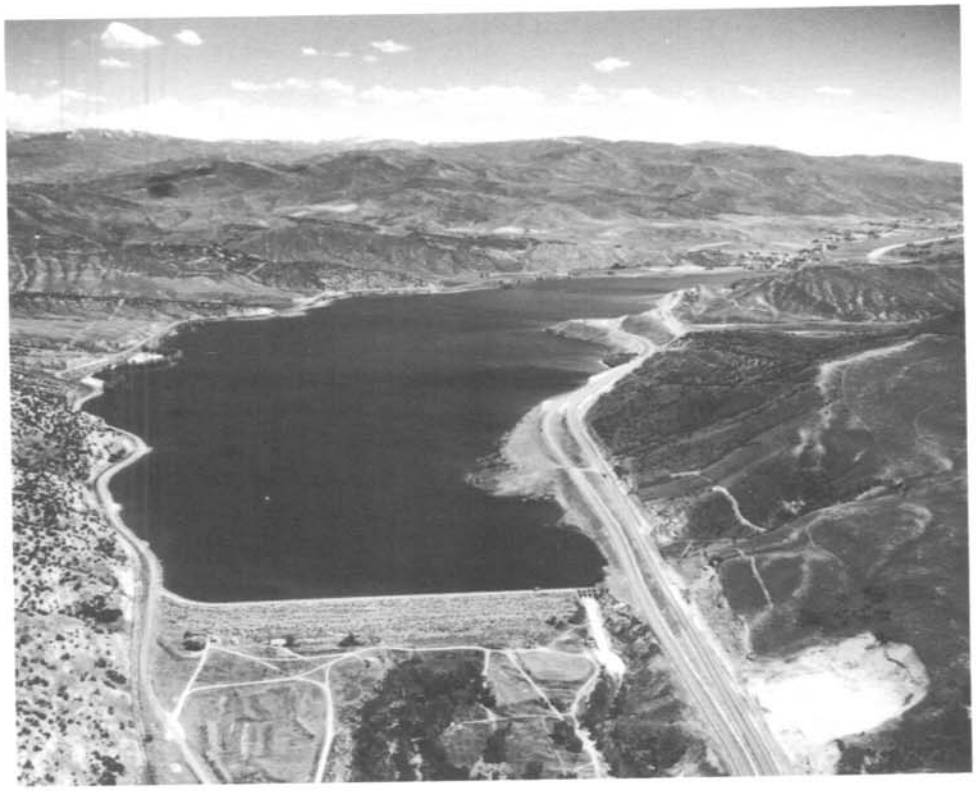
# WATER OPERATION AND MAINTENANCE

BULLETIN NO. 146

December 1988



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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 information for use by Bureau personnel and water user groups for operating and maintaining project facilities.

While every attempt is made to ensure high-quality and accurate information, Reclamation cannot warrant nor be responsible for the use or misuse of information that is furnished in this bulletin.

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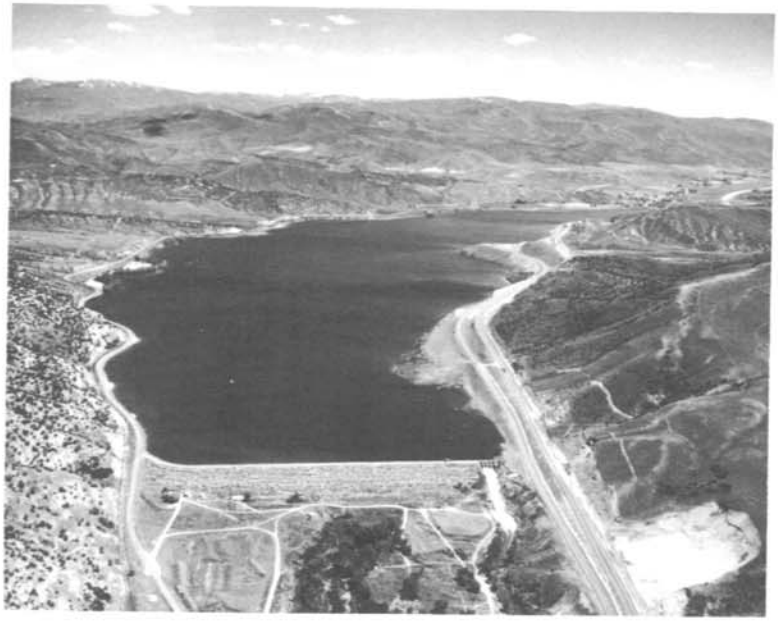

Cover photograph:

Echo Dam and Reservoir
near Coalville, Utah,
Weber River Project.
7/2/71

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# COLD WEATHER TIPS FOR CONSTRUCTION EQUIPMENT[1]

Construction equipment needs special attention in cold weather to operate at optimum productivity. Moisture can cause costly and possibly irreversible damage to equipment at freezing temperatures.

Precautions taken before and during the winter season will help ensure that construction equipment operates properly in cold weather.

Several precautions should be taken before and during the winter to help ensure that equipment will operate properly in cold weather, according to John Strangberg, field service training manager for J. I. Case, Racine, Wisconsin.

Pre-Season Check.–A proper maintenance schedule should include a change of transmission fluid, engine oil, and coolant at the start of cold weather. Fluids that have been used too many hours or left in the machine too many months are less able to provide the protection needed when the temperature drops to the freezing level. A machine's systems and parts are much more sensitive in winter than in warmer seasons because fluids tend to move more slowly when cold, taking longer to reach equipment parts.

Use a transmission fluid that absorbs and minimizes the effects of moisture resulting from cold weather condensation. Unabsorbed water can freeze, promote rust, reduce output of pumps, clog filters, and cause premature deterioration of machine parts. Use high-quality gasoline or diesel fuel. For diesel engines, use a fuel with a cloud point of at least 10 °F below the lowest anticipated temperature to prevent diesel fuel waxes from forming and plugging filters. The fuel should be a winterized grade 2-D meeting ASTM D-975 specifications.

Check the operator's manual to be sure that the engine oil is the correct viscosity for low-temperature operation. Newer engines use a multi-grade oil that does not require

[1] Reprinted with permission from the Editor, Public Works, July 1988 issue.

a viscosity change for cold weather use. Older engines require seasonal changes of oil that should be part of the machine's normal maintenance schedule.

Use a coolant low in silicates and a high-quality water low in minerals, chlorides, and sulfates. Mix the water with ethylene glycol, varying the amounts of each as required by the lowest anticipated temperature. Maintain the ethylene glycol concentrate at about 50 percent, which will provide protection to -34 °F. Never let it exceed 65 percent or fall below 45 percent because the additives in the antifreeze will not protect properly outside those limits.

Cold Weather Starting.–Keep the battery at full charge. Cold weather and thickened engine and transmission oil greatly increase cranking power requirements on a battery. Also, the electrolyte in a badly discharged battery can freeze in extremely cold temperatures.

A local dealer can supply starting aids, such as engine block, oil pan, battery, and coolant heaters. Strangberg does not recommend the dipstick heater because the heat is so localized that additives in the oil can be burned in one spot, while the rest of the oil is insufficiently heated. Use ether starting fluid only when the ether dosage can be controlled by an attachment mounted directly on the engine.

Cold Weather Operation.–Always heat the hydraulic transmission fluid to operating temperature by running the engine at 1,500 r/min for about 5 minutes before operating the machine. Operating a machine with cold transmission fluid can cause erratic or rough operation.

During cold temperatures, the engine may not warm up to or maintain the rated operating temperatures at slow engine speeds. When the engine is operated below 1,500 r/min, incomplete combustion may result. Before stopping the engine after heavy, sustained loading, run it at slow speed for 3 to 5 minutes to allow a gradual decrease of engine temperature and prevent excessive condensation.

At day's end, fill the fuel tank to prevent condensation from forming in the tank. Remove water from the water trap each day or damage to precision fuel injection parts will occur.

Park the machine on a hard, level surface, out of mud or water that can freeze the tires or tracks to the ground. Then cover the end of the exhaust pipe to prevent moisture from entering. If the machine is to be stored for a long period of time, jack up the machine to alleviate the load on and prevent "flattening" of the tires.

Cold Weather Dangers.–Never use gasoline or diesel fuel to reduce the viscosity of engine oil. Not only does fuel adversely affect the protective value of the oil, it creates a fire hazard when operating the engine. Never add gasoline or alcohol to diesel fuel. The mixture creates a vapor that is extremely explosive. Have the transmission fluid analyzed for water contamination at regular intervals. Fluid with over one-half percent water, by volume, does not absorb condensation effectively and increases the chance of premature deterioration of machine parts.

When storing equipment for long periods of time during cold weather, drain and replace the engine oil and coolant. Do not store a machine without oil in it so that, in an emergency situation, the machine will be operational.

"The performance and life of construction equipment are dependent on proper maintenance year-round," says Strangberg. "In freezing temperatures, just a few simple precautions can protect expensive machinery from premature wear and failure."

# PHYSIOLOGICAL INVESTIGATIONS OF HYDRILLA

## An Obnoxious Aquatic Weed

by Joan S. Thullen[1]

There are hundreds of thousands of miles of canals and waterways in the West. A majority of these water systems are plagued by a dilemma little known or understood by the average citizen. Annually, aquatic weeds create problems requiring expenditures well into millions of dollars for weed control. Research is currently underway to study the pattern of weed growth in waterways and to determine methods of controlling this aquatic menace which limits and obstructs waterflow.

Hydrilla (*Hydrilla verticillata*) is now well known throughout the warmer climates of the United States as a noxious aquatic weed which can, once it has infested a water body, clog waterways and reservoirs by its rapid growth and ability to adapt and proliferate even in extremely unfavorable conditions [1-6][2]. The numerous structures for reproducing itself include stem fragments, tubers (potato-like reproductive structures borne in the soil at the ends of rhizomes), axillary turions (buds borne where the leaves attach to the stem capable of producing a new plant after dropping to the ground), seeds, stolons, and rhizomes. The physiological mechanisms which produce each of these structures have yet to be fully understood.

Ongoing investigations in the Environmental Sciences Section attempt to pinpoint hydrilla's specific physiological responses to several different conditions. This information is necessary to fully understand the physiology of hydrilla, especially its reproduction, so more effective and less costly methods of control can be developed.

The investigations discussed here primarily evaluated tuber formation and tuber germination.

Investigations were performed in the laboratory using environmental growth chambers and incubators to regulate light, temperature, and day length as well as various atmospheric gasses including oxygen ($O_2$), carbon dioxide ($CO_2$), and air. Fresh hydrilla plants used in the studies came from canals in the Imperial Valley of southern California.

Results have shown that $CO_2$ at levels between 15 and 56 mL/min is toxic to hydrilla and restricts tuber production. Out of 12 subsamples, only 1 tuber was formed in two 24-week periods [7 and 8]. Hydrilla plants which produced the most tubers were plants which were aerated or oxygenated, especially those aerated. Plant material biomass was also significantly greater than those given $CO_2$ (4 to 3.3 times greater).

Aerated hydrilla sprigs grown in continuous fall-like conditions (warm, yet short, days and nights) produced the greatest numbers of tubers. More tubers were formed in the longer fall-like conditions. After 24 weeks, the maximum mean number of tubers produced per square meter was 2,145 [8].

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[1] Joan S. Thullen is a Botanist employed by the Bureau of Reclamation's Denver Office, Denver, Colorado 80225.
[2] Numbers in brackets refer to literature cited at end of report.

Data from preliminary investigations indicate that maintaining hydrilla in a cropped condition, as from fish feeding, may discourage tuber formation. Physiologically, this makes sense since plants must be able to make food (by converting light, oxygen, and water into sugars) before they can store it. Occasional fish feeding could have extremely different effects on tuber production and is an area where more research is needed.

Once the hydrilla plants formed tubers, they were harvested and studied for their germination characteristics. It is well documented that hydrilla tubers can remain in the soil for up to 10 years before conditions are right for them to germinate. Under ideal laboratory conditions, some tubers germinate within a few days, while other tubers will not have germinated after 6 months. Several vernalization techniques were investigated to determine what condition has to be met before germination occurs.

Vernalization is any kind of treatment of a seed, bulb, or tuber which hastens fruiting or germination. Numerous studies have been done in the Environmental Sciences Section to evaluate effects of cold temperatures on tuber germination. Results have shown that longer initial vernalization periods did not improve tuber germination, but additional periods of vernalization improved germination significantly. It is not known why some tubers will germinate almost immediately and why others in the laboratory require up to three vernalization treatments and 24 weeks after being harvested before they will germinate. Perhaps this could be an additional strategy used by hydrilla to ensure its survival regardless of the environmental conditions.

Although these results are preliminary, an understanding about hydrilla's physiology is becoming clearer. By applying some of this knowledge, less costly and more practical methods may be developed for restricting this noxious weed. Possible areas which could be investigated further to control tubers are methods to reduce the oxygen available for their formation (e.g., administering toxic levels of carbon dioxide) or methods to encourage tuber germination with a subsequent treatment to kill the young plants at a vulnerable time. Research will be continued in these and other areas.

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Figure 1. - A lateral canal is clogged with hydrilla which severely restricts the waterflow.

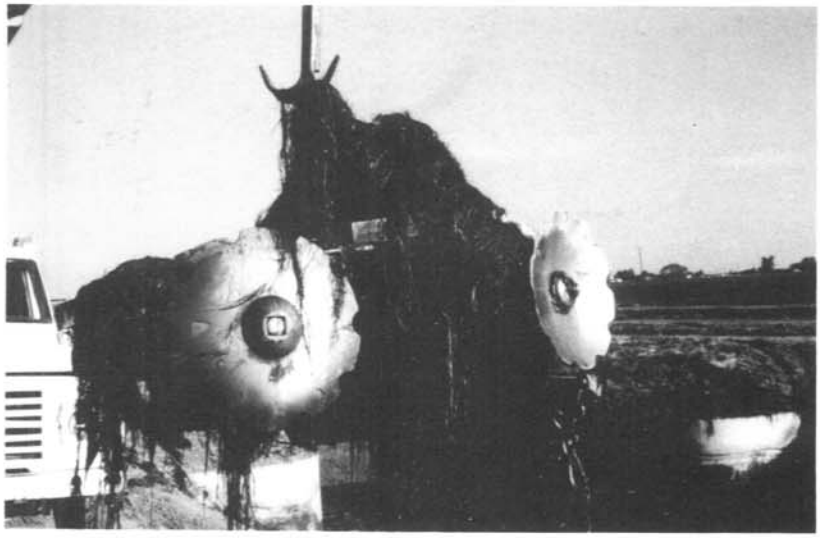


Figure 2. - During maintenance operations, large amounts of hydrilla are removed in order to allow water to be delivered.

Figure 3. - These hydrilla tubers and turions (second from left) enable the weed to survive long winters or dry periods. The tuber on the left has germinated (ruler in millimeters).

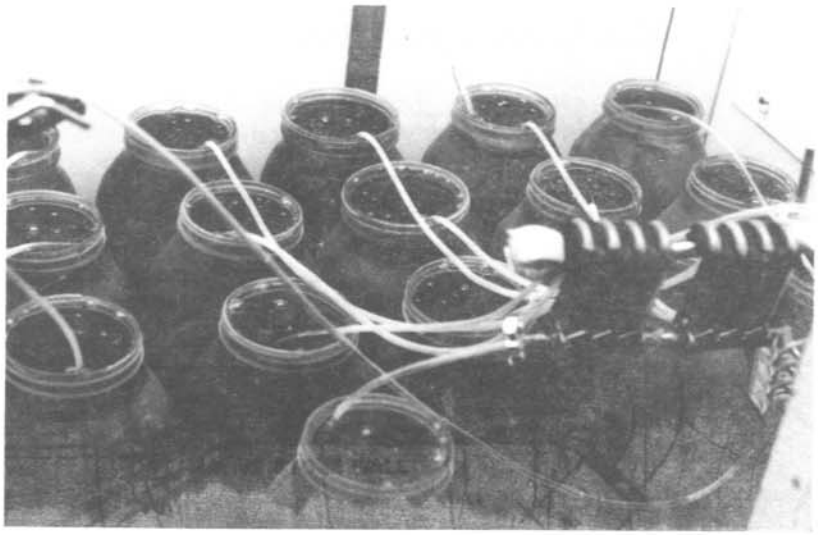


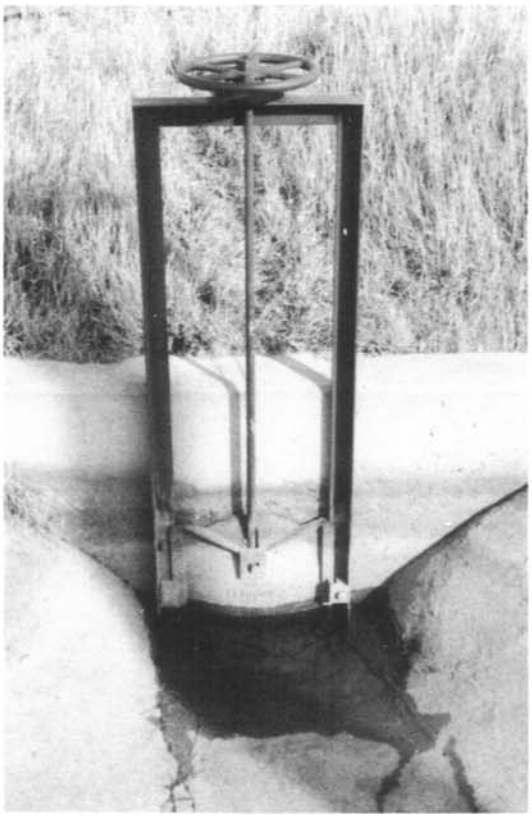
Figure 4. - Air is being bubbled into each test jar.

## LEAKY GATES[1]

### Two-Year Research Study Underway

Leaking turnout gates can be a nagging headache for farmers and ditchriders. Seepage through poorly sealed gates causes problems with trafficability in nearby fields, increased weed growth, soil degradation, reduced crop yields, and a needless loss of valuable water. A recent report by Associated Engineering Alberta Ltd., for the Irrigation Branch of Alberta Agriculture, has attempted to assess the severity of the problem of leaky turnout gates and proposes some viable solutions to minimize leakage.

To determine the severity of the problem, 16 gates (including Lethiron, Armco, and Whipps brands) ranging from 450 to 1200 mm (18 to 48 inches) in diameter and 1 to 34 years in age, were investigated. All of the gates were situated along main laterals in the Raymond Irrigation District. To determine the rate of leakage, the gates were closed and the downstream side was drained. The water level upstream of the gate was raised to its maximum level and the leakage through the gate was measured using a small pump and a measuring vessel.



[1] Reprinted with permission from the Editor from the Water Hauler's Bulletin, Volume 31, Spring/88 issue. Published by the Alberta Agriculture Center, Lethbridge, Alberta, Canada T1J 4C7.

Leakage rates were found to vary from a high of 1.035 L/s (1.65 gal/min) to a low of 0.009 L/s (0.02 gal/min), with an average rate of 0.3 L/s (0.48 gal/min). Reasons for the leakage included debris buildup, weed growth, silt, improper adjustment, and corrosion or gouging of the seating faces. Leakage rates were not wholly dependent on age, since a 34-year old Lethiron gate produced the least leakage of all the gates studied.

One proposal calls for the installation of scrapers to clean the seats when the gate is opened or closed. One wiper would be mounted on the gate frame to scrape the slide face, and another wiper mounted on the bottom of the slide would scrape the thimble seat face. Another solution could be the addition of a lever arm on the gate frame. The lever would be attached to the slide and pass through a fulcrum point above the slide, allowing this operation to exert additional pressure on the gate face and thereby produce better seat contact. However, reducing leakage can be as simple as properly adjusting the wedges so that the slide settles evenly on them, or thoroughly cleaning debris from the inlet so that it will not be caught between the seat faces.

Although it is easy to disregard a small trickle of water leaking through a gate, consider these numbers: a 0.3 L/s (0.48 gal/min) flow over a 163-day irrigation season translates into 4225 $m^3$ (3.43 acre-feet) of water. If the estimated 9,000 turnout gates in use in southern Alberta are shut and leaking for 30 percent of the irrigation season, 11,407,500 $m^3$ - approximately 9,250 acre-feet - of valuable water is trickling away each year.

Funding for the continuance of this research study in 1988-89 has been provided by Farming For the Future. Associated Engineering will return to the original study area in 1988 to further monitor the gates and implement some gate improvements. Hopefully some viable solutions can be found for this often ignored waste of water.

For more information, please contact Svat Jonas, P. Eng., Irrigation Branch, Alberta Agriculture, Agriculture Centre, Lethbridge, Alberta, T1J 4C7. Telephone (403) 381-5164.

# GUIDELINES FOR TESTING GATES AND VALVES AT MAJOR FACILITIES

These guidelines were issued originally Bureau-wide on August 14, 1987, from the Denver Office to establish consistency during Review of Operation and Maintenance Program examinations of major facilities.

These guidelines can also assist personnel in ensuring all gates and valves are performing properly and continue to perform properly. Following completion of any operational test, the results should be documented in the operating log for the facility. If, during any operational test, the gate or valve used will not open or close from any position or otherwise malfunctions, the test should be stopped and the cause of the malfunction determined and corrected. The responsible Bureau office should be contacted for assistance before further testing.

## Verification of Gate/Valve Operations

When onsite examinations of dams and their appurtenant features are performed, the operational adequacy of the mechanical features of the spillway and outlet works should be determined. Ideally, during these examinations it is desirable to observe full operation of all equipment. However, because of conditions at the dam, such as valid downstream delivery requirements which cannot be interrupted for any reason, ongoing maintenance, damaging discharges, loss of water and power revenues, etc., testing and observation through the full range of operation is not always possible. Therefore, operating personnel should establish a gate/valve testing program, in conjunction with periodic examinations and in the interim time periods, to ensure the reliability of its equipment.

The frequency of testing gates and valves should be stated in the SOP (Standing Operating Procedures) for the facility. Regulating gates/valves should be given a full operation test at least annually with the downstream portion of the outlet works unwatered and also under flow conditions. For emergency (guard) gates/valves, an unbalanced head test is recommended at least once every 6 years and a balanced head test at least annually. However, UNBALANCED OPERATION OF OUTLET WORKS EMERGENCY (GUARD) GATES (WHEN ASSOCIATED WITH A PIPE DOWNSTREAM OF THE GATE) SHOULD NOT BE PERFORMED UNLESS THE PIPE DOWNSTREAM FROM THE GATE IS EQUIPPED WITH EITHER AN AIR INTAKE VENT OR AN AIR INLET AND AIR RELEASE VALVE THAT HAS BEEN SIZED AND APPROVED AND AN OPERATION TEST PROCEDURE HAS BEEN DEVELOPED FOR THE SPECIFIC INSTALLATION. The need and procedures for unbalanced testing will be determined and arranged separately, prior to the onsite examinations. In addition to established lubrication and maintenance frequencies, the equipment should be lubricated and any other needed maintenance performed prior to operational testing and exercising.

To the extent possible, the following procedures should be followed during onsite examinations.

a. Equipment operation should be discussed with appropriate operating personnel with sufficient lead time prior to the examination so that necessary arrangements can be made.

b. Any gate/valve operation performed during an examination should be in accordance with the facility's SOP and performed only by trained operators at the dam. Thus, operating procedures, the capability of the operator to perform the operation, and the performance of the equipment can be observed.

c. If the full range of gate/valve operation is possible:

(1) Have operation performed using normal power.

(2) Have operation performed using auxiliary power to the extent that maximum power load is demanded.

d. If full gate/valve operation is not possible:

(1) Initially, verify in logbook or other documentation the results of latest full-travel testing by field personnel in accordance with the SOP.

(2) Use normal power to operate gate/valve to the extent possible.

(3) Use auxiliary power to operate gate/valve to the extent possible, at least to a level that demands largest power output by the auxiliary power system (usually during unseating of the gate/valve).

e. If verification of full gate/valve operation cannot be determined by the above procedures, it should be noted in the examination report to test operate the equipment through a full-travel cycle as soon as conditions at the dam permit, but in accordance with these guidelines and the SOP, and to document the accomplished operation and its results in the operating log at the dam.

f. The reasons for an inability to fully operate the equipment during the examination should be documented in the operating log for the facility and in the examination report.

g. The SOP should be reviewed to ensure that adequate procedures exist for periodically testing gates and valves. If the procedures are inadequate, the operating procedures should be updated and/or corrected.

Verification of Full-Travel Operation of Spillway Gates With Continuous High Reservoir Levels

In the particular situation of spillway gates where a continuously high reservoir level exists and, hence, damaging discharges would result from full operation, these guidelines for full-travel operational testing of spillway gates should be considered.

A differential-head (nonfull-travel) test should be performed in accordance with the SOP on each spillway gate (if possible) while subjected to the maximum head expected for the season. If the spillway gates have not been operated in the past year, a 10 percent opening test should be made in progressive steps as follows:

a. Barely raise or crack gate (i.e.; minimum movement that produces flow or additional flow or leakage) - then lower gate.

b. Raise the gate 1 inch - then lower gate.

c. Raise the gate 6 inches - then lower gate.

d. Open the gate 10 percent of total travel - then lower gate. If 10 percent opening is impossible because of downstream restrictions, open it as far as possible - then lower gate.

Full-travel cycling should be performed at scheduled intervals (generally on an annual basis) under a balanced-head (unwatered) condition. However, in the event of a continuously high reservoir, which prohibits a fully open gate for operational testing, tests should be postponed until conditions allow or stoplogs can be installed. Postponement of maximum gate operational testing should not exceed a 6-year period.

In instances where stoplogs are not available for use, full-travel operational testing of spillway gates at scheduled intervals is generally prohibitive due to consequential loss of water or power revenues and the damaging downstream effects from associated large discharges. As a result, such testing may not be accomplished, invariably exceeding the 6-year postponement limitation.

Satisfactory partial-travel gate exercising under differential-head conditions generally ensures hoist reliability for full-travel operation since maximum loading occurs during unseating of the gate. However, if deformation of the spillway structure has occurred, partial-travel exercising does not ensure that the gate can be physically operated through a full-travel cycle without binding. Assurance of full-travel operation can be obtained directly, by performing operational gate testing through the complete cycle (in the dry or against reservoir head), or indirectly, by verifying the alignment and/or designed spacing of the gate guides, wallplates, and structure walls by survey or other means.

Spillway gates which have not been operated full-travel for 6 years or more because of a continuously high reservoir and lack of stoplogs, should be addressed on a case-by-case basis. Estimated costs and impacts resulting from the proposed testing (loss of water and/or power revenues, downstream damages, etc.) need to be evaluated. Following this evaluation, a determination should be made of the necessity of performing actual full-travel testing (with or without stoplogs). If deemed necessary, instructions will need to be provided for such testing. If full-travel testing is not deemed necessary, an indirect means should be provided for checking the capability for full-travel operation of the gates. Indirect testing to verify conformance with design drawings may include surveying the position of gate bay walls, embedded wallplates, and pedestals; measuring clearances between the gate faceplates/guide shoes and bay wall or embedded wallplates; and underwater inspection of wire rope connectors.

In addition to indirect testing, if possible, the coupling on the output shaft of the hoist gear motor should be disconnected and operation of the motor verified.

## SPOTLIGHT ON ECHO DAM & RESERVOIR

### Weber River Project
### Utah

The Weber River Project, formerly designated as the Salt Lake Basin Project, is in the vicinity of Ogden, Utah. It was developed primarily to supply supplemental irrigation water to about 109,000 acres of land east of the Great Salt Lake, lying between the lake and the Wasatch Mountains. Its principal engineering features are Echo Dam and Reservoir, 42 miles southeast of Ogden on the Weber River.

Irrigation of lands from the Weber River started about 1850. The late summer natural flow was sufficient for full water supply for about 3,000 acres; but before many years had passed, a larger area was developed for which there was only a partial supply.

The Bureau of Reclamation (then called Reclamation Service) made a preliminary investigation of this area in 1904 and 1905, which resulted in the Geological Survey establishing stream-gauging stations in 1905. Early in 1922 in cooperation with the Utah State Water Storage Commission, Reclamation started investigations for a storage reservoir. Final selection of a site for the dam and reservoir was made in 1924. Congressional approval and an appropriation for construction of Echo Dam was received in 1924; and the project was approved for construction after 2 years of detailed investigation, design, and legal work.

Construction commenced on November 26, 1927, and was completed in December 1931. It was necessary to relocate portions of the Union Pacific Railroad branch lines and the Lincoln Highway. The original Weber-Provo Diversion Canal also was constructed during this time, and is located about 5 miles north of Kamas, Utah.

Echo Dam is a zoned earthfill structure 1 mile upstream from the town of Echo and about 6 miles north of Coalville in Utah. It has a structural height of 158 feet, crest length of 1,887 feet, and a volume of 1,540,000 $yd^3$. The spillway has a capacity of 15,000 $ft^3/s$. The outlet conduit is a concrete-lined horseshoe tunnel to the gatehouse, from which two steel pipes pass through a tunnel to the valvehouse. The outlet works was originally constructed with a capacity of 2,100 $ft^3/s$. (This capacity has changed to 2,250 $ft^3/s$ based on replacing of the 30-inch needle valves to 30-inch jet-flow gates in April 1987.) For information regarding the replacement of needle valves, refer to Bulletin No. 144, June 1988.

Echo Reservoir has an active capacity of 73,900 acre-feet. Water stored in Echo Reservoir is released as needed by the irrigators. Delivery to the land is made through privately owned distribution systems that divert water from Weber River.

Project soils are deep, fertile, and generally well-drained. They are particularly adapted to production of barley, wheat, corn, alfalfa, potatoes, fruits, vegetables, and sugar beets. An abundance of fruits and vegetables (including tomatoes, peas, beans, cabbage, cherries, peaches, and apricots) are raised primarily for canning purposes. Carload lots of fruits and vegetables are shipped to outside markets.

The project and the recreation facilities at Echo Reservoir are operated and maintained by the Weber River Water Users Association. By agreement, the association also operates and maintains the Weber-Provo Diversion Dam and Canal. The recreation facilities consist primarily of camping, swimming, boating, and water skiing. There were 47,729 visitor-days generated by the facilities during 1977.

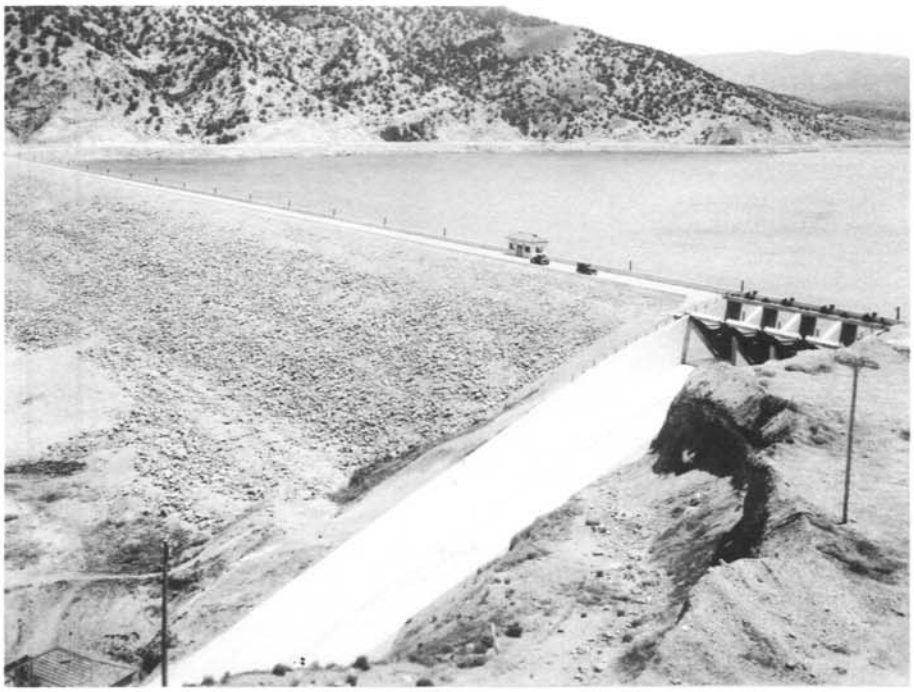


Photo 1. - Aerial view of Echo Dam and spillway. 6/13/32

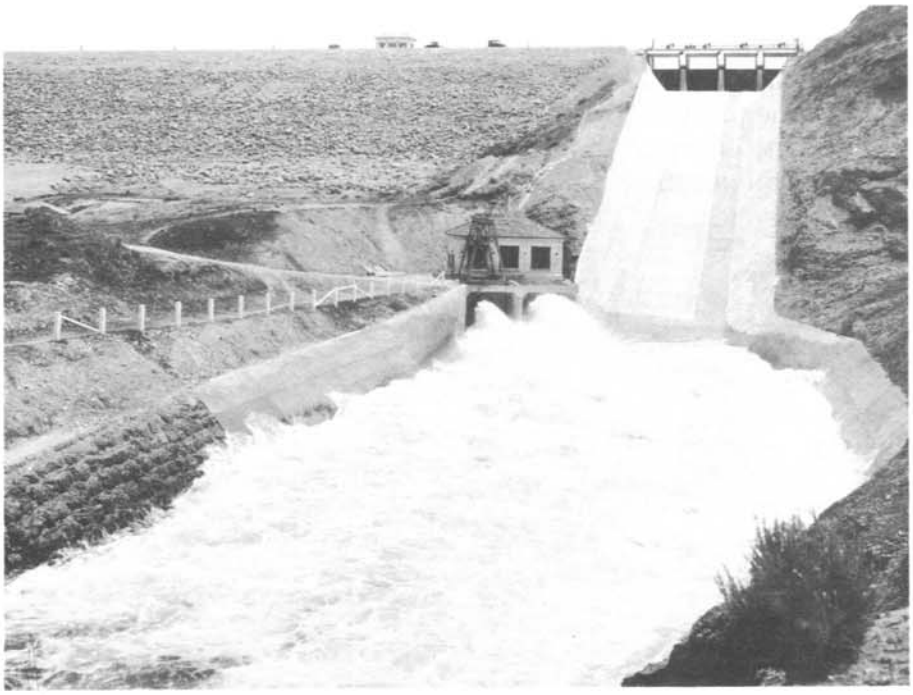
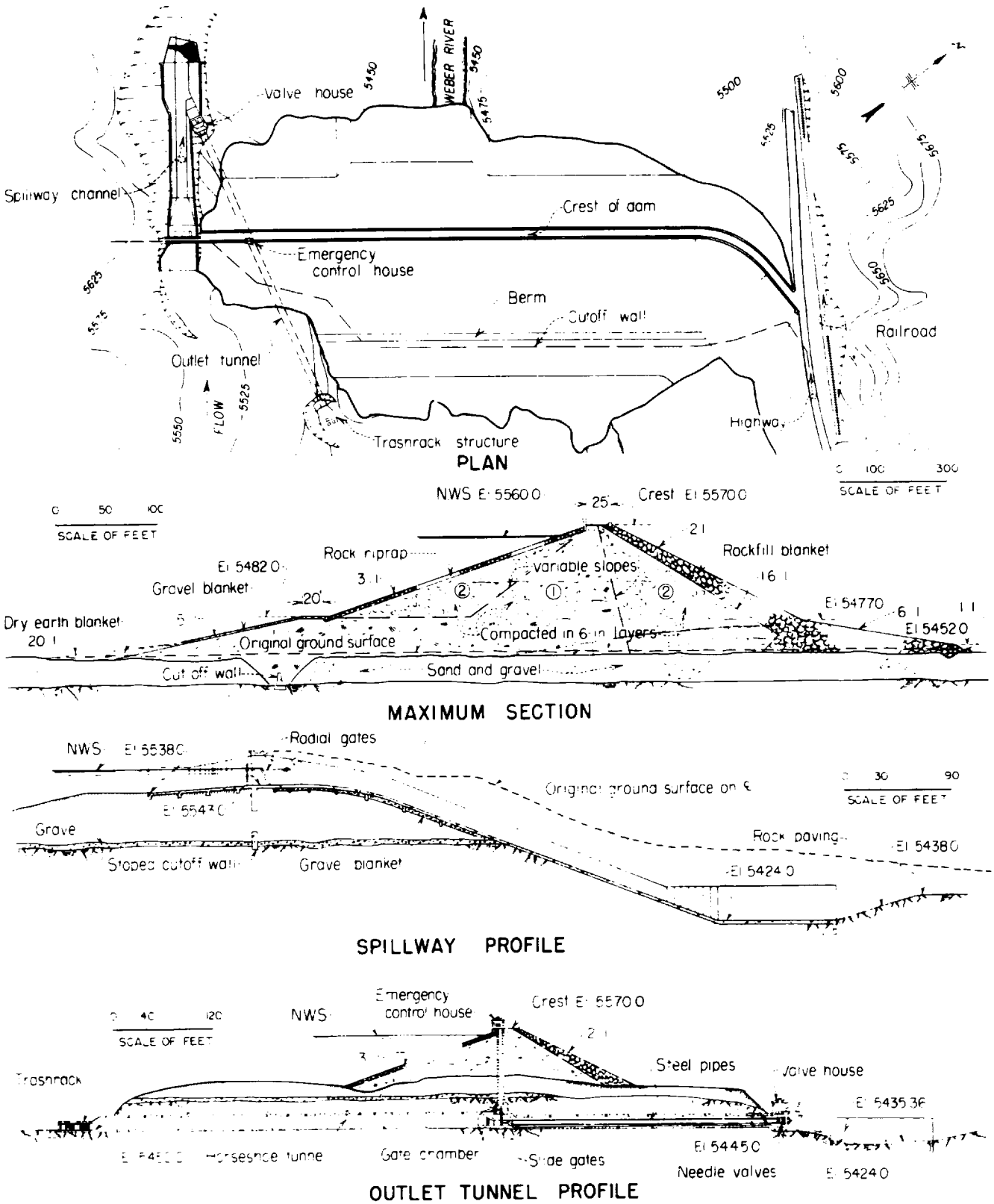


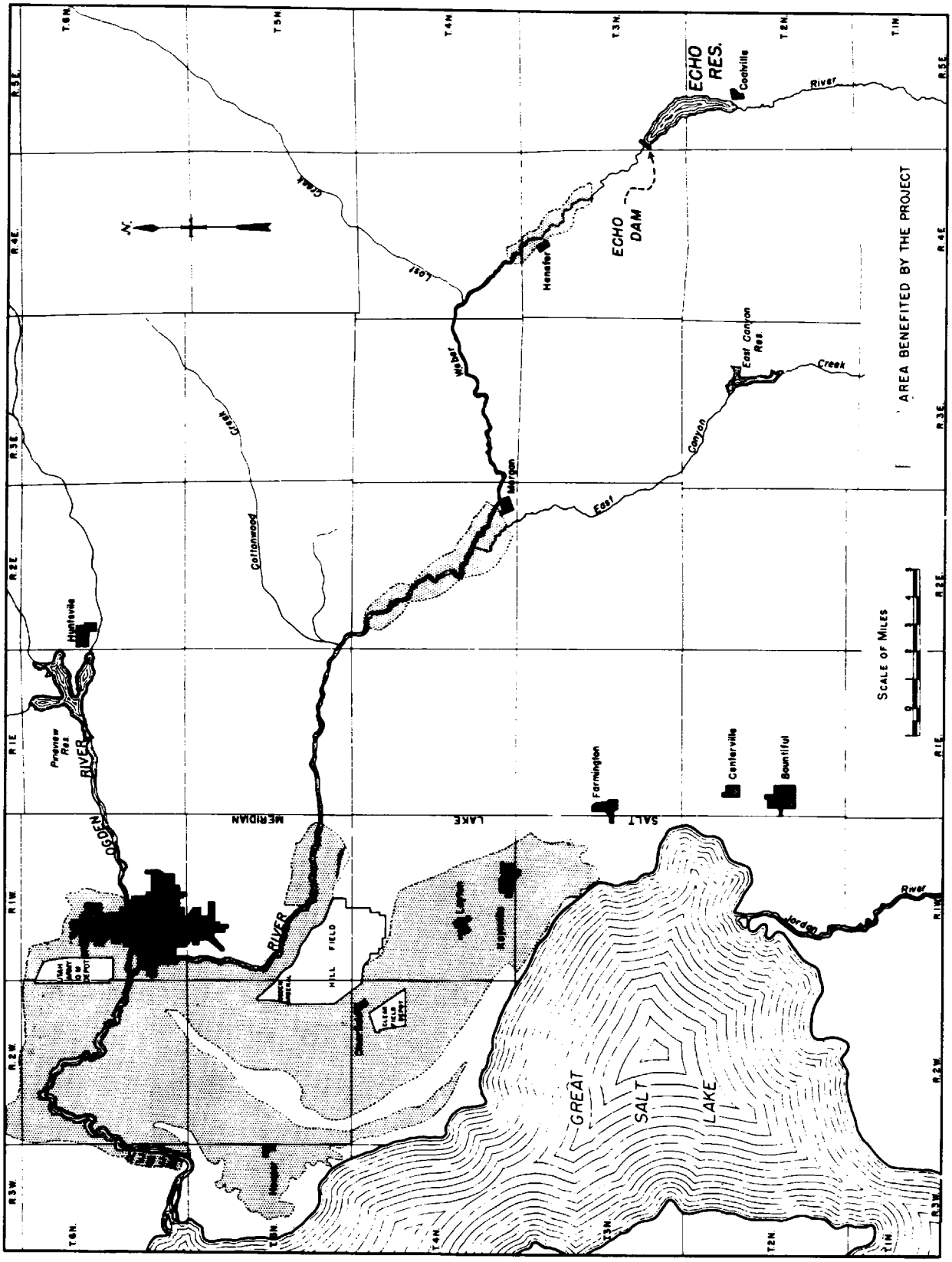
Photo 2. - View of Echo Dam spillway and release from balanced needle valves. 6/13/32 (These needle valves were replaced with jet flow gates in April 1987.)

Photo 3. - Aerial view of Echo Dam and Reservoir. 7/1/58

## *Weber River Project*




**Echo Dam. Plan and Sections**




Weber River Project

## CASE STUDY

## SAN LUIS DAM - EMBANKMENT UPSTREAM SLOPE FAILURE

| | |
|---|---|
| Project: | Central Valley |
| State: | California |
| Type: | Zoned earthfill |
| Completed: | 1967 |
| Function(s): | Offstream pump storage, irrigation, power |
| Crest length: | 18,600 |
| Hydraulic height: | 305 feet |
| Active capacity: | 1,961,000 acre-feet |
| Surface area: | 13,000 acres |

Design characteristics: The principal features involved in the construction of San Luis Dam are a zoned earthfill embankment, spillway, outlet works, dike, and roadway.

A cutoff trench of limited width averaging 3 to 5 feet in depth was constructed on the abutments under the dam to reach groutable sedimentary rocks of the Panoche Group of Cretaceous age. These consist of thin- to medium-bedded sandstones, claystones, and clay shales and of medium- to thick-bedded cobble conglomerate. A grout cap was placed into foundation rock in the bottom of the cutoff trench, and a grout curtain was constructed in the foundation. Because of the depth to sedimentary rocks in the valley floor, the cutoff trench was discontinued in the vicinity of San Luis Creek, and upstream and downstream foundation trenches up to 100 feet deep were excavated. These trenches bottom on firm clayey gravel and extend below two weak clay beds in the alluvium. This construction provides for a bond between the impervious core of the dam and the natural impervious blanket, as well as support for the dam between the stability trenches and adjacent to the cutoff. The foundation for the embankment upstream and downstream of the cutoff and foundation trenches was stripped on an average of 2 feet. Fat, saturated, soft clays were found which were considered unstable but were not removed downstream of the cutoff trench.

Zone 1 of the dam, derived from older terrace deposits, is a large central impervious core of the embankment and consists predominantly of clay, clayey gravel, and clayey sand compacted by tamping rollers to 6-inch layers. The zone 2 filter blanket, derived from the San Luis Creek alluvium, consists of mostly selected sand and gravel which had an average of 59 percent plus No. 4 material and was compacted by a crawler-type tractor to 12-inch layers. A miscellaneous zone 3 consisting of sedimentary rock and fat clays was compacted in 12-inch layers. Zones 4 and 5 are rockfill zones derived from basalt quarried from Basalt Hill. Zone 4 is minus 8-inch rock fragments compacted by a crawler-type tractor to 12-inch layers. Zone 5 consisted of plus 8-inch rock. Basalt riprap was placed in 2-foot layers of a 12-inch bedding on the upstream slope below elevation 400. Downstream slope protection was also provided by basalt.

Evidence: Analysis of settlement point survey data and longitudinal cracking observed in 1981 and pre-1981 in the dam crest road gave evidence of embankment settlement prior to the failure. The repeated cracking and patching of the crest road were also evidence of a stability problem prior to the slide.

Incident: After a reservoir drawdown of 180 feet in less than 4 months (May 1 to August 24), an examination team observed a vertical scarp about 2 feet high on the upstream slope of San Luis Dam near the crest that exposed zone 1 embankment. On September 14, 1981, a major slide occurred in the embankment on the upstream left abutment slope. The slide was marked by a prominent head scarp that continued to move and grow both horizontally and vertically after the initial failure. The slide ultimately attained a horizontal length of approximately 1,700 feet and an overall width of 600 feet, extending from dam crest (elevation 554) into the foundation. It involved approximately 1.3 million cubic yards of zones 4 and 5 rockfill, miscellaneous zone 3 fill of sedimentary rock and fat clay, and zone 1 impervious core. Slide movement virtually ceased by mid-December 1981. The slide was obviously critical to the stability of the dam and had to be repaired before filling for the next irrigation season.

Cause: Static analysis indicated a combination of increased pore pressures associated with rapid drawdown of the reservoir and weakening of the natural slope wash (the fat clay which was not excavated from the natural slope during construction), and layers of weakness in the random fill zone 3 material contributed to the failure. The local westward (upstream) and southwestward sloping foundation topography was also associated with the failure.

Remedy: The following plan for investigation and remedial action was prepared and implemented immediately following the incident:

1. Surveys determined the extent of the slide and provided an indicator for progressive slip movement and expansion.

2. An exploration and materials testing program was established to provide information on the mechanism for the slide and to provide reliable data for stability analysis.

3. Inclinometers were installed in six drill holes to locate the depth of the slide. Six additional inclinometers were installed in close proximity to monitor the possible expansion of the slide and slope stability after repairs. The slide proved to be an average of 50 to 60 feet in depth, with a maximum depth of 71 feet.

4. Vibrating-wire piezometers were installed in another six drill holes on the slide to initially monitor pore pressures. Subsequently, piezometers were installed in 11 additional drill holes in the slide area.

5. An evaluation of other areas for potential stability was conducted. It consisted of a battery of tests including index testing, vane shear testing, and other soil testing and analysis. Drill holes equipped with inclinometers and piezometers were completed at other locations on the dam. In addition, existing historical test data were gathered and analyses were performed.

6. The detailed investigations were also reviewed by a panel of consultants for the Bureau of Reclamation and the California Department of Water Resources. It was determined that a 2,100-foot-long stability berm (berm 1) was required along the slide toe to buttress the dam. The berm was constructed with a basal rock drainage blanket (zone 6) and compacted embankment derived by common means from terrace alluvium and weathered sedimentary rocks. It was also determined that the portion of the dam

above the stability berm could be reconstructed to dam crest. In the slide scarp area, a sizable quantity of zones 1, 3, and 4 materials were removed and the embankment reconstructed of rock drainage blanket material covered with plus 8-inch basalt. Berm 1 construction required 1,670,000 $yd^3$ of material.

7. Additional analysis of existing data and exploration revealed two other upstream areas and one downstream area where foundation conditions required construction of stability berms (foundation topography sloping toward the reservoir or downstream, the presence of slope wash of fat clay, and the absence of the 8:1 sloping embankment buttresses). Upstream berm 2 near the south end of the dam required 420,000 $yd^3$ and upstream berm 3 north of the intake structure required 714,900 $yd^3$ of material. Berm 4 on the downstream side near the north end of the dam required 392,160 $yd^3$. These berms were similar in construction to berm 1 at the slide.

8. Vibrating-wire piezometers and inclinometers were installed in the berms to monitor the behavior of the stability berms. Some of the inclinometer casings contain permanently installed inclinometer instruments for remote readout.

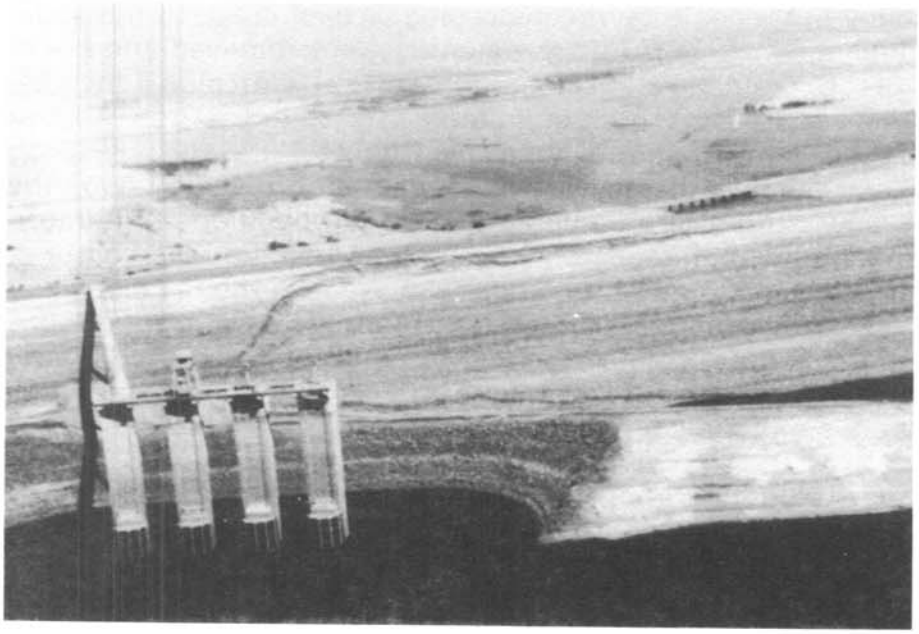


Figure 1. - Showing San Luis Dam failure. 12/81.

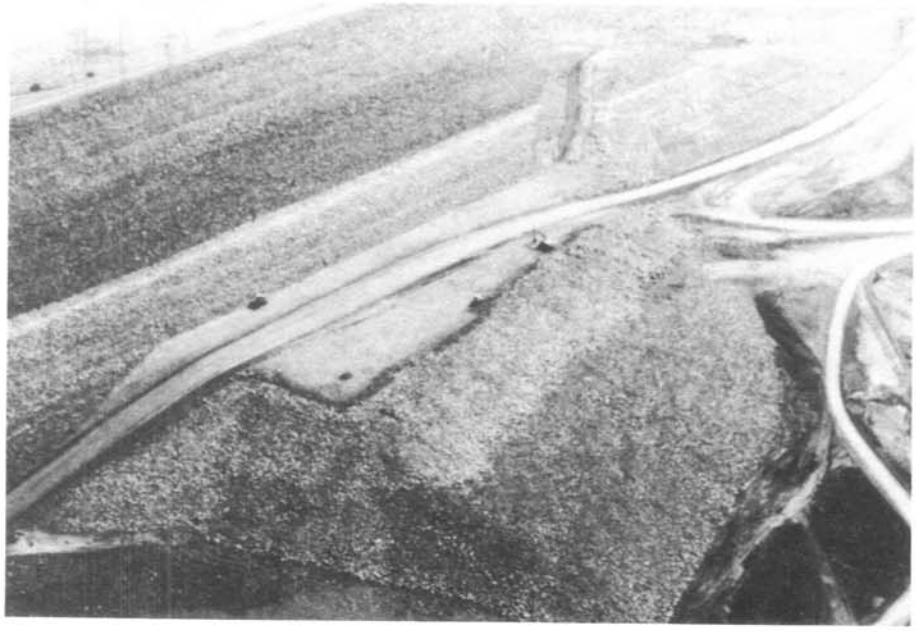
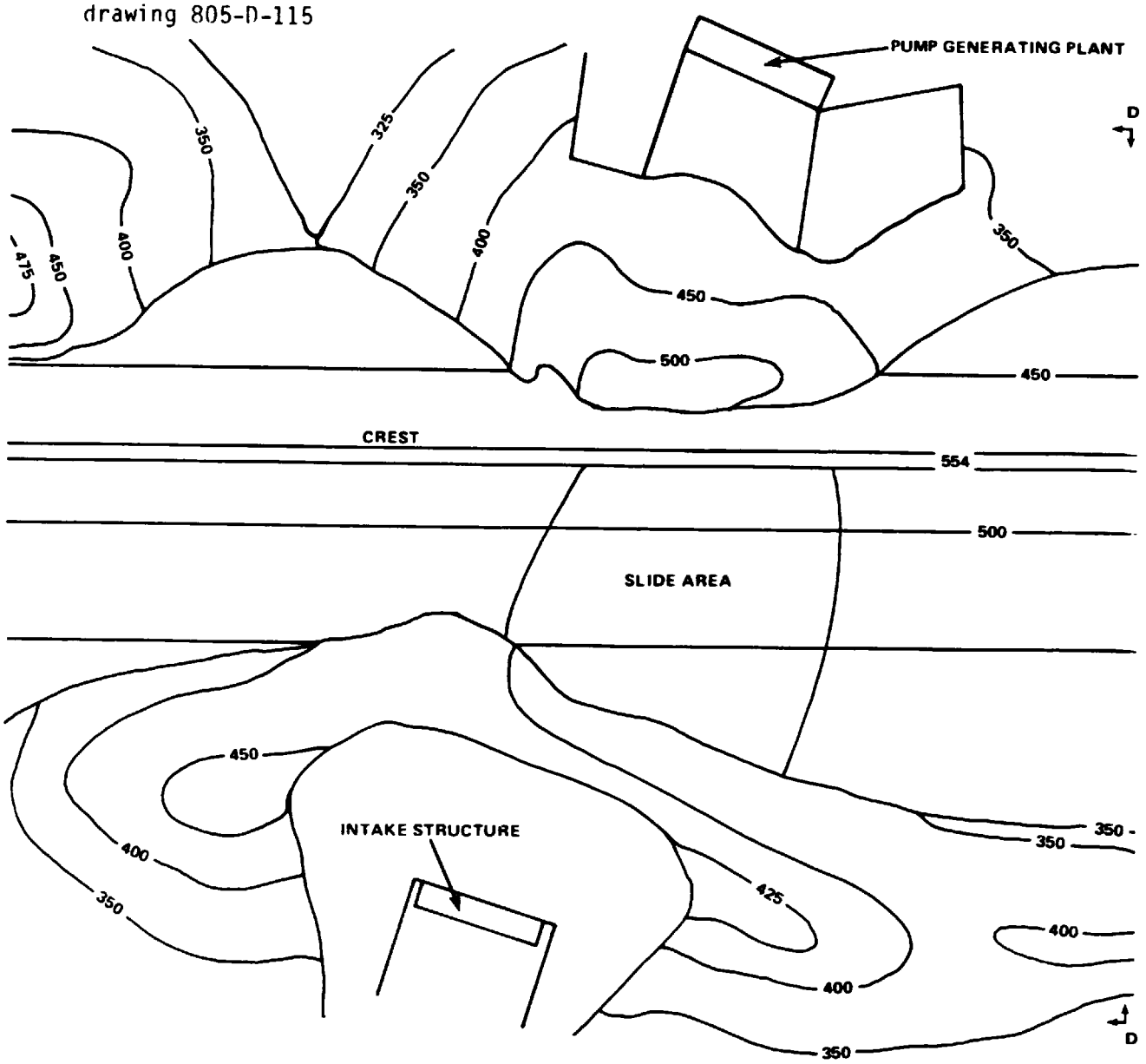
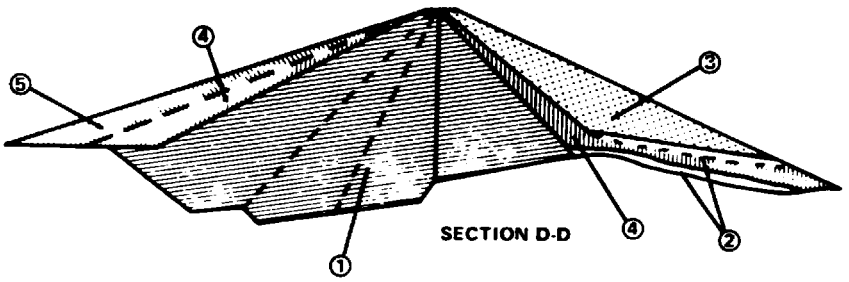


Figure 2. - San Luis Dam repair. Aerial view looking easterly at completed berm at upstream station 58, near the right abutment of the dam. 10/82.

drawing 805-D-115




PLAN SECTION AT SLIDE AREA




SAN LUIS DAM

## WATER SYSTEMS OPERATION AND MAINTENANCE COST INDEX

Trends of operation and maintenance (O&M) costs are known to differ in general from those of construction costs. Therefore, the trends of water systems project O&M costs are not properly measured by existing popular construction cost indices. O&M costs experienced on Bureau of Reclamation irrigation projects have been used to develop an index which measures the trends of these costs.

All Reclamation projects receiving full or supplemental water service for which operation, maintenance, and replacement (OM&R) costs and irrigated acres are reported in the annual Crop Production and Water Utilization Reports are used in computing the Bureau-wide O&M Cost Index. Both Bureau and water user costs are included. This index should be used where there is need to update O&M costs when it is appropriate to do so by use of an index.

O&M cost index numbers for the years 1970 through 1987 are presented in Table 1.

Figure 1 compares graphically the Bureau of Reclamation O&M Cost Index with the Engineering News Record Construction Cost Index and Reclamation's Composite Construction Cost Index. The average O&M cost per irrigated acre for each region also has been calculated and is presented in Table 2. Table 3 provides a breakdown of 1987 cost data by individual district.

### Use of O&M Cost Index

The three basic uses of the O&M Cost Index are:

1. To adjust to a common year price level annual O&M costs experienced during a given year.

2. To adjust to the current price level values obtained from O&M cost estimating guides.

3. To adjust to the current price level an O&M cost estimates based on some past price level. This would be appropriate where the earlier estimate is adequately prepared for the proposed use provided the intervening local area wage rate trends are not abnormal. The following example illustrates use of the cost index for adjusting Reclamation's OM&R cost estimates:

   Given: An estimate prepared in 1980 to be adjusted to 1988 costs. Estimates of annual provisions for major replacement and electrical energy costs should be adjusted by using current construction costs and energy rates, respectively.

O&M costs, exclusive of major replacement and energy costs, should be indexed as follows:

| Date of Estimate | O&M Cost Index |
|---|---|
| 1980 | Use 1979[1] = 113 |
| 1988 | Use 1987[2] = 205 |

Ratio of indices $\frac{205}{113} = 1.81$

The 1980 subtotal for personnel, equipment, materials, supplies, administration, and general expenses = $35,000.

The 1988 subtotal for personnel, equipment, materials, supplies, administration, and general expenses = $35,000 x 1.81 = $63,350.

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1 1979 index is based on same O&M costs experience as used in 1980 O&M estimate.
2 1988 O&M estimate would be based on 1987 cost experience, on which the 1987 index is also based.

Table 1.–Water Systems
Operation and Maintenance Cost Index
1977* = 100

| Year | Index |
|---|---|
| 1970 | 66 |
| 1971 | 68 |
| 1972 | 71 |
| 1973 | 74 |
| 1974 | 78 |
| 1975 | 84 |
| 1976 | 92 |
| 1977 | 100 |
| 1978 | 106 |
| 1979 | 113 |
| 1980 | 128 |
| 1981 | 144 |
| 1982 | 153 |
| 1983 | 164 |
| 1984 | 165 |
| 1985 | 181 |
| 1986 | 197 |
| 1987 | 205 |

* 1976-78 average ($13.32 per irrigated acre)

Table 2.–Average O&M Cost Per Irrigated Acre
by Region, 1987

| Region | $ Per Acre | Reporting Entities |
|---|---|---|
| Pacific Northwest | 22.23 | 108 |
| Mid-Pacific | 37.69 | 118 |
| Lower Colorado | 73.64 | 11 |
| Upper Colorado | 9.94 | 49 |
| Southwest | 42.17 | 15 |
| Missouri Basin | 10.42 | 93 |
| Bureau-wide | 27.29 | 394 |

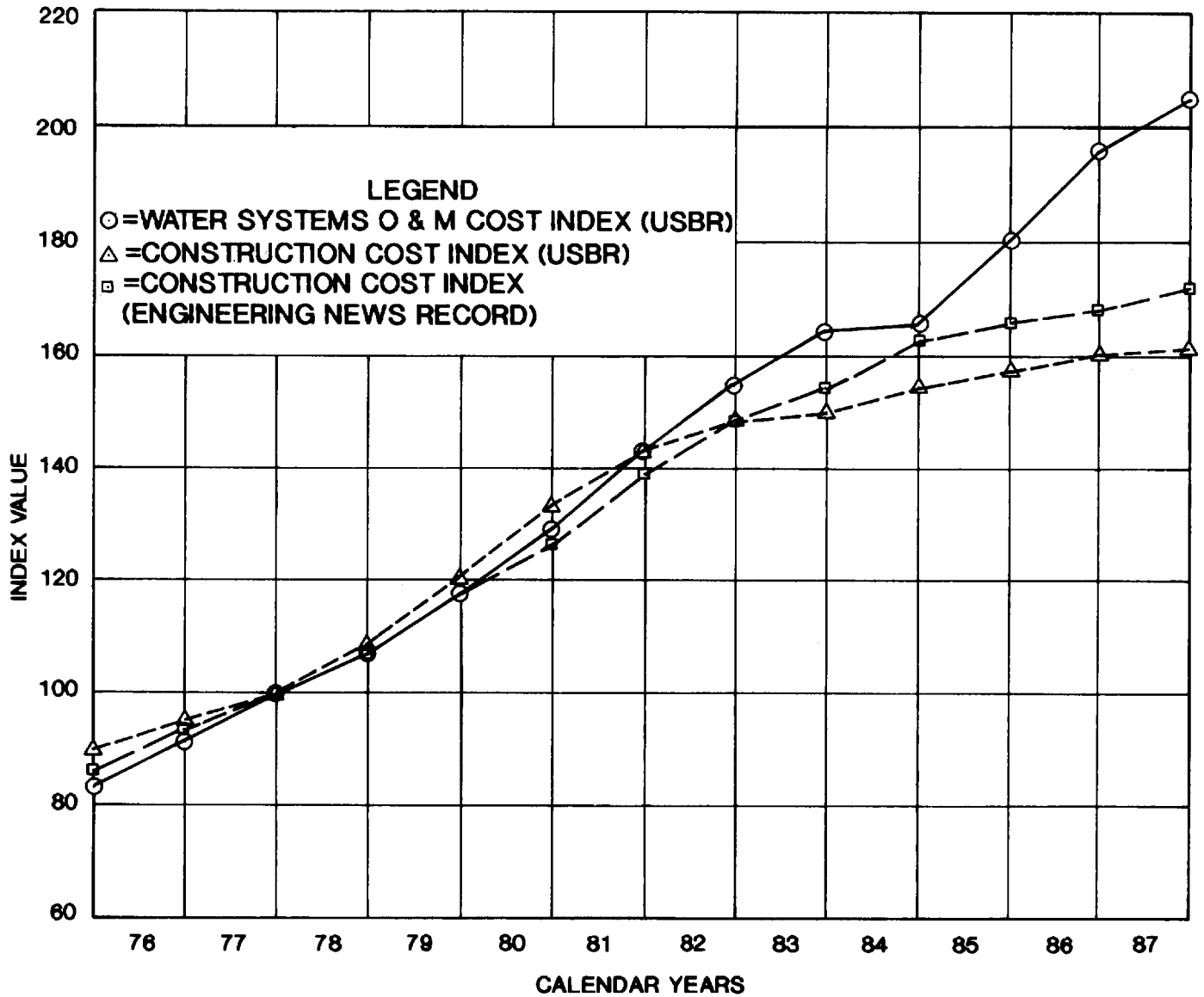


FIGURE 1 - WATER SYSTEMS OPERATION AND MAINTENANCE
COST INDEX COMPARISON
1977=100

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

AGRICULTURE OPERATION AND MAINTENANCE COSTS AND GROSS CROP VALUES PER IRRIGATED ACRE - 1987



| REGION, PROJECT | SUPPLY | IRRIGATED ACRES | GROSS CROP VALUE PER IRRIGATED ACRES | AGRICULTURAL O&M COST PER IRRIGATED ACRE ($) BUREAU | WATER USER | TOTAL |
|---|---|---|---|---|---|---|
| PACIFIC NORTHWEST REGION | | | | | | |
| ARNOLD | F | 1,021 | 180.02 | | 148.99 | 148.99 |
| AVONDALE | F | 253 | 137.98 | | 687.43 | 687.43 |
| BAKER | | | | | | |
| LOWER POWDER RIVER I D | S | 7,145 | 208.92 | | 3.40 | 3.40 |
| BAKER VALLEY I D | S | 17,450 | 170.92 | | 12.97 | 12.97 |
| BITTER ROOT | F | 15,533 | 134.80 | | A/ 11.12 | A/ 11.12 |
| BOISE, OR-ID | | | | | | |
| ARROWROCK DIVISION | | | | | | |
| BIG BEND I D | F | 1,198 | 346.02 | 1.57 | 29.76 | 31.33 |
| BOISE-KUNA I D | F | 36,357 | 416.38 | 1.41 | 26.67 | 28.08 |
| NAMPA - MERIDIAN I D | F | 25,435 | 469.56 | 1.35 | 25.48 | 26.83 |
| NEW YORK I D | F | 7,882 | 266.23 | 1.37 | 25.75 | 27.12 |
| SETTLERS I D | F | 455 | 303.53 | 3.01 | 22.55 | 25.56 |
| SP-WN ACT CONTR | | | | | | |
| BALLENTYNE D C | S | 580 | 376.13 | .10 | A/ 9.69 | A/ 9.79 |
| BOISE VALLEY IDC | S | 1,500 | 205.82 | .11 | A/ 6.71 | A/ 6.82 |
| CAPITOL VIEW I D | S | 318 | 291.71 | .23 | A/ 10.33 | A/ 10.56 |
| FARMERS CO-OP D C | S | 14,555 | 427.91 | .03 | A/ 21.99 | A/ 22.02 |
| FARMERS UNION D C | S | 7,371 | 319.81 | .28 | A/ 21.86 | A/ 22.14 |
| NAMPA - MERIDIAN I D | S | 23,077 | 416.67 | .05 | 27.96 | 28.01 |
| NEW DRY CREEK D C | S | 2,030 | 274.42 | .11 | A/ 11.96 | A/ 12.07 |
| PIONEER DITCH C | S | 1,220 | 440.99 | .34 | A/ 13.99 | A/ 14.33 |
| PIONEER I D | S | 29,245 | 461.65 | .35 | 20.22 | 20.57 |
| RIVERSIDE I D | S | 9,111 | 522.48 | | A/ 20.01 | A/ 20.01 |
| SETTLERS I D | S | 8,872 | 357.65 | .06 | A/ 21.86 | A/ 21.92 |
| SO BOISE MUTUAL I C | S | 260 | 115.69 | .34 | A/ 18.35 | A/ 18.69 |
| WILDER I D | F | 44,060 | 878.46 | 1.40 | 26.86 | 28.26 |
| PAYETTE DIVISION | | | | | | |
| BLACK CANYON I D NO 1 | F | 6,251 | 845.87 | | 23.39 | 23.39 |
| BLACK CANYON I D NO 2 | F | 42,887 | 408.69 | 1.38 | 26.36 | 27.74 |
| SP-WN ACT CONTR | | | | | | |
| EMMETT I D | S | 20,180 | 467.43 | 3.93 | 9.76 | 13.69 |
| FARMERS CO-OP I C | S | 15,035 | 428.86 | .15 | A/ 14.73 | A/ 14.88 |
| LOWER PAYETTE D C | S | 11,844 | 407.12 | .05 | A/ 13.78 | A/ 13.83 |
| BURNT RIVER | S | 15,070 | 175.40 | | 1.95 | 1.95 |
| CHIEF JOSEPH DAM | | | | | | |
| CHELAN DIVISION | | | | | | |
| LAKE CHELAN RECL DIST | F | 5,946 | 3,310.02 | 62.96 | 57.59 | 120.55 |
| FOSTER CREEK DIVISION | | | | | | |
| BREWSTER FLAT I D | F | 2,316 | 2,350.81 | | 55.55 | 55.55 |
| BRIDGEPORT BAR I D | F | 425 | 1,838.31 | | 26.37 | 26.37 |
| GREATER WENATCHEE DIVISION | F | 6,196 | 6,030.79 | | 86.93 | 86.93 |
| OKANOGAN-SIMILKAMEEN | | | | | | |
| OROVILLE-TONASKET I D | F | 7,819 | 2,477.05 | | 97.67 | 97.67 |
| WHITESTONE COULEE UNIT | S | 2,615 | 1,147.64 | | 35.03 | 35.03 |
| COLUMBIA BASIN | | | | | | |
| EAST COLUMBIA BASIN I D | F | 111,171 | 520.18 | 5.05 | 29.40 | 34.45 |
| QUINCY-COLUMBIA BASIN I D | F | 206,499 | 644.79 | 4.50 | 24.92 | 29.42 |
| SOUTH COLUMBIA BASIN I D | F | 187,946 | 699.52 | 3.37 | 24.70 | 28.07 |
| CRESCENT LAKE DAM | F | 9,076 | 220.53 | | 34.01 | 34.01 |
| CROOKED RIVER | F | 15,707 | 379.89 | | 18.45 | 18.45 |
| DALTON GARDENS | F | 9 | 40.00 | | 117.78 | 117.78 |
| DESCHUTES | | | | | | |
| 1/ CENTRAL OREGON I D | S | 43,730 | 193.50 | | 24.61 | 24.61 |
| CROOK COUNTY IMP D NO 1 | S | 2,285 | 334.47 | . | A/ 19.08 | A/ 19.08 |
| NORTH UNIT I D | F | 41,046 | 601.33 | | 27.97 | 27.97 |
| FRENCHTOWN | F | 3,835 | 204.06 | | 8.11 | 8.11 |
| 1/ KING HILL I D | F | 7,684 | 615.34 | | 114.41 | 114.41 |
| LITTLE WOOD RIVER | S | 4,489 | 121.61 | | 2.36 | 2.36 |
| MANN CREEK | | | | | | |
| MANN CREEK I D | S | 3,376 | 311.35 | | 3.13 | 3.13 |
| MONROE CREEK I D | S | 830 | 217.86 | | 12.56 | 12.56 |
| MICHAUD FLATS | F | 9,668 | 507.50 | .85 | 38.18 | 39.03 |
| MINIDOKA-PALISADES | | | | | | |
| A-B IRRIGATION DISTRICT | F | 67,935 | 590.19 | .25 | 38.50 | 38.75 |
| AMERICAN FALLS RES D NO 2 | B | 76,506 | 429.51 | 1.83 | 28.34 | 30.17 |
| BURLEY I D | F | 39,511 | 569.43 | 1.84 | 29.79 | 31.63 |
| FREMONT-MADISON I D | S | 99,400 | 260.18 | .53 | A/ 1.43 | A/ 1.96 |
| MINIDOKA I D | F | 59,067 | 556.18 | .99 | 17.44 | 18.43 |
| SP-WARREN ACT CONTR | | | | | | |
| ABOVE AMERICAN FALLS | S | 323,716 | 300.01 | .55 | A/ 6.94 | A/ 7.49 |
| BELOW AMERICAN FALLS | S | 356,762 | 437.54 | .53 | A/ 6.64 | A/ 7.17 |
| MISSOULA VALLEY | F | 150 | 170.50 | | A/ 19.79 | A/ 19.79 |
| OKANOGAN | F | 4,197 | 1,291.92 | | 71.81 | 71.81 |
| OWYHEE, OR-ID | | | | | | |
| NORTH DIVISION | | | | | | |
| ADVANCEMENT I D | F | 239 | 596.08 | | 20.33 | 20.33 |
| BENCH I D | F | 2,125 | 924.46 | | 22.19 | 22.19 |
| CRYSTAL I D | F | 984 | 960.11 | | 26.45 | 26.45 |
| ONTARIO-NYSSA I D | F | 5,294 | 5,007.61 | | 22.40 | 22.40 |
| OWYHEE IRRIGATION DIST | F | 42,583 | 669.08 | | 23.76 | 23.76 |
| PAYETTE-OREGON SLOPE I D | F | 4,298 | 1,257.95 | | 22.14 | 22.14 |
| SLIDE IRRIGATION DIST | F | 1,097 | 1,021.28 | | 21.21 | 21.21 |
| OWYHEE DITCH COMPANY | S | 12,475 | 1,036.09 | | A/ 21.24 | A/ 21.24 |
| SOUTH DIVISION | | | | | | |
| GEM I D | F | 29,080 | 457.92 | | 28.26 | 28.26 |

## AGRICULTURE OPERATION AND MAINTENANCE COSTS AND GROSS CROP VALUES PER IRRIGATED ACRE - 1987



| REGION, PROJECT | SUPPLY | IRRIGATED ACRES | GROSS CROP VALUE PER IRRIGATED ACRES | AGRICULTURAL O&M COST PER IRRIGATED ACRE ($) BUREAU | WATER USER | TOTAL |
|---|---|---|---|---|---|---|
| RIDGEVIEW I D | F | 5,717 | 427.34 | | 25.11 | 25.11 |
| RATHDRUM PRAIRIE | | | | | | |
| EAST GREENACRES I D | F | 4,080 | 167.57 | | 40.92 | 40.92 |
| HAYDEN LAKE I D | F | 1,092 | 152.41 | | A/ 63.79 | A/ 63.79 |
| POST FALLS I D | F | 1,753 | 210.77 | | 51.59 | 51.59 |
| ROGUE RIVER BASIN | | | | | | |
| TALENT DIVISION | | | | | | |
| MEDFORD I D | F | 6,745 | 1,161.06 | .59 | 41.70 | 42.29 |
| ROGUE RIVER VALLEY I D | S | 6,098 | 441.73 | 1.65 | 28.69 | 30.34 |
| TALENT I D | S | 12,088 | 704.52 | 3.71 | 37.52 | 41.23 |
| 1/ SALMON RIVER CANAL C | S | 21,948 | 246.59 | | A/ 12.90 | A/ 12.90 |
| SPOKANE VALLEY | F | 4,240 | 283.97 | | 112.33 | 112.33 |
| THE DALLES | F | 5,414 | 2,313.65 | | 38.89 | 38.89 |
| TUALATIN | F | 13,516 | 2,086.89 | 1.41 | 28.17 | 29.58 |
| UMATILLA | | | | | | |
| EAST DIVISION | | | | | | |
| HERMISTON I D | F | 7,800 | 228.77 | | 26.89 | 26.89 |
| SOUTH DIVISION | | | | | | |
| STANFIELD I D | S | 5,477 | 409.83 | 1.91 | 44.53 | 46.44 |
| WESTLAND I D | S | 6,293 | 238.24 | 1.95 | A/ 45.48 | A/ 47.43 |
| WEST DIVISION | | | | | | |
| WEST EXTENSION I D | F | 5,500 | 194.73 | | 45.94 | 45.94 |
| VALE | F | 32,707 | 247.59 | | 17.13 | 17.13 |
| WAPINITIA | S | 2,018 | 242.30 | | A/ 14.08 | A/ 14.08 |
| 1/ WENATCHEE HEIGHTS RECL D | F | 739 | 1,148.39 | | 83.48 | 83.48 |
| YAKIMA | | | | | | |
| KENNEWICK DIVISION | F | 8,764 | 907.93 | 8.65 | 96.72 | 105.37 |
| KITTITAS DIVISION | F | 52,065 | 350.66 | 2.71 | 12.84 | 15.55 |
| ROZA DIVISION | F | 65,599 | 1,483.99 | 3.51 | 46.49 | 50.00 |
| SUNNYSIDE DIVISION | | | | | | |
| BENTON I D | F | 2,846 | 908.17 | .94 | 56.50 | 57.44 |
| GRANDVIEW I D | F | 2,901 | 1,233.45 | 1.00 | 57.35 | 58.35 |
| GRANGER I D | F | 1,231 | 804.45 | .95 | 69.60 | 70.55 |
| OUTLOOK I D | F | 3,603 | 875.15 | .94 | A/ 50.90 | A/ 51.84 |
| PROSSER I D | F | 1,531 | 1,016.18 | 1.03 | 61.64 | 62.67 |
| SNIPES MOUNTAIN I D | F | 1,157 | 841.34 | .96 | 40.53 | 41.49 |
| SUNNYSIDE VALLEY I D | F | 58,875 | 1,045.45 | .93 | 33.18 | 34.11 |
| SP-WN ACT CONTR | | | | | | |
| BROADWAY I D | S | 14 | 5,000.00 | 6.79 | 19.79 | 26.58 |
| CASCADE I D | S | 10,671 | 199.73 | .49 | 25.47 | 25.96 |
| MOXEE | S | 325 | 2,062.63 | .51 | 74.44 | 74.95 |
| NACHES-SELAH I D | S | 9,300 | 1,454.27 | .51 | 41.51 | 42.02 |
| SELAH-MOXEE I D | S | 6,165 | 1,410.32 | .49 | A/ 54.50 | A/ 54.99 |
| SMALL WARREN ACT CONTR | S | 80 | 365.00 | .54 | | .54 |
| TERRACE HEIGHTS I D | S | 270 | 819.85 | .76 | A/ 34.55 | A/ 35.31 |
| UNION GAP I D | S | 3,100 | 1,978.46 | .54 | 37.63 | 38.17 |
| WEST SIDE I C | S | 5,800 | 246.38 | .58 | 10.47 | 11.05 |
| YAKIMA VALLEY C C | S | 2,430 | 1,448.29 | .51 | 29.11 | 29.62 |
| TIETON DIVISION | | | | | | |
| YAKIMA-TIETON I D | F | 25,574 | 1,447.02 | 2.01 | A/ 4.50 | A/ 6.51 |
| MID-PACIFIC REGION | | | | | | |
| 1/ BROWNS VALLEY I D | S | 7,559 | 253.98 | | 10.66 | 10.66 |
| 1/ BYRON-BETHANY I D | S | 9,835 | 847.08 | | 75.75 | 75.75 |
| CACHUMA | | | | | | |
| CARPINTERIA CY W D | S | 3,442 | 15,889.78 | | 189.05 | 189.05 |
| 2/ GOLETA CY W D | S | 6,842 | 3,811.37 | | 103.54 | 103.54 |
| SUMMERLAND CY W D | S | 153 | 2,388.00 | | 364.64 | 364.64 |
| 1/ CAMROSA COUNTY W D | S | 3,620 | 5,962.76 | | 485.15 | 485.15 |
| CENTRAL VALLEY | | | | | | |
| AMERICAN RIVER DIV | | | | | | |
| FOLSOM UNIT | | | | | | |
| SAN JUAN SUBURBAN W D | S | 2,054 | 1,156.10 | .44 | | .44 |
| SLY PARK UNIT | | | | | | |
| EL DORADO I D | S | 5,659 | 1,527.34 | 1.28 | 191.46 | 192.74 |
| DELTA DIVISION | | | | | | |
| CONTRA COSTA CANAL | | | | | | |
| CONTRA COSTA W D | S | 1,170 | 491.99 | .44 | 111.79 | 112.23 |
| DELTA-MENDOTA | | | | | | |
| 2/ BANTA-CARBONA I D | S | 15,464 | 1,047.37 | 12.47 | 71.26 | 83.73 |
| 3/ BROADVIEW W D | S | 7,870 | 900.64 | 22.10 | 134.78 | 156.88 |
| CENTINELLA W D | F | 425 | 1,829.18 | 39.33 | 5.23 | 44.56 |
| DAVIS WATER DISTRICT | F | 1,393 | 1,692.21 | 31.54 | 3.23 | 34.77 |
| DEL PUERTO W D | F | 3,505 | 1,593.58 | 28.72 | 2.82 | 31.54 |
| EAGLE FIELD W D | S | 1,306 | 835.65 | 22.59 | | 22.59 |
| FOOTHILL WATER DIST | F | 3,190 | 1,507.29 | 27.68 | 2.78 | 30.46 |
| FRESNO SLOUGH W D | S | 910 | 858.44 | 34.28 | | 34.28 |
| HOSPITAL W D | F | 9,436 | 1,734.73 | 30.36 | 2.79 | 33.15 |
| HUGHES, MELVIN D | S | 35 | 660.34 | 2.86 | | 2.86 |
| JAMES IRRIGATION DIST | S | 21,635 | 823.36 | 17.09 | 42.34 | 59.43 |
| KERN CANON W D | F | 2,320 | 1,483.46 | 27.60 | 1.72 | 29.32 |
| MERCY SPRINGS W D | F | 2,336 | 271.93 | 56.58 | 23.25 | 79.83 |
| MUSTANG WATER DIST | F | 3,672 | 791.55 | 34.53 | 2.96 | 37.49 |
| ORESTIMBA W D | F | 5,052 | 1,337.28 | 24.37 | 2.56 | 26.93 |
| ORO LOMA W D | S | 992 | 339.20 | 36.26 | | 36.26 |
| PACHECO W D | S | 1,936 | 1,393.21 | 30.43 | | 30.43 |
| PANOCHE W D | S | 22,166 | 824.43 | 15.31 | 51.41 | 66.72 |

# AGRICULTURE OPERATION AND MAINTENANCE COSTS AND GROSS CROP VALUES PER IRRIGATED ACRE - 1987



| | REGION, PROJECT | SUPPLY | IRRIGATED ACRES | GROSS CROP VALUE PER IRRIGATED ACRES | AGRICULTURAL O&M COST PER IRRIGATED ACRE ($) BUREAU | WATER USER | TOTAL |
|---|---|---|---|---|---|---|---|
| | PATTERSON W D | S | 6,625 | 1,745.56 | 18.85 | 100.45 | 119.30 |
| | PLAIN VIEW W D | F | 5,050 | 1,076.04 | 34.87 | 21.78 | 56.65 |
| | QUINTO W D | S | 1,985 | 1,174.98 | 33.95 | 3.65 | 37.60 |
| | RECLAMATION D #1606 | S | 117 | 820.80 | 14.74 | | 14.74 |
| | ROMERO W D | S | 915 | 1,210.10 | 46.00 | 4.70 | 50.70 |
| | SALADO W D | F | 2,916 | 1,194.67 | 21.68 | 3.24 | 24.92 |
| | SAN LUIS W D | S | 9,016 | 1,388.36 | 28.36 | 180.21 | 208.57 |
| | SUNFLOWER W D | F | 4,027 | 1,007.37 | 36.56 | 3.04 | 39.60 |
| | THE WEST SIDE I D | S | 8,280 | 688.69 | 6.50 | 63.27 | 69.77 |
| | TRACTION RANCH-CASPER | S | 2,014 | 582.53 | 17.37 | | 17.37 |
| | TRANQUILLITY I D | S | 8,669 | 696.69 | 12.79 | 59.71 | 72.50 |
| | WEST STANISLAUS I D | S | 20,755 | 2,317.38 | 20.57 | | 20.57 |
| | WIDREN W D | S | 765 | 776.69 | 33.56 | | 33.56 |
| | FRIANT DIV | | | | | | |
| | FRIANT-KERN CANAL | | | | | | |
| 1/ | ALPAUGH I D | S | 5,000 | 626.03 | | 133.10 | 133.10 |
| 3/ | ARVIN-EDISON WSD | S | 97,135 | 2,473.07 | 4.78 | 66.32 | 71.10 |
| | DELANO-EARLIMART I D | S | 49,455 | 1,988.55 | 15.60 | 24.52 | 40.12 |
| | EXETER I D | S | 10,874 | 11,052.09 | 7.31 | 33.42 | 40.73 |
| | FRESNO I D | S | 166,083 | 2,325.47 | .92 | 26.56 | 27.48 |
| 3/ | GARFIELD W D | S | 1,523 | 4,134.65 | 17.56 | | 17.56 |
| | GREEN VALLEY W D | S | 552 | 816.20 | 4.99 | | 4.99 |
| | HILLS VALLEY I D | S | 1,987 | 2,891.46 | 14.17 | 76.03 | 90.20 |
| | INTERNATIONAL W D | S | 480 | 5,374.28 | 15.43 | 75.78 | 91.21 |
| | IVANHOE I D | S | 9,772 | 2,718.48 | 5.03 | 31.27 | 36.30 |
| | KERN-TULARE W D | S | 15,262 | 2,962.09 | 25.39 | | 25.39 |
| 3/ | LEWIS CREEK W D | S | 1,075 | 2,239.16 | 8.73 | | 8.73 |
| | LINDMORE I D | S | 23,957 | 3,114.31 | 8.02 | | 8.02 |
| | LINDSAY-STRATHMORE I D | S | 12,643 | 4,070.90 | 14.94 | | 14.94 |
| | LOWER TULE RIVER I D | S | 74,558 | 1,123.69 | 13.59 | 10.37 | 23.96 |
| | ORANGE COVE I D | S | 23,415 | 3,051.46 | 9.32 | | 9.32 |
| | PIXLEY W D | S | 49,943 | 962.06 | 6.16 | | 6.16 |
| | PORTERVILLE I D | S | 13,367 | 1,449.96 | 9.77 | | 9.77 |
| | RAG GULCH W D | S | 5,739 | 1,718.22 | 18.43 | | 18.43 |
| 3/ | SAUCELITO I D | S | 15,555 | 1,767.25 | 9.91 | | 9.91 |
| | SHAFTER-WASCO I D | S | 30,887 | 2,711.91 | 12.60 | 22.12 | 34.72 |
| | SO SAN JOAQUIN MUD | S | 46,136 | 1,746.11 | 13.91 | | 13.91 |
| | STONE CORRAL I D | S | 5,404 | 3,181.43 | 8.84 | 45.41 | 54.25 |
| | TEA POT DOME W D | S | 3,081 | 3,371.63 | 12.96 | 111.03 | 123.99 |
| 3/ | TERRA BELLA I D | S | 11,315 | 4,098.00 | 14.05 | 183.21 | 197.26 |
| | TRI-VALLEY W D | S | 564 | 2,090.77 | 20.25 | | 20.25 |
| | TULARE I D | S | 60,881 | 997.14 | 3.17 | 2.56 | 5.73 |
| | MADERA CANAL | | | | | | |
| 3/ | CHOWCHILLA W D | S | 47,985 | 1,094.50 | 11.63 | 22.69 | 34.32 |
| | MADERA I D | S | 94,971 | 1,556.91 | 7.90 | 21.97 | 29.87 |
| | SACRAMENTO RIVER DIV | | | | | | |
| | CORNING CANAL | | | | | | |
| | CORNING W D | S | 5,011 | 363.18 | 39.76 | | 39.76 |
| | ELDER CREEK W D | F | 1,068 | 304.87 | 26.05 | | 26.05 |
| 3/ | PROBERTA W D | F | 1,970 | 256.71 | 17.18 | | 17.18 |
| | THOMES CREEK W D | S | 1,727 | 401.19 | 30.21 | 1.12 | 31.33 |
| | TEHAMA-COLUSA | | | | | | |
| | COLUSA COUNTY W D | S | 28,678 | 1,037.39 | 14.36 | 8.08 | 22.44 |
| | CORTINA W D | F | 478 | 222.95 | 23.87 | | 23.87 |
| | DAVIS W D | S | 890 | 899.57 | 30.81 | | 30.81 |
| | DUNNIGAN W D | S | 5,793 | 551.17 | 15.55 | | 15.55 |
| | FOUR-M W D | F | 868 | 507.33 | 18.69 | | 18.69 |
| | GLENN VALLEY W D | F | 379 | 769.33 | 12.75 | | 12.75 |
| | GLIDE WATER DIST | F | 3,443 | 480.51 | 19.92 | | 19.92 |
| | HOLTHOUSE W D | F | 478 | 685.54 | 30.58 | | 30.58 |
| 3/ | KANAWHA W D | F | 11,093 | 396.70 | 21.97 | 18.38 | 40.35 |
| | KIRKWOOD W D | F | 153 | 290.27 | 20.53 | | 20.53 |
| | LA GRANDE W D | F | 1,109 | 480.89 | 34.77 | | 34.77 |
| | MYERS-MARSH MWC | S | 225 | 288.91 | 11.12 | | 11.12 |
| | ORLAND-ARTOIS W D | S | 20,182 | 579.69 | 22.23 | 31.88 | 54.11 |
| | RICHFIELD W D | S | 60 | 248.70 | 16.10 | | 16.10 |
| | TEHAMA W D | F | 122 | 300.00 | 6.09 | | 6.09 |
| 3/ | WESTSIDE W D | S | 9,409 | 732.64 | 25.89 | | 25.89 |
| | SHASTA DIVISION | | | | | | |
| | SHASTA DAM UNIT | | | | | | |
| | ANDERSON-COTTONWOOD ID | S | 19,194 | 243.37 | .97 | 22.09 | 23.06 |
| | COLUSA I C | S | 197 | 637.69 | .94 | | .94 |
| 3/ | FEATHER W D | S | 7,072 | 1,357.44 | 4.54 | | 4.54 |
| 2/ | GLENN-COLUSA I D | S | 96,600 | 492.68 | 1.95 | 38.93 | 40.88 |
| | MAXWELL I D | S | 3,380 | 388.03 | 1.65 | | 1.65 |
| | MERIDIAN FARMS W C | S | 7,579 | 549.49 | 3.11 | | 3.11 |
| | MISCELLANEOUS CONTR | S | 52,341 | 642.30 | 1.26 | | 1.26 |
| | NATOMAS CENTRAL MWD | S | 21,016 | 468.99 | 1.95 | | 1.95 |
| | PELGER MUTUAL W C | S | 2,073 | 604.26 | 1.30 | | 1.30 |
| | PLEASANT GROVE-VERONA | S | 4,640 | 571.71 | 1.00 | | 1.00 |
| | PRINCETON-CODORA-GLENN | S | 6,871 | 517.17 | 4.06 | | 4.06 |
| | PROVIDENT I D | S | 10,203 | 427.73 | .91 | 29.49 | 30.40 |
| | RECL DIST NO 1004 | S | 10,320 | 443.94 | 2.70 | | 2.70 |
| | ROBERTS DITCH I C | S | 1,330 | 576.74 | .42 | | .42 |
| | SARTAIN MUTUAL W C | S | 636 | 496.76 | 2.18 | | 2.18 |
| | SUTTER MUTUAL W C | S | 33,218 | 859.23 | 5.19 | | 5.19 |
| | SWINFORD TRACT I C | S | 184 | 1,549.40 | .57 | | .57 |

## AGRICULTURE OPERATION AND MAINTENANCE COSTS AND GROSS CROP VALUES PER IRRIGATED ACRE - 1987



| REGION, PROJECT | SUPPLY | IRRIGATED ACRES | GROSS CROP VALUE PER IRRIGATED ACRES | AGRICULTURAL O&M COST PER IRRIGATED ACRE ($) BUREAU | WATER USER | TOTAL |
|---|---|---|---|---|---|---|
| TISDALE I&D C | S | 1,876 | 504.75 | 1.98 | | 1.98 |
| TRINITY RIVER DIV | | | | | | |
| CLEAR CREEK SOUTH UNIT | | | | | | |
| CLEAR CREEK CSD | F | 3,121 | 381.56 | 11.40 | | 11.40 |
| COW CREEK UNIT | | | | | | |
| BELLA VISTA W D | S | 1,548 | 170.36 | 34.72 | 195.20 | 229.92 |
| W SAN JOAQUIN DIV | | | | | | |
| SAN LUIS CANAL | | | | | | |
| PACHECO W D | S | 1,562 | 1,413.37 | 23.30 | | 23.30 |
| PANOCHE W D | S | 12,078 | 749.69 | 41.51 | | 41.51 |
| 3/ SAN LUIS W D | S | 28,888 | 1,576.96 | 33.27 | | 33.27 |
| WESTLANDS W D | S | 500,598 | 1,497.17 | 23.88 | 21.89 | 45.77 |
| COE PROJ(INTGR) | | | | | | |
| BUCHANAN UNIT | | | | | | |
| COE PROJ(NON-INTGR) | | | | | | |
| NEW HOGAN | | | | | | |
| 1/ GEORGETOWN DIVIDE PUD | S | 1,869 | 762.64 | | 157.30 | 157.30 |
| HUMBOLDT | S | 32,800 | 389.55 | | 11.36 | 11.36 |
| KLAMATH, OR-CA | | | | | | |
| 2/ SAN BENITO | S | 22,445 | 1,824.92 | 1.28 | | 1.28 |
| SOLANO | | | | | | |
| 1/ SOUTH SUTTER W D | S | 26,429 | 516.43 | | 15.75 | 15.75 |
| 1/ TEHACHAPI-CUMMINGS CY W D | S | 1,903 | 7,517.38 | | 99.20 | 99.20 |
| LOWER COLORADO REGION | | | | | | |
| BOULDER CANYON, CA-AZ-NV | | | | | | |
| ALL-AMERICAN CANAL | | | | | | |
| COACHELLA DIVISION | F | 59,829 | 4,489.12 | | 59.06 | 59.06 |
| IMPERIAL DIVISION | F | 455,718 | 1,164.76 | | 49.01 | 49.01 |
| GILA | | | | | | |
| WELLTON-MOHAWK DIVISION | F | 59,331 | 1,455.29 | | 68.26 | 68.26 |
| YUMA MESA DIVISION | | | | | | |
| MESA UNIT | F | 16,949 | 1,045.51 | | 50.10 | 50.10 |
| NORTH GILA VALLEY UNIT | F | 6,128 | 5,249.68 | | 17.68 | 17.68 |
| SOUTH GILA VALLEY UNIT | F | 9,655 | 4,903.57 | | 34.65 | 34.65 |
| SALT RIVER | | | | | | |
| SALT RIVER VALLEY WUA | F | 51,319 | 1,430.41 | | 338.72 | 338.72 |
| YUMA, CA-AZ | | | | | | |
| RESERVATION DIV | | | | | | |
| BARD UNIT | F | 6,522 | 4,484.40 | | 42.62 | 42.62 |
| INDIAN UNIT | F | 5,106 | 1,958.58 | | 46.81 | 46.81 |
| VALLEY DIVISION, AZ | F | 45,921 | 3,050.78 | | 76.93 | 76.93 |
| YUMA AUXILIARY | F | 2,649 | 1,465.30 | | 118.41 | 118.41 |
| UPPER COLORADO REGION | | | | | | |
| BOSTWICK PARK | S | 4,854 | 120.03 | | 11.10 | 11.10 |
| CENTRAL UTAH | | | | | | |
| BONNEVILLE UNIT | | | | | | |
| DUCHESNE RIVER | S | 15,197 | 161.50 | | 2.17 | 2.17 |
| JENSEN UNIT | S | 3,880 | 244.25 | | 2.46 | 2.46 |
| VERNAL UNIT | S | 13,013 | 170.07 | | 3.68 | 3.68 |
| COLLBRAN | S | 20,210 | 105.38 | 1.19 | 2.68 | 3.87 |
| EDEN | F | 15,989 | 107.56 | | 7.07 | 7.07 |
| EMERY COUNTY | | | | | | |
| COTTONWOOD CREEK CONS I C | S | 4,807 | 180.44 | | 7.42 | 7.42 |
| HUNTINGTON-CLEVELAND I C | S | 12,616 | 101.26 | | 11.30 | 11.30 |
| FLORIDA | S | 14,765 | 141.32 | | 6.04 | 6.04 |
| 2/ FRUITGROWERS DAM | S | 2,295 | 317.41 | | 10.24 | 10.24 |
| GRAND VALLEY | | | | | | |
| GARFIELD GRAVITY DIV | F | 19,601 | 293.19 | | 24.59 | 24.59 |
| ORCHARD MESA DIVISION | F | 5,568 | 1,396.44 | | 73.06 | 73.06 |
| HAMMOND | F | 3,492 | 286.19 | | 27.48 | 27.48 |
| HYRUM | S | 6,394 | 253.34 | | 5.21 | 5.21 |
| LYMAN | S | 37,064 | 64.04 | | .86 | .86 |
| 1/ MALAD VALLEY I C | S | 5,600 | 128.97 | | 5.34 | 5.34 |
| MANCOS | S | 7,114 | 124.77 | | 10.51 | 10.51 |
| MIDVIEW EXCHANGE | S | 6,027 | 105.83 | | 9.04 | 9.04 |
| MOON LAKE WUA | S | 72,676 | 109.12 | | 1.30 | 1.30 |
| NAVAJO UNIT, CRSP | F | 230 | 6.52 | | 12.00 | 12.00 |
| NEWTON | S | 2,591 | 396.05 | | 6.12 | 6.12 |
| OGDEN RIVER | | | | | | |
| 1/ WEBER-BOX ELDER C D, PROJ1 | S | 365 | 875.64 | | 18.18 | 18.18 |
| 1/ WEBER-BOX ELDER C D, PROJ2 | S | 825 | 731.77 | | 27.15 | 27.15 |
| OTHER PROJECT LANDS | S | 13,373 | 820.62 | | 3.54 | 3.54 |
| PAONIA | S | 10,639 | 152.03 | | 7.58 | 7.58 |
| PINE RIVER | | | | | | |
| PINE RIVER, CO | S | 32,162 | 131.89 | | 6.71 | 6.71 |
| PRESTON BENCH | S | 5,191 | 243.09 | | 5.23 | 5.23 |
| PROVO RIVER | S | 36,249 | 357.90 | | 6.27 | 6.27 |
| SANPETE | | | | | | |
| EPHRAIM DIVISION | S | 6,730 | 122.45 | | 2.87 | 2.87 |
| SPRING CITY DIVISION | S | 6,830 | 199.04 | | 1.78 | 1.78 |
| SCOFIELD | S | 15,305 | 221.26 | | .64 | .64 |
| 1/ SETTLEMENT CANYON I C | S | 835 | 338.28 | | 54.00 | 54.00 |

# AGRICULTURE OPERATION AND MAINTENANCE COSTS AND GROSS CROP VALUES PER IRRIGATED ACRE - 1987



| REGION, PROJECT | SUPPLY | IRRIGATED ACRES | GROSS CROP VALUE PER IRRIGATED ACRES | AGRICULTURAL O&M COST PER IRRIGATED ACRE ($) BUREAU | WATER USER | TOTAL |
|---|---|---|---|---|---|---|
| SILT | S | 5,143 | 166.93 | | 17.41 | 17.41 |
| SMITH FORK | S | 8,924 | 119.43 | | 9.58 | 9.58 |
| STRAWBERRY VALLEY | | | | | | |
| HIGHLINE DIVISION | F | 15,685 | 359.85 | | 16.21 | 16.21 |
| SPANISH FORK DIVISION | S | 16,832 | 273.86 | | 9.86 | 9.86 |
| SPRINGVILLE-MAPLETON DIV | S | 7,925 | 288.75 | | 3.77 | 3.77 |
| UNCOMPAHGRE | | | | | | |
| UNCOMPAHGRE CLASS 1-3 | F | 58,874 | 300.89 | | 24.68 | 24.68 |
| WEBER BASIN | | | | | | |
| 1/ BOUNTIFUL WATER SUBCON D | S | 456 | 1,198.72 | | 76.17 | 76.17 |
| 1/ CENTERVILLE-DEUEL CRK I D | S | 396 | 7,756.10 | | 123.33 | 123.33 |
| 1/ FARMINGTON AREA PRESS. I D | S | 2,338 | 350.24 | | 24.70 | 24.70 |
| 1/ HAIGHTS CREEK I C | S | 1,805 | 342.63 | | 49.00 | 49.00 |
| 1/ KAYS CREEK I C | S | 324 | 431.42 | | 38.94 | 38.94 |
| 1/ SOUTH DAVIS CY WID | S | 246 | 1,676.96 | | 350.12 | 350.12 |
| OTHER PROJECT LANDS | S | 20,870 | 936.00 | | 13.39 | 13.39 |
| WEBER RIVER | | | | | | |
| 1/ HOOPER IRRIGATION COMPANY | S | 10,471 | 324.92 | | 19.38 | 19.38 |
| 1/ ROY WATER CONSERV SUBD | S | 840 | 827.65 | | 280.59 | 280.59 |
| 1/ SOUTH WEBER WID | S | 537 | 236.06 | | 57.73 | 57.73 |
| OTHER PROJECT LANDS | S | 80,040 | 419.29 | | 6.10 | 6.10 |
| SOUTHWEST REGION | | | | | | |
| 1/ BROWNSVILLE IDD | F | 10,394 | 511.94 | | 44.72 | 44.72 |
| CARLSBAD | F | 22,745 | 330.53 | | 30.84 | 30.84 |
| 1/ DONNA I D | F | 28,572 | 587.24 | | 31.11 | 31.11 |
| FORT SUMNER | F | 5,835 | 144.38 | | 23.19 | 23.19 |
| 1/ HARLINGEN I D | F | 32,341 | 372.76 | | 16.61 | 16.61 |
| LOWER RIO GRANDE REHAB | | | | | | |
| LA FERIA DIVISION | F | 27,500 | 629.20 | | 11.12 | 11.12 |
| MERCEDES DIVISION | F | 54,387 | 662.21 | | 20.13 | 20.13 |
| MIDDLE RIO GRANDE | F | 56,127 | 357.35 | 4.60 | 98.72 | 103.32 |
| RIO GRANDE | | | | | | |
| RIO GRANDE, NM | | | | | | |
| ELEPHANT BUTTE I D | F | 77,597 | 1,354.91 | 3.81 | 39.98 | 43.79 |
| RIO GRANDE, TX | | | | | | |
| EL PASO CY WID NO 1 | F | 47,428 | 812.39 | 3.23 | 41.60 | 44.83 |
| HUDSPETH CY NO 1 | S | 15,043 | 667.07 | | 41.82 | 41.82 |
| SAN JUAN-CHAMA | F | 2,162 | 221.58 | 162.72 | 55.41 | 218.13 |
| 1/ SANTA MARIA I D | F | 3,791 | 361.37 | | 20.69 | 20.69 |
| TUCUMCARI | F | 26,134 | 141.30 | | 28.67 | 28.67 |
| VERMEJO | F | 5,238 | 102.37 | | 25.53 | 25.53 |
| WASHITA BASIN | | | | | | |
| MISSOURI BASIN REGION | | | | | | |
| BUFFALO RAPIDS | | | | | | |
| 2/ IRRIGATION DISTRICT NO 1 | F | 11,679 | 312.87 | | 19.87 | 19.87 |
| 2/ IRRIGATION DISTRICT NO 2 | F | 8,603 | 234.57 | | 19.21 | 19.21 |
| BUFORD-TRENTON | F | 8,041 | 474.46 | | 19.13 | 19.13 |
| 2/ CENTRAL NEBRASKA PP&ID | S | 116,522 | 238.98 | .05 | 15.09 | 15.14 |
| COLORADO-BIG THOMPSON | S | 629,631 | 348.45 | .78 | 1.95 | 2.73 |
| 1/ COONEY DAM REHAB | S | 17,750 | 273.09 | .39 | | .39 |
| 1/ FORT COLLINS, CITY OF | S | 1,594 | 206.58 | | 1.42 | 1.42 |
| FRYINGPAN-ARKANSAS | S | 166,996 | 246.61 | 1.08 | | 1.08 |
| HUNTLEY | F | 25,365 | 255.30 | | 24.33 | 24.33 |
| INTAKE | F | 769 | 104.37 | | 2.71 | 2.71 |
| KENDRICK | F | 21,674 | 88.23 | .46 | 11.07 | 11.53 |
| LOWER YELLOWSTONE | | | | | | |
| DISTRICT NO 1, MT | F | 27,535 | 355.62 | | 24.60 | 24.60 |
| DISTRICT NO 2, ND | F | 16,217 | 485.92 | | 19.61 | 19.61 |
| MILK RIVER | | | | | | |
| CHINOOK DIVISION | F | 34,607 | 73.63 | .91 | 6.94 | 7.85 |
| DODSON PUMPING UNIT | F | 922 | 48.43 | 1.10 | 6.77 | 7.87 |
| FORT BELKNAP INDIAN RESV | F | 4,136 | 41.16 | 1.85 | 34.87 | 36.72 |
| GLASGOW DIVISION | F | 10,718 | 82.09 | 1.85 | 24.51 | 26.36 |
| MALTA DIVISION | F | 38,914 | 48.94 | .66 | 10.78 | 11.44 |
| PRIVATE PUMPERS PERMANENT | F | 9,514 | 74.83 | 1.85 | .97 | 2.82 |
| MIRAGE FLATS | F | 9,102 | 284.07 | | 12.43 | 12.43 |
| NORTH PLATTE | | | | | | |
| NEBRASKA LANDS | | | | | | |
| GERING-FT LARAMIE I D | F | 51,147 | 296.12 | 3.23 | 15.68 | 18.91 |
| NORTHPORT I D | F | 15,659 | 223.99 | 1.47 | 9.48 | 10.95 |
| PATHFINDER I D | F | 86,313 | 222.43 | 1.70 | 16.18 | 17.88 |
| SP-WARREN ACT CONTR | | | | | | |
| BEERLINE ICC | S | 880 | 89.14 | .74 | 18.24 | 18.98 |
| BROWNS CREEK I D | S | 5,589 | 134.56 | 1.46 | 7.12 | 8.58 |
| CENTRAL I D | S | 1,557 | 260.47 | 1.04 | 11.86 | 12.90 |
| CHIMNEY ROCK I D | S | 5,306 | 165.42 | .82 | 6.74 | 7.56 |
| FARMERS I D | S | 60,564 | 216.50 | .64 | 17.69 | 18.33 |
| GERING I D | S | 11,562 | 228.15 | 1.13 | 10.09 | 11.22 |
| WYOMING LANDS | | | | | | |
| GOSHEN I D | F | 49,867 | 259.39 | 1.50 | 4.41 | 5.91 |
| SP-WARREN ACT CONTR | | | | | | |
| HILL I D | S | 3,336 | 217.22 | 1.21 | 11.50 | 12.71 |
| LINGLE WUA | S | 10,710 | 218.68 | 1.36 | 6.59 | 7.95 |
| ROCK RANCH D C | S | 900 | 387.52 | 1.42 | 2.22 | 3.64 |
| WYOMING NON-DIST LANDS | F | 1,603 | 246.72 | 1.07 | 7.39 | 8.46 |

## AGRICULTURE OPERATION AND MAINTENANCE COSTS AND GROSS CROP VALUES PER IRRIGATED ACRE - 1987



| REGION, PROJECT | SUPPLY | IRRIGATED ACRES | GROSS CROP VALUE PER IRRIGATED ACRES | AGRICULTURAL O&M COST PER IRRIGATED ACRE ($) BUREAU | WATER USER | TOTAL |
|---|---|---|---|---|---|---|
| 1/ NORTH POUDRE I C | S | 31,752 | 213.37 | | 7.97 | 7.97 |
| PICK-SLOAN MBP | | | | | | |
| BELLE FOURCHE UNIT | F | 52,327 | 165.99 | .06 | 8.70 | 8.76 |
| BIGHORN BASIN DIV | | | | | | |
| HANOVER-BLUFF UNIT | | | | | | |
| HIGHLAND-HANOVER I D | F | 5,451 | 403.27 | 1.55 | 17.23 | 18.78 |
| UPPER BLUFF I D | F | 1,333 | 424.10 | 1.49 | 15.49 | 16.98 |
| OWL CREEK UNIT | | | | | | |
| LUCERNE PUMP | S | 3,480 | 144.98 | .06 | 4.00 | 4.06 |
| MIDDLE & UPPER | S | 8,470 | 96.63 | .06 | 5.00 | 5.06 |
| BOSTWICK DIV | | | | | | |
| KANSAS-BOSTWICK I D | F | 33,585 | 209.36 | 1.48 | 17.69 | 19.17 |
| NEBRASKA-BOSTWICK I D | F | 18,415 | 248.78 | 1.39 | 18.42 | 19.81 |
| BOYSEN DIVISION | | | | | | |
| BOYSEN UNIT | | | | | | |
| HANOVER I D | S | 8,250 | 411.82 | .02 | 12.61 | 12.63 |
| LECLAIR I D | S | 9,400 | 163.94 | .01 | | .01 |
| RIVERTON VALLEY I D | S | 5,827 | 134.62 | .03 | 21.45 | 21.48 |
| WORLAND AREA | S | 1,710 | 246.90 | .02 | | .02 |
| CHEYENNE DIVISION | | | | | | |
| ANGOSTURA UNIT | F | 9,911 | 156.37 | | 17.16 | 17.16 |
| BELLE RIVER PUMP ASSOC | S | 1,721 | 99.02 | .74 | 24.28 | 25.02 |
| RAPID VALLEY UNIT | S | 7,800 | 113.23 | | .47 | .47 |
| FRENCHMAN-CAMBRIDGE | | | | | | |
| FRENCHMAN-CAMBRIDGE I D | F | 38,178 | 250.24 | 1.76 | 24.37 | 26.13 |
| FRENCHMAN VALLEY I D | S | 7,437 | 250.07 | 3.37 | 11.95 | 15.32 |
| H&RW IRRIGATION DIST | F | 9,737 | 221.36 | 1.12 | 11.07 | 12.19 |
| GRAND DIV | | | | | | |
| SHADEHILL UNIT | F | 809 | 112.85 | 14.64 | 2.68 | 17.32 |
| HEART DIVISION | | | | | | |
| DICKINSON UNIT | F | 198 | 121.21 | 2.02 | | 2.02 |
| HEART BUTTE | | | | | | |
| LOWER HEART I C | F | 2,474 | 229.01 | 1.81 | .61 | 2.42 |
| INDIVIDUAL PUMPERS | F | 917 | 195.06 | 1.83 | | 1.83 |
| W HEART RIVER I D | F | 1,575 | 130.97 | 2.32 | .46 | 2.78 |
| HELENA-GREAT FALLS DIV | | | | | | |
| HELENA VALLEY UNIT | | | | | | |
| HELENA VALLEY I D | F | 13,867 | 102.42 | .79 | 12.54 | 13.33 |
| JAMES DIV | | | | | | |
| KANASKA DIV | | | | | | |
| ALMENA UNIT | F | 4,520 | 230.69 | 1.57 | 16.52 | 18.09 |
| MARIAS DIV | | | | | | |
| LOWER MARIAS UNIT | F | 1,409 | 164.02 | .75 | | .75 |
| MIDDLE LOUP DIV | | | | | | |
| FARWELL UNIT | F | 39,123 | 213.59 | .90 | 21.29 | 22.19 |
| SARGENT UNIT | F | 10,312 | 181.78 | .50 | 22.18 | 22.68 |
| NO DAKOTA PUMPING DIV | | | | | | |
| FORT CLARK UNIT | F | 707 | 43.98 | | 26.83 | 26.83 |
| NORTH LOUP DIV | F | 1,044 | 171.61 | 301.19 | 4.54 | 305.73 |
| OREGON TRAIL DIV | | | | | | |
| GLENDO UNIT-NE | | | | | | |
| BRIDGEPORT I D | S | 13,197 | 181.76 | .29 | 4.26 | 4.55 |
| ENTERPRISE I D | S | 7,362 | 323.64 | .11 | 12.50 | 12.61 |
| 1/ MITCHELL I D | S | 12,125 | 323.56 | 2.30 | 13.00 | 15.30 |
| GLENDO UNIT-WY | | | | | | |
| BURBANK DITCH C | S | 316 | 136.52 | .18 | 18.67 | 18.85 |
| LUCERNE CANAL&POWER C | S | 3,411 | 198.05 | .28 | 3.75 | 4.03 |
| NEW GRATTON DITCH C | S | 1,183 | 244.52 | .22 | .96 | 1.18 |
| TORRINGTON I D | S | 2,008 | 190.12 | .14 | 8.55 | 8.69 |
| SANDHILLS DIV | | | | | | |
| AINSWORTH UNIT | F | 26,915 | 234.02 | | 13.78 | 13.78 |
| SMOKY HILL DIV | | | | | | |
| SOLOMON DIV | | | | | | |
| KIRWIN UNIT | F | 6,838 | 217.75 | 1.44 | 20.14 | 21.58 |
| WEBSTER UNIT | F | 4,168 | 177.70 | 2.35 | 24.41 | 26.76 |
| THREE FORKS DIV | | | | | | |
| CROW CREEK PUMP UNIT | F | 4,398 | 212.60 | .20 | 14.71 | 14.91 |
| EAST BENCH UNIT | B | 26,497 | 106.64 | | 11.21 | 11.21 |
| WIND DIVISION | | | | | | |
| RIVERTON UNIT | F | 36,616 | 188.58 | .81 | 26.00 | 26.81 |
| YELLOWSTONE DIV | | | | | | |
| SAVAGE UNIT | F | 1,971 | 357.50 | | 20.24 | 20.24 |
| SHOSHONE | | | | | | |
| ELK WATER USERS ASSOC | S | 3,557 | 240.33 | .33 | .78 | 1.11 |
| FRANNIE DIVISION | | | | | | |
| MONTANA LANDS | F | 75 | 88.56 | .31 | 10.00 | 10.31 |
| WYOMING LANDS | F | 13,664 | 162.19 | .31 | 9.26 | 9.57 |
| GARLAND DIVISION | F | 31,602 | 308.50 | .33 | 23.32 | 23.65 |
| HEART MOUNTAIN DIVISION | F | 29,449 | 219.36 | 2.07 | 15.33 | 17.40 |
| LOVELL I D | S | 9,411 | 240.80 | .33 | 6.91 | 7.24 |
| WILLWOOD DIVISION | F | 10,235 | 317.15 | .33 | 23.10 | 23.43 |
| SUN RIVER | | | | | | |
| FORT SHAW DIVISION | F | 8,681 | 83.79 | | 13.15 | 13.15 |
| GREENFIELDS DIVISION | F | 70,646 | 170.51 | | 17.17 | 17.17 |

## AGRICULTURE OPERATION AND MAINTENANCE COSTS AND GROSS CROP VALUES PER IRRIGATED ACRE - 1987



| REGION, PROJECT | SUPPLY | IRRIGATED ACRES | GROSS CROP VALUE PER IRRIGATED ACRES | AGRICULTURAL O&M COST PER IRRIGATED ACRE ($) | | |
|---|---|---|---|---|---|---|
| | | | | BUREAU | WATER USER | TOTAL |
| TRINIDAD | S | 16,092 | 163.15 | 4.39 | | 4.39 |
| 1/ WATER SUPPLY&STORAGE C | S | 37,425 | 329.13 | | 8.78 | 8.78 |
| 1/ WEST BENCH I D | S | 5,382 | 120.77 | | 1.31 | 1.31 |
| 1/ WHITNEY I D | F | 6,947 | 89.80 | | 6.17 | 6.17 |

1/ PROJECT CONSTRUCTED OR REHABILITATED UNDER THE SMALL RECLAMATION PROJECTS ACT OF 1956, P.L. 84-984.
2/ THIS LEGAL ENTITY HAS A SMALL RECLAMATION PROJECTS LOAN IN ADDITION TO A SERVICE REPAYMENT CONTRACT.
3/ PROJECT CONSTRUCTED UNDER THE DISTRIBUTION SYSTEM LOANS ACT OF 1955, P.L. 84-130.
A/ ESTIMATED
B/ INCLUDES TRANSPORTATION LOSSES
C/ INCLUDES OPERATIONAL SPILLS

SUPPLY CODE
F - FULL WATER SUPPLY
S - SUPPLEMENTAL WATER SUPPLY
B - BOTH FULL & SUPPLEMENTAL

## JUST ADD WATER

by David J. Ford

The words on labels tell this tale,
In recipes, in ads by mail,
And chances are, at work or play,
You'll see these famous words today -
Just add water.

You'd be surprised how many things
Are dry and useless till one brings
The magic liquid known to all;
You use it when you heed the call -
Just add water.

To illustrate and prove this thought,
Remember all the food you've bought
On which was printed, clear and bright,
Instructions that make cooking light -
Just add water.

You now can buy, in many makes,
Dried fruits, or soups, or tasty cakes;
To powdered milk and frozen juices,
To products with a thousand uses,
Just add water.

Imagine for a minute, please,
An arid wasteland, bare of trees;
This could be farmland, rich and good
And quite productive if we could
Just add water.

What turns cement into concrete?
What changes seed to golden wheat?
No other words now known to man
Can answer that; but these words can:
Just add water.

GPO 857-975

**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.*