overall UF system recovery to 82 percent. The UF filtrate is then pumped to a 3,000-gallon RO break tank. The volume in this tank allows for a continuously operating RO process even during the UF backwashing cycle. Sodium metabisulfite can be injected prior to the RO skid if there is a desire to operate on chlorinated feed waters.

The EUWP is capable of operating in a single or two pass mode when operating on highly contaminated or NBC agent contaminated waters. The first pass is a 3 x 8 array, with 24 8-inch RO elements, and the second pass is a 2 x 4 array followed by a 1 x 4 with 12 8-inch RO elements. The electric RO feed pump delivers 175 gpm to the RO skid where an antiscalant is injected prior to the water being separated into two streams. Two-thirds of the water is fed to the high-pressure pump, and one-third to a pressure exchanger. The RO feed water is pressurized by the RO high pressure pump and flows through the 2 x 8 RO element array. The brine from this array is then directed to the pressure exchanger and used to pressurize the other RO feed stream. The high-pressure flow from the pressure exchanger is directed to the 1 x 8 RO element array.

The first pass of the EUWP consists of a hybrid configuration incorporating RO elements with various fluxes. Elements in positions one and two in the first three arrays are occupied by Filmtec SW30HR LE-400 standard high rejection seawater elements with a flux of 7,000 gpd and a rejection of 99.8 percent. Elements in positions three and four are occupied by Filmtec SW30XLE-400 seawater elements with a flux of 9,000 gpd and a rejection of 99.7 percent. Elements in positions five through eight are occupied by an experimental Filmtec element, SW30HR-12000, with a flux of 12,000 gpd and a rejection of 99.7 percent. This hybrid configuration normalizes the water production over the entire RO element train thus reducing fouling and decreasing the number of RO elements required to meet the rated water production.

The EUWP is rated at 100,000 GPD when operating at 77 degrees Fahrenheit and 35,000 mg/L TDS feed. The EUWP is capable of operating at 1,200 pounds per square inch, allowing it to produce potable water from source waters with a 60,000 mg/L TDS, but at a reduced capacity. The first pass system is designed for a recovery of 50 percent.

If the source water contains a contaminant of dire concern, such as NBC or cyanide, a second pass array is available for added protection. The filtrate from the first pass is combined and pressured by an 87 gpm electric centrifugal pump. The feed is processed through a 2 x 4 array followed by a 1 x 4 array, for a total of 12 Filmtec BW elements. The second pass system is designed for a recovery of 87 percent. Chorine is injected into the RO product water prior to storage in either of two 20,000-gallon collapsible storage tanks.

The EUWP is designed to produce potable water from seawater and highly contaminated source waters. The multiple unit processes provide a level of redundancy and safety. Whether or not the water produced by the EUWP will always meet every water quality standard is dependent on the initial concentration of the contaminant in the feedwater and the environment in which it is operated. Rest assured, the EUWP was designed to remove NBC contaminants at very high threat levels and, therefore, should be very reliable at producing safe, clean water under almost any condition. Operation of the EUWP is through a programmable logic control and a series of sensors, alarms, and automatic shutdown devices. The product water is constantly monitored to ensure that the system is operating effectively, but more importantly, to make sure the water is safe to drink.

The Team

Many people are responsible for the success of this effort – Bureau of Reclamation associates Michelle Chapman, John Walp, Saied Delagah, John Shaffer, Kevin Price, Susan Martella, Harry Remmers, Dan Gonzales, and Alex Goloskewitsch, and U.S. Army TARDEC associates Mark Miller, Bob Shalewitz, Kevin Oehus, Jeremy Walker, Don Roberts, Scott Nielsen, Mark Silbernagel, and Keith Hutchinson. A special thank you goes to Mike McCain and Steve Yoshimura of Village Marine Technology, Inc., and Carl Behrens and Casey Jaworski from the Southeast Desalination Association. These individuals helped operate both EUWP units and were instrumental to the success of this mission.

Figure 1.—Biloxi Regional Medical Center.

Figure 2.—Hard Rock Casino pool area – operations site.

Figure 3.—Offloading donated by Roy Anderson Corp.

Figure 4.—Extending the intake to the end of the pier – plumbing donated by Ivey Mechanical.

Figure 5.—Mississippi Department of Transportation building a ramp over the distribution line.

Figure 6.—Fully operational UF skid to the right, RO skid to the left, UF feed tank, and 20-kgal product storage tank and makeshift kitchen in the front.

Figure 7.—Additional storage at the hospital – 3 6-kgal trucks and another 20-kgal bladder.

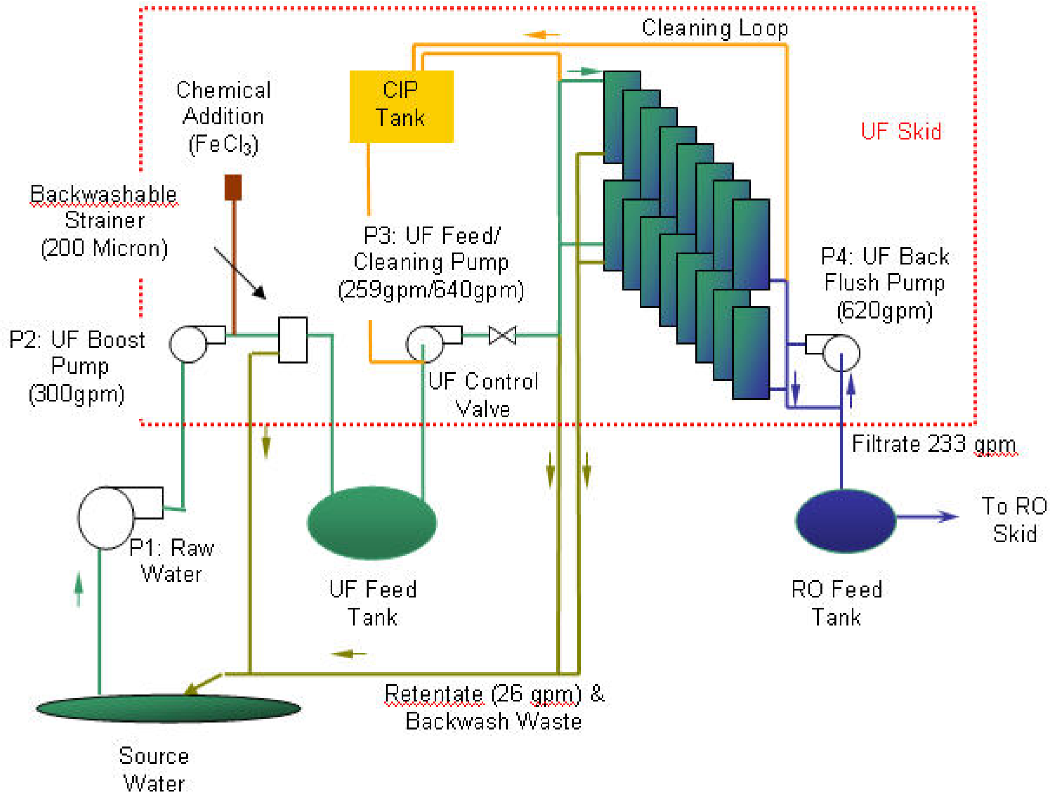

Figure 8.—UF process schematic.

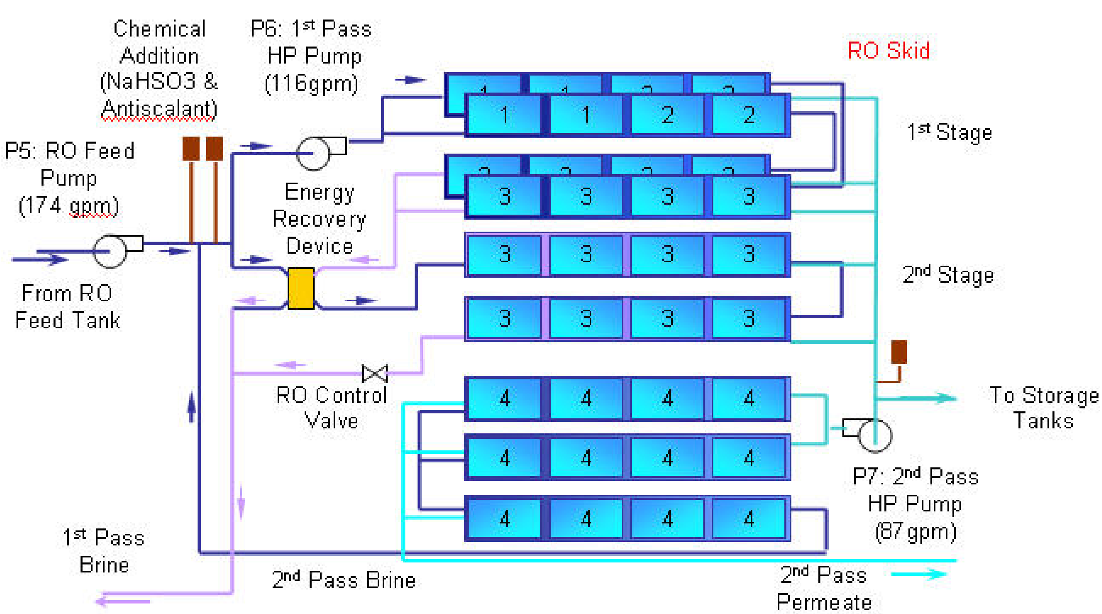

Figure 9.—RO system schematic with FilmTec Membranes: (1) SW30HR LE-400, (2) SW30XLE-400, (3) SW30HR-12000, and (4) BW30.

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

The purpose of this bulletin is to serve as a medium of exchanging operation and maintenance information. Its success depends upon your help in obtaining and submitting new and useful operation and maintenance ideas.

Advertise your district's or project's resourcefulness by having an article published in the bulletin—let us hear from you soon!

Prospective articles should be submitted to one of the Bureau of Reclamation contacts listed below:

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