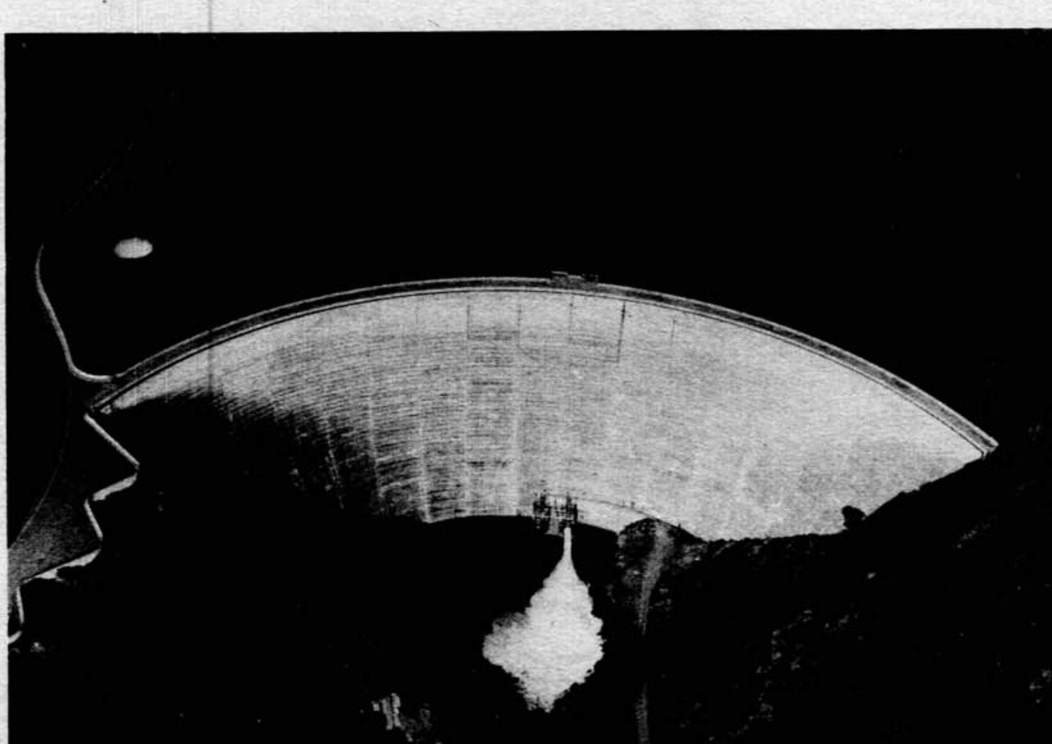
WATER OPERATION AND MAINTENANCE

BULLETIN NO. 128

JUNE 1984



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UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

The Water Operation and Maintenance Bulletin is published quarterly for the benefit of those operating water supply systems. Its principal purpose is to serve as a medium of exchanging operation and maintenance information. It is hoped that the reports herein concerning laborsaving devices and less costly equipment and procedures will result in improved efficiency and reduce costs of the systems for those operators adapting these ideas to their needs.

To assure proper recognition of those individuals whose suggestions are published in the bulletins, the suggestion number as well as the person's name is given. All Bureau offices are reminded to notify their Suggestions Award Committee when a suggestion is adopted.

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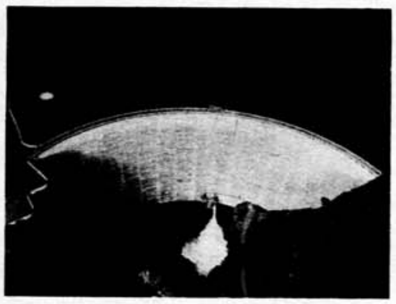

Cover photograph:

Monticello Dam, Solano Project, California. Aerial view looking upstream at Monticello Dam and Lake Berryessa on Putah Creek near Winters, California. The dam is an arch-type concrete structure 304 ft (92.7 m) high with a crest length of 1,023 ft (311.8 m). It stores surplus water for irrigation, municipal, and industrial purposes in the project service area.

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WATER OPERATION AND MAINTENANCE
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June 1984

INTRODUCTION

A detailed description of the deteriorated condition and repair process of two hollow-jet valves at Monticello Dam, starts on page 1. This is an excellent article on the steps taken to obtain satisfactory repair of damaged cast iron material.

Use of large square concrete stilling wells, instead of round pipe stilling wells, in a lateral of the East-Columbia Basin Water District has provided improved conditions for obtaining accurate water measurements, see page 15. For measuring flow in small laterals, they are using a portable calibrated slide gate, see page 16.

Bucket seats provide softer rides, see page 17.

REBUILDING THE HOLLOW-JET OUTLET VALVES AT
MONTICELLO DAM, SOLANO PROJECT
by
Richard Fairall,[1] Harold Task,[2]
Tom Simms,[3] and Clifford Quinton[4]

Extensive cavitation damage to the two hollow-jet valves at Monticello Dam, Solano Project, California, was noted when the valves were examined in June 1980. The damage included a 3-in (76-mm) diameter hole in one of the splitters, a 5-in-long by 2-in-wide (127-mm-long by 50-mm-wide) gouge in another splitter, a small hole which penetrated the 1-1/2-in (38-mm) thick cast iron body, and severe damage to both metal seats. The valves were installed in 1954; the first use was in 1958.

Because of the deteriorated condition of the valves and the probable losses resulting from a failure, the decision was made to repair both valves to original or better than original condition.

A description of the known and probable condition of the valves was included with a statement of the repair to be performed in a request for proposal. The lowest qualified bidder was selected, the first valve was repaired, and is operating satisfactorily. The second valve is now being repaired by the same contractor.

The article describes in detail the condition of the valves, the operation and maintenance problems which dictated the repair sequence and schedule, the welding, fabrication, and testing problems and solutions, and a summary of the lessons learned from the experience which will be applicable to similar future valve repairs.

Introduction

This article will describe the repair of two 54-in (1375-mm), hollow-jet valves which were installed in Monticello Dam, Solano Project. Two 60-in (1525-mm), pivot valves, which are used as guard gates for the hollow-jet valves, were also repaired. Because there is too much operation and maintenance material to be included in one article and because the hollow-jet valve is more widely used than the pivot valve, the material on the pivot valve is not included here.

Monticello Dam, located on Putah Creek, is a medium-thick-arch concrete structure with a crest of 1023 ft (311.8 m), a structural height of 304 ft (92.7 m), and an axis of 500 ft (152.4 m). See figure 1. Two river outlets are provided through the dam, each 90 in (2275 mm) in diameter, and each controlled by a 54-in (1375-mm), hollow-jet valve. The 60-in (1525-mm) guard valves installed immediately upstream from the hollow-jet valves are for emergency closure. One 9.68- by 9.68-ft (2.950- by 2.950-m) bulkhead gate is provided for use on either outlet pipe at the bellmouth intakes to unwater the outlet pipes when required. The hollow-jet valves were manufactured to Bureau designs and specifications in San Francisco in 1953.

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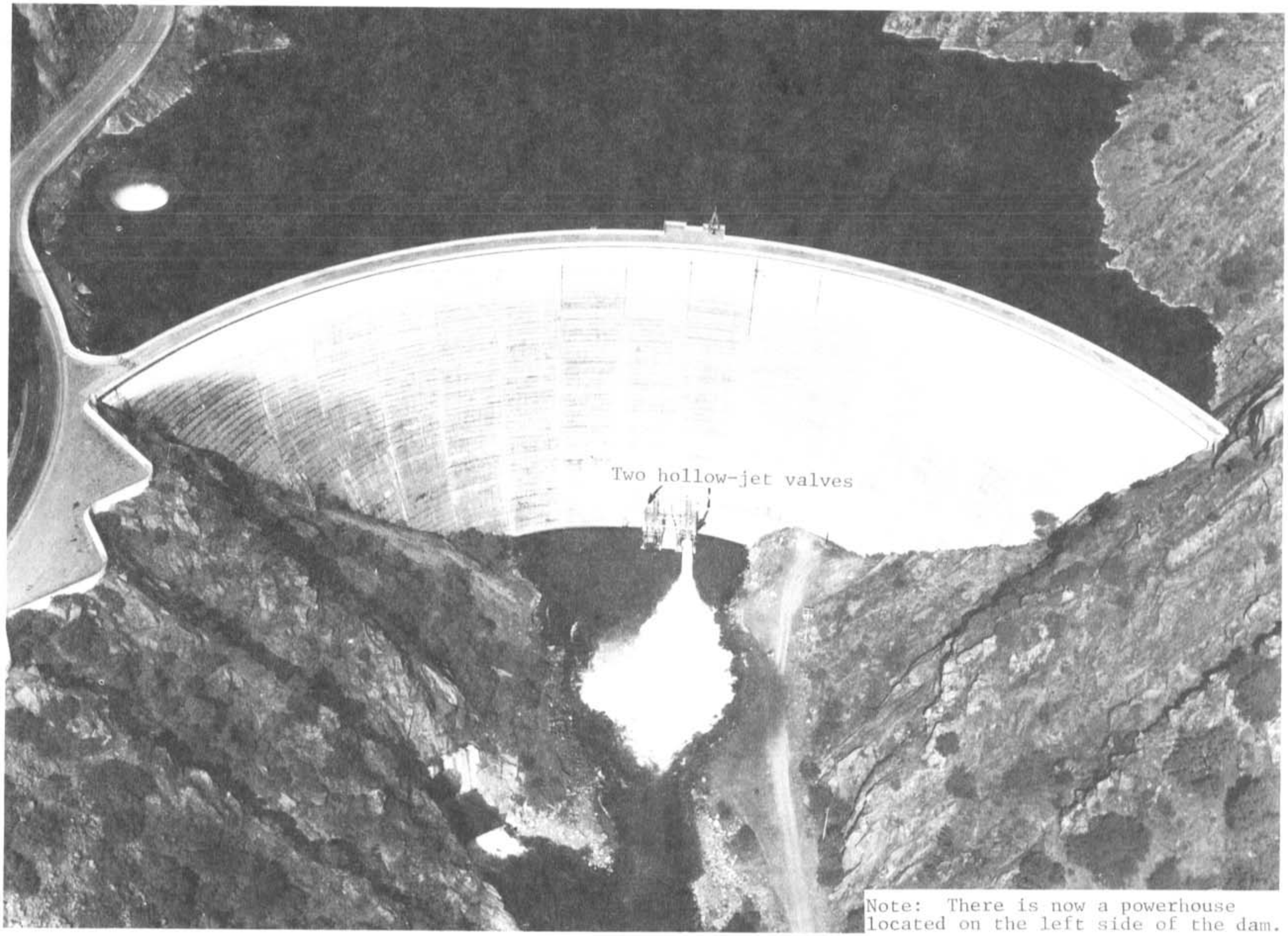

Figure 1. Monticello Dam, Solano Project.

The discharge of the valve is regulated by a needle moving axially within the valve. A control screw placed inside the needle along the valve centerline is used to move the needle. The screw is driven through a coupling and bevel gears by the control stand. When the needle is moved to the upstream end of the valve, it seats and closes the valve. When closed, there is no water in the valve body, except in the balancing chamber of the needle. As the valve is opened, the water flows past the periphery of the needle in the shape of a cylindrical ring along the inside of the valve body. This cylindrical ring of water is cut into sectors as it passes the ribs and splitters, which support the needle. Atmospheric pressure is maintained in the interior of the ring inside the valve through the openings between the sectors of water leaving the splitters. The water discharges from the valve in the shape of a hollow cylinder made up of eight separate jets.

Balancing holes are drilled through the upstream face of the needle to allow water from the outlet pipe to enter its interior and counterbalance about 87 percent of the force of the water acting in a downstream direction against the needle.

Extensive cavitation damage was noted when the valves were examined in June 1980. The damage to valve No. 1 included a 3-in (76-mm) diameter hole in one of the ribs, a 5-in-long by 2-in-wide (127-mm-long by 50-mm) gouge in another splitter, a small hole which had penetrated the 1-1/2-in (38-mm) thick cast iron body, and severe damage to both metal seats. Valve No. 2 was in similar condition. The valves were installed in 1954 and first used in 1958. See figures 2, 3, 4, 5, 6, and 7.

The valve body is gray cast iron; needle support is cast steel; needle is cast steel; body seat is "K" Monel; needle seat is bronze; seals are leather, rubber, and neoprene; paint is vinyl resin (Bureau VR-6) and miscellaneous commercial paints.

The important weights are as follows: Body – 11 000 lbs (4990 kg), needle – 5000 lbs (2270 kg), needle support – 3400 lbs (1540 kg), and valve assembly (without operator) – 25 000 lbs (11 340 kg). The maximum head the valves will ever experience is 258 ft (78.64 m). The maximum flow is 1250 ft^3/s (35.4 m^3/s) each.

Requirements for the Rebuilt Valves

Because of the badly deteriorated condition of the valves and the probable losses resulting from a structural failure, the decision was made to repair both valves to original or better than original condition.

The repair was accomplished by the Groth Equipment Company, Houston, Texas, under the direction of the Bureau's Sacramento Office. Quality control was performed by the Bureau's Equipment Installation and Inspection Branch, E&R Center, Denver.

The valve designers in the Gates and Valves Section, E&R Center, were consulted in an effort to find a solution to cavitation problems. The suggestions by the designers were accepted, and the Design Branch changed the needle seat to stainless steel and recontoured the body splitters, ribs, and shell. The surface finish on the repaired areas was also finished to a 250-root-mean-square texture.

Shop tests specified to be conducted on the valve, after it was repaired, were the same as those specified in 1953 on the new valve. Pass-fail criteria are also the same: Proof pressure, 125 lb/in^2 (860 kPa) for 1 hour. Leakage shall be no more than a trace when the valve is closed.

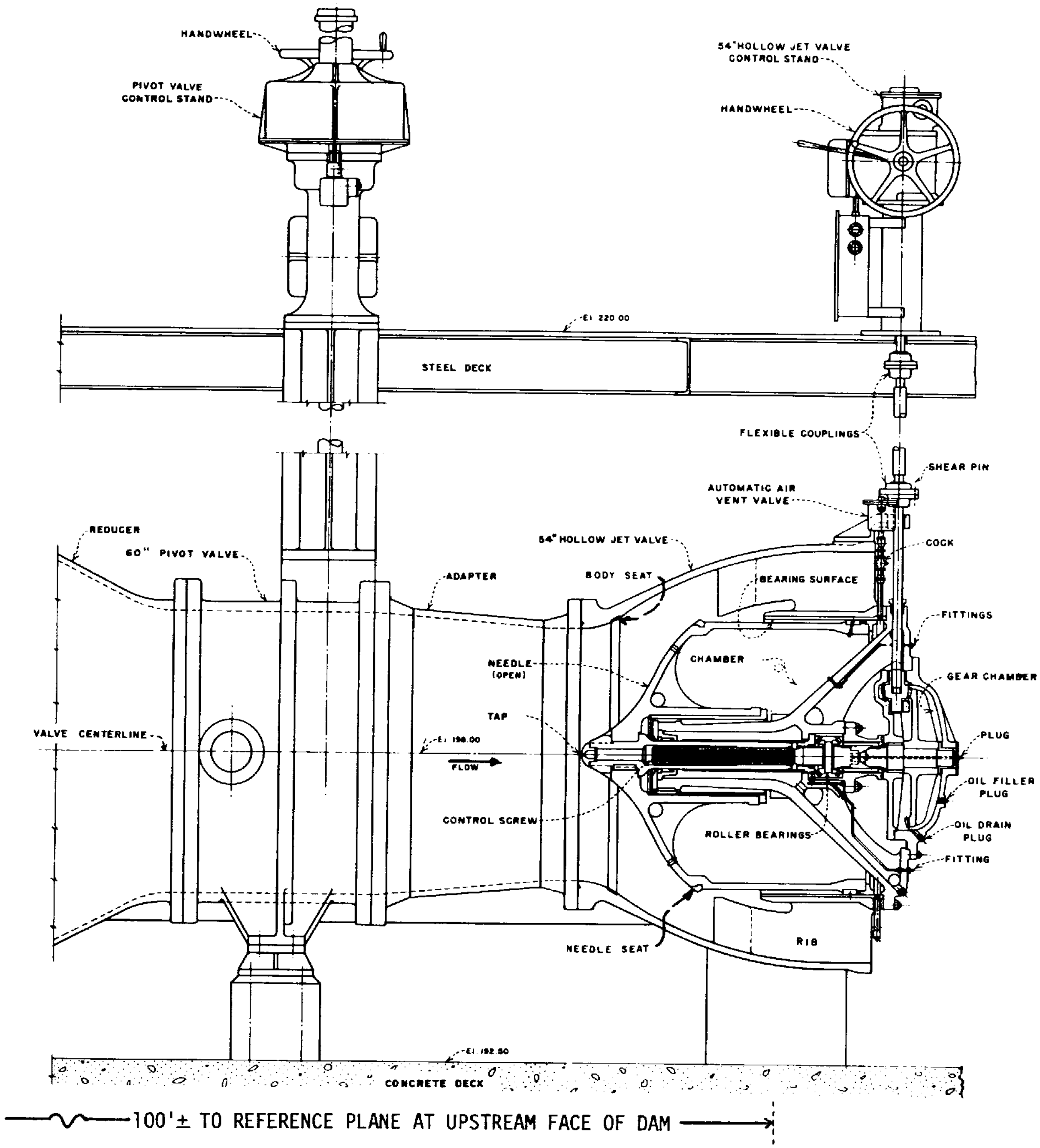

Figure 2. Hollow-jet and pivot valves.

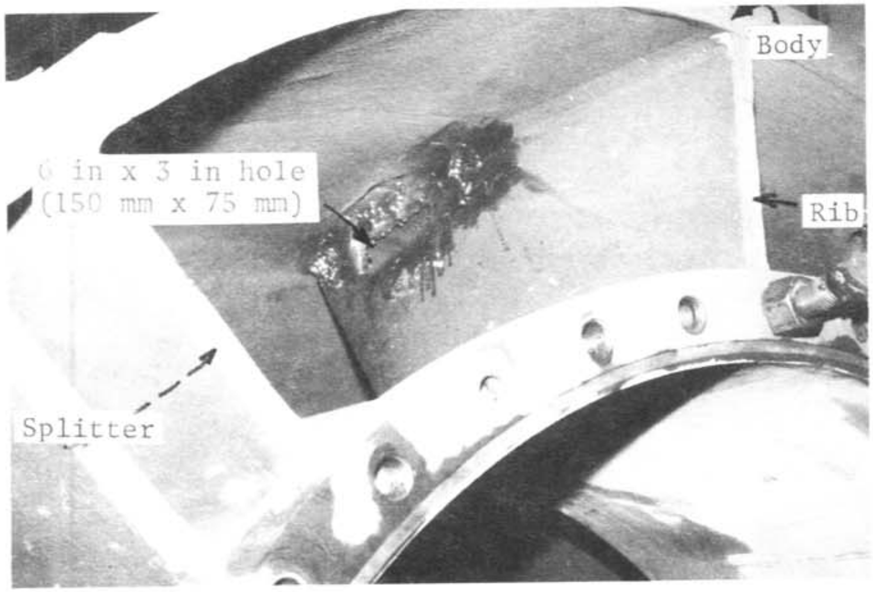

Figure 3. Cavitation damage to hollow-jet valve.

Figure 4. Cavitation damage to hollow-jet valve body.

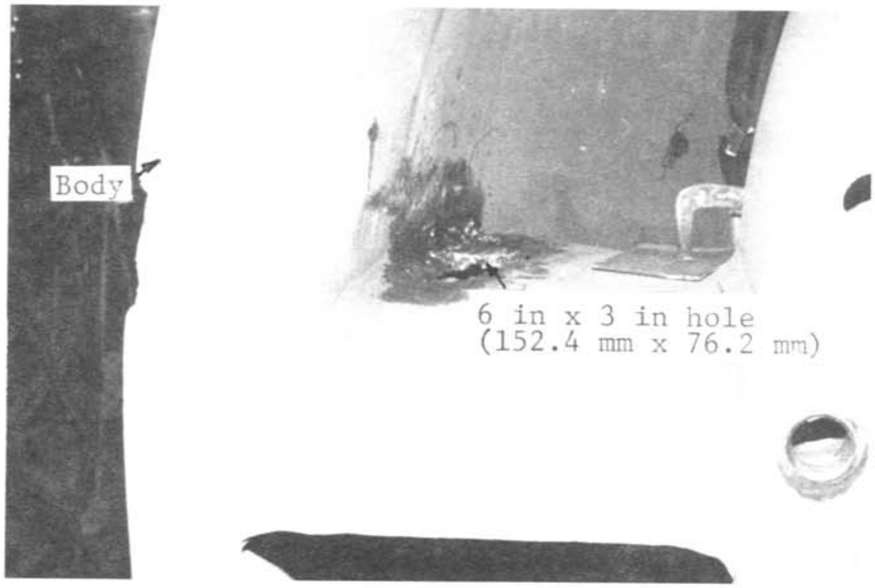

Figure 5. Cavitation damage to the hollow-jet valve rib.

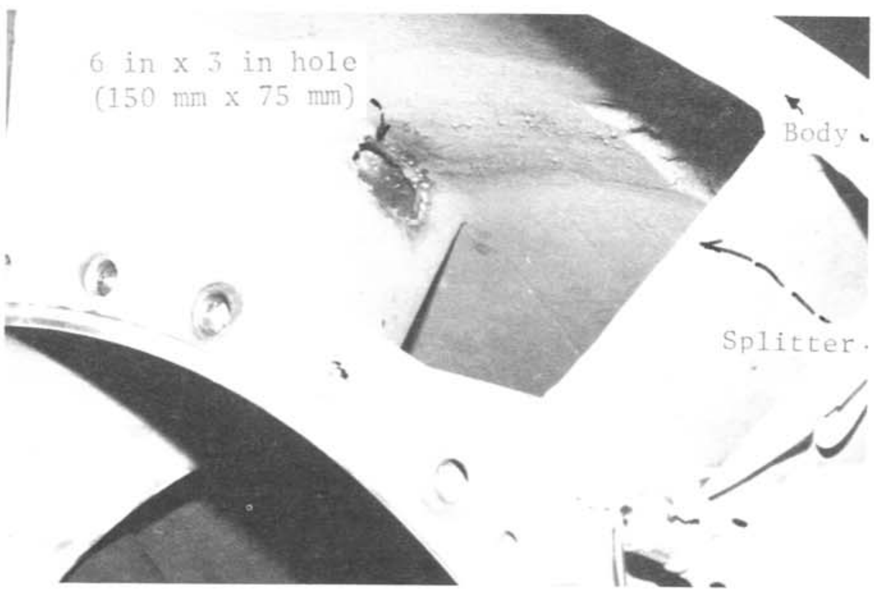

Figure 6. The hole is completely through the valve rib.

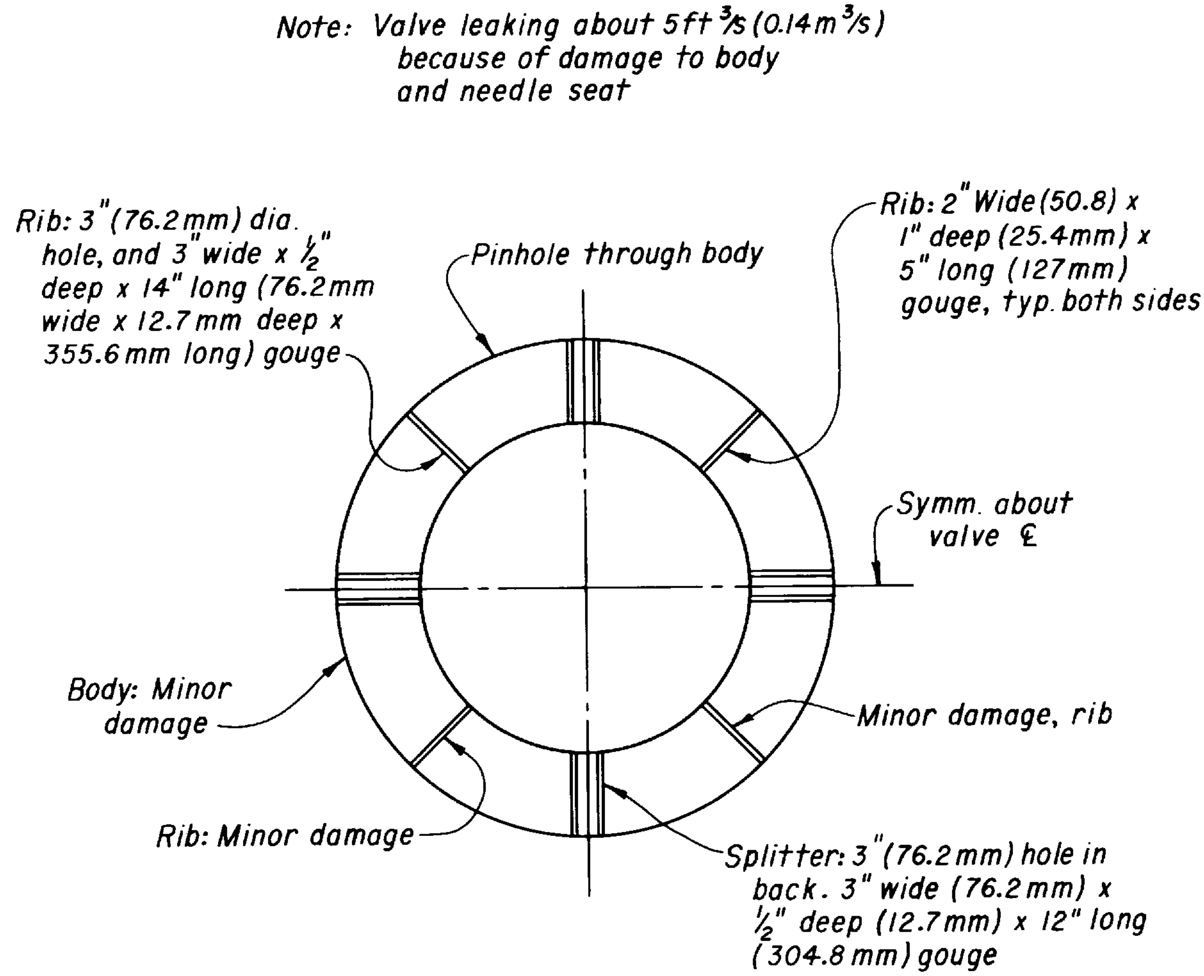

Figure 7. Summary of cavitation damage to hollow-jet valve No. 1 (looking upstream).

Rebuilding the Valves

Refurbishment of hollow-jet valve No. 1 was not attempted in the field, as the disassembly of the valve, the enormity of the parts, the machining and welding requirements, and the final testing all dictate that a qualified shop environment be utilized. In selecting the contractor to accomplish the work, the factors considered were:

1. Sufficient overhead crane capacity (13-ton minimum)
2. Ample lay-down area
3. Size of available machine tools
4. Qualified welders and welding procedures
5. Certified nondestructive testing inspectors
6. Stringent Quality Control and Assurance Program
7. Adequate testing facilities
8. Proper technical backup

All of the above criteria were important in assuring that the rebuilt valve met the specifications. The valve required considerably more work than initially envisioned when the contract was awarded.

Disassembly of the valve was accomplished with the valve in the open position and vertical. This greatly facilitated the removal of the internal parts from the body and significantly reduced the rigging requirements. Extreme care was taken to assure that the bronze and Monel seats were not bumped during the removal of the needle and needle support and that no extraneous forces were exerted on the gears or gear casing during their removal.

Once removal of the internal parts was complete from the body, the remaining sections were totally disassembled to their smallest component and all parts cleaned and inspected.

Inspection included:

Seats

Wear
Nicks and cuts
Contact area

Gears

Tooth condition
Wear pattern
Lubrication accessibility
Bearing movement

Seals

Wear and shape
Retainer condition
Seal ring

Control shaft

Total indicated runout
Wear
Cracks

Control nut and screw

Wear
Total indicated runout
Threads
Coupling
Seal

Upon completion of the inspection, all components were recleaned and those requiring rework or replacement identified for the appropriate action; the others were given a protective coating and placed in sealed bags or boxed.

Inspection of the body was not accomplished until the entire body was sandblasted to white metal, inside and outside. This proved to be time consuming due to the vast amount of epoxy which had previously been applied to the ribs and splitters. However, once the sandblasting was complete, it was easily discernible that both valves had been subjected to severe cavitation. This condition manifested itself in gaping holes in both the ribs and splitters, as well as deep gouges in the body wall.

Nondestructive examination (dye penetrant) confirmed the visual examination and ascertained that the surrounding metal was porous, and there were paths through the body, splitters, and ribs.

Normal welding techniques and materials would neither repair the affected areas nor preclude future cavitation. So outside welding consultants were engaged. The consultants' charge was to recommend a method of both repairing the existing damaged areas without causing additional problems to the base metal and utilizing a weld material which would be compatible with the body, yet have sufficient strength and ductility to withstand cavitation. After innumerable materials and methods were explored, and many coupons tested, the Bureau and Groth Equipment agreed to the following procedure:

1. Sandblast the body to white metal.

2. Conduct dye penetrant examination of all ribs, splitters, and body areas where wear is evident.

3. Grind all areas where cracking, porosity, or abnormal wear is evident, removing all deteriorated material.

4. Conduct another dye penetrant examination to assure all bad areas are totally removed and no residual cracking remains.

5. Weld using N1-ROD 1/8 inch (3 mm) conforming to AWS A5.15 Class ENi-C1.

a. The welding procedure for gouged areas is as follows:

(1) Reduce amperage to approximately 60 amperes.

(2) Maintain a steady ambient condition in the 65 ° to 80 °F (18.3 ° to 26.7 °C) range.

(3) Apply no more than 2 inches (50 mm) of weld at any time in one area. (The surrounding area should not see an appreciable increase in temperature and should be touchable with a bare hand).

(4) Remove all scale with wire brush and peen welded area.

(5) Move to another area and repeat steps (3) and (4).

(6) Periodically conduct dye penetrant examination to assure integrity of welded areas and base metal.

(7) Continue steps (3), (4), (5), and (6) until completed.

(8) When welding is complete, grind welded areas to smooth surface, contouring to original or desired shape.

(9) Recheck with dye penetrant or magnaglow to assure no cracks or voids exist.

b. The welding procedure for areas where all metal was removed is as follows:

(1) Bevel edges of hole.

(2) Make insert of mild steel to fit space where metal has been removed.

(3) Overlay insert with Eutectic electrode CP H-002 (this is a hard material designed to withstand abrasion and cavitation).

(4) Overlay edges of insert with the N1-ROD previously mentioned.

(5) Follow steps a.(1) through a.(9) above.

The reassembly of the valve was routine except for the replacement of the bronze seat. The seat was replaced with a new ring made of 304 stainless steel. This 54-in (1375-mm) ring was given a shrink fit. All seals and seal carriers were also replaced. Extreme care was taken to assure that the seats were not damaged and that no forces were exerted on the gears. The valve was reassembled in the open position, closed by hand after all parts had been lubricated, and painted. A template was used to verify that the desired contour was obtained for all the wetted metal surfaces.

Testing of the valve was conducted with the valve bolted to the transition piece that is normally installed between the hollow-jet and pivot valves. A test flange was bolted to the transition piece, and with both pieces sitting in a vertical mode and with the hollow-jet valve closed, hydrostatic pressure was applied to the valve with excellent results.

Subsequent testing of the valve at the site, in its installed location, indicated that future testing should be accomplished in the horizontal mode, as the site tests showed some leakage from the top of the valve. This leakage was attributed to the weight of the internal parts which does not influence the testing in a vertical mode.

Water, Operations, and Safety Considerations

Minimum releases from 15 to 46 ft^3/s (0.425 to 1.30 m^3/s) are made throughout the year for fish and aquatic life. These flows, too small to be released through the hollow-jet valve, are released through smaller jet-flow gate valves elsewhere in the outlet works.

The other releases in acre-feet per year are: Municipal and industrial, 30 000 ($37.0 \times 10^6 m^3$); irrigation, 161 000 ($198.6 \times 10^6 m^3$); and miscellaneous, 10 000 ($12.3 \times 10^6 m^3$). The irrigation is the largest and generally occurs between April 15 and October 15. Irrigation releases for the years 1979 to 1981, a typical period, varied from 60 to 910 ft^3/s (1.7 to 25.8 m^3/s) and utilized the hollow-jet valves. Floodflows have also been released through the hollow-jet valves to reduce the flow and volume passed by the spillway. When releases are made during severe rainstorms, the hollow-jet valves are usually open as fully as possible. Now that a powerplant is at the dam, water will be released first through the turbines to use the energy available to generate electricity. The hollow-jet valves will be used much less than in the past. The hollow-jet valves will be in use only when the powerplant releases are not large enough to meet downstream water requirements.

The removal and reinstallation of valve No. 1 was complicated by the following:

1. The powerplant contractor was actively engaged in constructing a powerplant in an area which included valve No. 1.

2. The valve was to be installed in the powerplant, not reinstalled in its old position in the outlet works.

3. Both valves are needed for the cited irrigation water releases between April 15 and October 15.

In order to reduce possible problems and keep accidents to a minimum, the powerplant contractor removed and placed valve No. 1 on the valve contractor's truck when the valve was removed from the dam. The powerplant contractor also removed the valve from the valve contractor's truck and installed it in the powerplant. The removal and installation, because of planning and contractor cooperation, was accomplished without damage to the valve or personnel.

The considerations for repair of valve No. 2 are simpler: The powerplant contract is complete, and the powerplant can release water as required up to 700 ft^3/s (19.8 m^3/s). The only new problem is the presence of the powerplant which is between the valve and the only support for the crane. Valve No. 2 has now been removed from the dam outlet works and is being rebuilt. The removal was accomplished with a tracked crane without damage to the valve or personnel. A single nylon sling was used to avoid damaging the valve. Reinstallation will be done in a similar manner. Valve operation is restricted; i.e., no operation below 10 percent or above 60 percent of stroke. This prevents (cutting) damage to the seats of the valve at small openings and vibration damage at large openings. The restriction was added to the operation procedure in 1964. Since the repair has not affected any of the physical causes which damage the valve, the restrictions are still in effect.

The Quality Control Program

The Groth Equipment Company has an exceptional Quality Control Program that is faithfully maintained throughout their facility in Houston. Because of the size of valve No. 1 and the operating conditions under which it operates, it was crucial that special attention be paid to these repair procedures. Therefore, in addition to the day-by-day quality assurance exercised by Groth, the Bureau engineers monitored the progress of the repair and test program on a regular basis.

The following procedure for quality control was implemented: Upon delivery of the valve to the Groth plant, it was cleaned and the damaged areas identified. After the paint coating, rust, and epoxy filler were removed, the damage was found to be more extensive than first suspected. In order to determine the extent of the damage, it was necessary to grind away the rough, cavitated metal down to sound base. A dye penetrant was used to determine if all cracks had been removed before the repair welding could begin. See figure 8. As can be seen in this figure, there were cracks that continued in the casting.

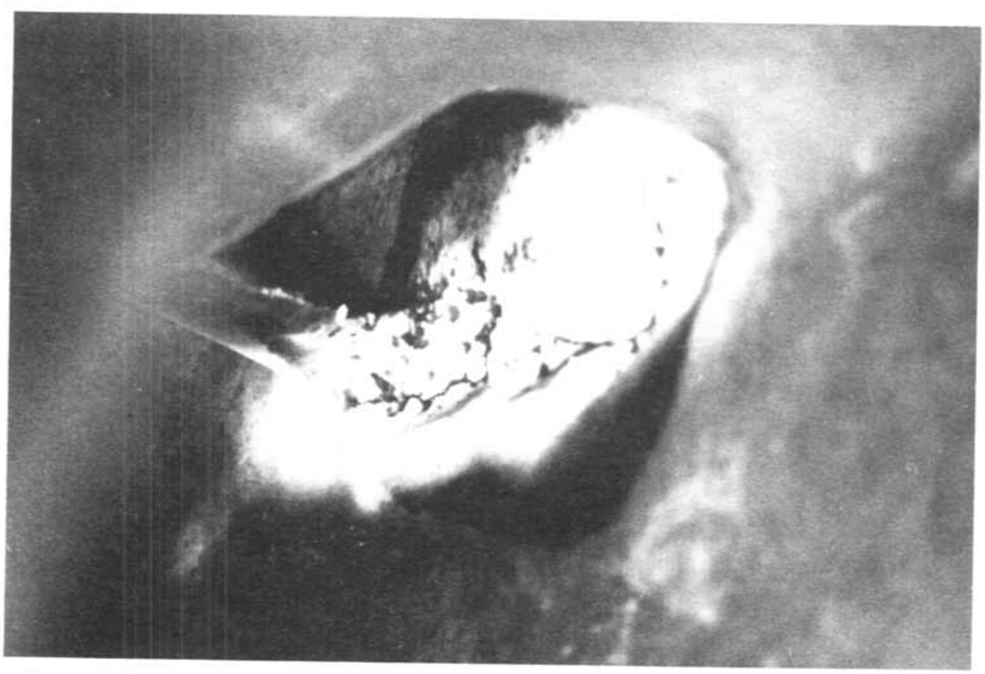

Figure 8. Damaged area of valve No. 1 splitter. (Note: Rough cavitated metal has been ground away to clean cast iron, and surface has been treated with dye penetrant).

Before the repair welding began, Groth conducted numerous sample welds to determine the best procedure for the cast iron repair. The procedure finally selected was a "cold technique" proposed by the Eutectic Corporation: short weld passes with a high nickel content rod to reduce the heat input to the cast iron body, thereby reducing cracking. This technique was found to be very time consuming but necessary to avoid cracking the weld metal and the cast iron body. Another technique used to reduce the propagation of cracks was to "butter" the cast iron with a mild steel rod. This was found to provide a good anchor for the continuation of the weld procedure.

After each pass, the welds were examined thoroughly for cracks before the next pass was made. If cracks were discovered, they were gouged out before the repair procedure was continued.

The Quality Control Program for valve No. 2 does not differ significantly from that for valve No. 1.

It is believed that the "cold technique" and the controlled weld procedure by qualified welders are the best methods of repair for the extensive damage suffered by these valves.

Conclusions and Valuable Lessons

1. Rebuilding the hollow-jet valves has provided a financial savings for the taxpayers of about $190,000[5] each. If the valves had not been rebuilt, failure would have probably occurred in less than 5 years, and replacement valves would have cost about $250,000[5] each. Rebuilding cost about $60,000[5] each.

2. A large mass of cast iron, missing due to cavitation, is expensive to replace with weldment material. Replacement with inserts of steel, cut to fit, is much less expensive. Steel is also stronger and more ductile than cast iron. The insert should be welded in place with an electrode compatible with the steel insert and cast iron. Nondestructive testing should be used for checking progress at each repair step.

3. When small pieces of cast iron are missing due to cavitation, repair is best accomplished by building up the surface with weld metal and then grinding back to contour. The needle seat can and should be replaced with one of stainless steel for added cavitation damage resistance. Before placing weld metal, the damaged surface should be sandblasted and ground to sound, bright metal. The welding rod used to build up the overlay must be compatible with the cast iron.

4. The metal-critical surfaces must be ground to a smooth, even contour. A template should be used to maintain the proper contour. Any ridge, bumps, or indentations left on the surface will trigger new cavitation.

5. A comparison of construction and factory organizations shows that factories generally have more expertise, better tools, QA (quality control and assurance program), and temperature and humidity control. Removal from the dam is not as critical as installation because field damage can be repaired at the factory along with the planned repair. Critical machines, such as motors, gear boxes, and seals, should not be assembled in the field.

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[5] At January 1982 prices.

6. The selection of a contractor from the bidders is a difficult task. The selected contractor should have a successful record of rebuilding large cast iron valves. The contractor should have adequate shop equipment and experienced personnel. The most common failures in contracts of this nature are due to welding errors. The contractor must also have a fully staffed QA organization with adequate facilities and resources.

7. When valve No. 1 was reinstalled at the dam, after being rebuilt, it leaked. The leakage is about 1 ft^3/s (28.3 L/s). This leakage does not cause a serious problem. The leakage was difficult to explain because factory tests showed only 1.5 gal/min (0.095 L/s) leakage at 125 lbs/in^2 gage (860 kPa) pressure. In an attempt to determine the cause of this sudden increase in leakage, the pattern of the leakage and test records were reexamined. It appears that the needle seat of valve No. 1 does not center on the body seat because of the large weight of the needle and normal manufacturing clearances. This problem should be solved on future valve repairs by machining the body seat to fit the needle seat. Valve No. 2 will be tested in the horizontal (operating) position. Valve No. 1 was tested in the vertical position.

8. The cavitation damage would not have been enough to cause a problem if each hollow-jet valve had not been mounted too close to the pivot valve outlet. The cavitation is caused by turbulence introduced in the water by the pivot valve. To keep maintenance expenses within reason, the hollow-jet valves should have been located greater than 50 ft (15 m) (10 pipe diameters) downstream of the pivot valve.

Acknowledgments

Certain individuals contributed valuable assistance by consultation, frequently on their own time. Their contribution is gratefully acknowledged. Ken Jukkala, Chief of the Design Branch, and James Andrews, Regional Engineer, Bureau of Reclamation, Mid-Pacific Regional Office, suggested changes in the welding procedure which were incorporated. James Wadge, Supervisor of the Gates and Valves Section, E&R Center, Bureau of Reclamation, Denver, suggested changes in the valve design to help improve its life expectancy. William Hagbery, Supervisor of the Electro-Mechanical Section, Bureau of Reclamation, Mid-Pacific Regional Office, reconstructed the valve electrical wiring schematic from incomplete data.

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WATER MEASUREMENT TECHNIQUES[6]

In a recent Review of Operation and Maintenance examination of the minor structures and facilities of the East-Columbia Basin Irrigation District, it was observed that the District has accomplished some modifications to improve their water measurement techniques.

A problem the District was having with obtaining measurements in a lateral was solved with the installation of large square concrete stilling wells. A right angle turn at the outlet end of the railroad siphon crossing had created turbulence in the lateral, making it difficult to read the staff gages for the large constant head orifice turnouts. Pipe stilling wells installed outside the constant head orifice structures had not stilled the water enough to obtain accurate measurement. The round pipe stilling wells were removed and new large square concrete stilling wells were constructed. The new facilities have improved the conditions and accurate reading can be obtained from the constant head orifices. See figure 9.

Figure 9. Square concrete stilling wells were constructed to replace round pipe stilling wells.

For measuring flow in small laterals, they are using a portable calibrated slide gate. This portable structure is installed in the concrete lateral and sealed so that all the water passes through the orifice opening. After the flow has stabilized, the head differential is measured and the lateral flow can be determined. See figure 10.

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[6] Excerpted from 1983 Review of Operation and Maintenance Examination report dated February 3, 1984, by Virgil D. Temple, Bureau of Reclamation, Boise, Idaho; and Eugene Sell, Bureau of Reclamation, Columbia Basin Project Office, Washington.

Figure 10. Portable calibrated slide gate.

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BUCKET SEATS DO THE TRICK[7]

Having a problem with compact pickup truck seats?

The East Columbia Basin Irrigation District has been using compact pickup trucks, such as the Ford Courier and Chevy Luv, as ditchriders' vehicles. The ditchriders complained that the vehicles did not provide as soft a ride as the heavier pickups did when traveling the gravel O&M roads. As a result, the bench seats were removed and replaced with bucket seats which provided a more comfortable ride. A small writing table was built into the space between the seats, providing the ditchriders with a table to do their bookwork. See figure 11.

Figure 11. Rebuilt seats provide softer ride.

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[7] Excerpted from 1983 Review of Operation and Maintenance Examination report dated February 3, 1984, by Virgil D. Temple, Bureau of Reclamation, Boise, Idaho; and Eugene Sell, Bureau of Reclamation, Columbia Basin Project Office, Washington.

GPO 843-586

Mission of the Bureau of Reclamation

The Bureau of Reclamation of the U.S. Department of the Interior is responsible for the development and conservation of the Nation's water resources in the Western United States.

The Bureau's original purpose "to provide for the reclamation of arid and semiarid lands in the West" today covers a wide range of interrelated functions. These include providing municipal and industrial water supplies; hydroelectric power generation; irrigation water for agriculture; water quality improvement; flood control; river navigation; river regulation and control; fish and wildlife enhancement; outdoor recreation; and research on water-related design, construction, materials, atmospheric management, and wind and solar power.

Bureau programs most frequently are the result of close cooperation with the U.S. Congress, other Federal agencies, States, local governments, academic institutions, water-user organizations, and other concerned groups.

A free pamphlet is available from the Bureau entitled "Publications for Sale." It describes some of the technical publications currently available, their cost, and how to order them. The pamphlet can be obtained upon request from the Bureau of Reclamation, Attn D-922, P O Box 25007, Denver Federal Center, Denver CO 80225-0007.