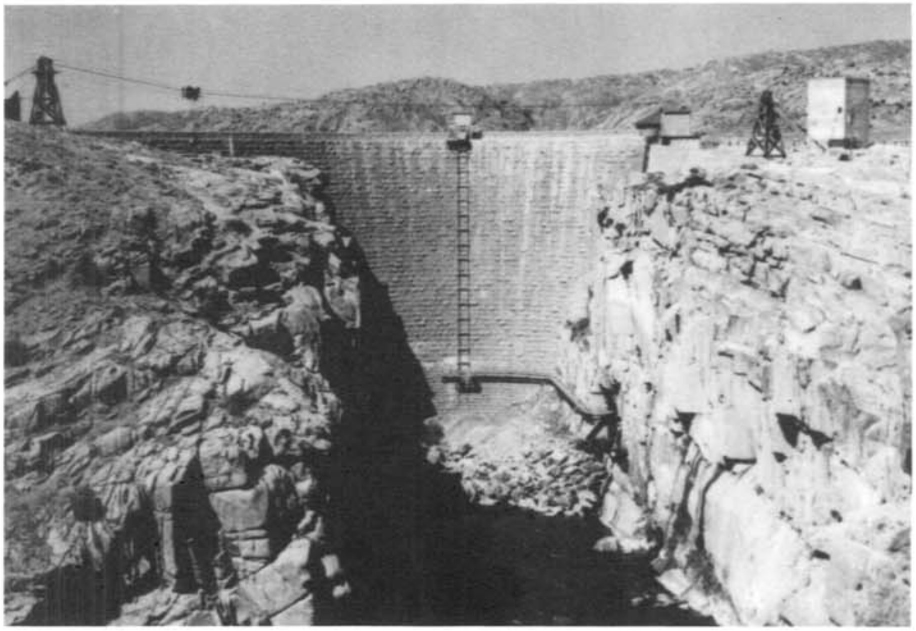
WATER OPERATION AND MAINTENANCE

BULLETIN NO. 139

MARCH 1987



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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 reduced 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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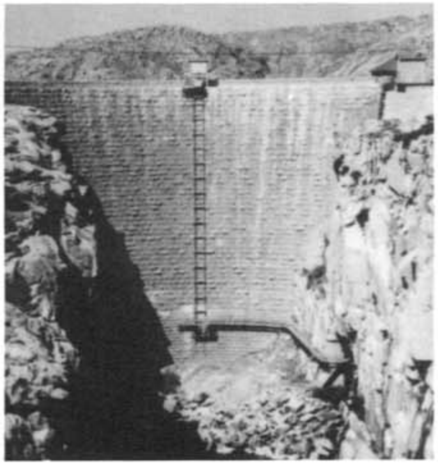

Cover photograph:

Pathfinder Dam, which is a major feature of the North Platte Project. The North Platte Project is the subject of the first Water O&M Bulletin Spotlight.

INTRODUCTION

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Page 1 is general information on the Bureau of Reclamation's program for replacement of needle valves.

The article beginning on page 2 summarizes the results of testing of samples received to determine the cause for the corrosion activity in the reinforced concrete canal lining of the Granite Reef Aqueduct.

Page 18 begins an article on the importance of improving water production from wells.

Beginning on page 20 is a new feature. Beginning with this issue, different Bureau of Reclamation projects will be discussed. Readers with similar projects and facilities can then become familiar with, share, and perhaps implement new or different procedures in anticipation of improved operations.

The digest statement for this issue features erosion below the spillway at Bartlett Dam. The digest statement begins on page 24.

REPLACEMENT OF NEEDLE VALVES

On January 7, 1984, the lower needle valve at Bartlett Dam failed during changing discharge through the valve, which resulted in the death of the operator. On December 5, 1984, four employees of a non-Federal installation were killed when a penstock ruptured due to pressure transients that developed from erratic needle valve movement. Both of these accidents were attributed to operator error.

From approximately 1919 through 1946, the Bureau of Reclamation installed 67 needle valves ranging in size from 10- to 84-inch at 24 dams. An intense investigation of these needle valve installations, since the above accidents occurred, has verified similar conditions conducive to operator error at all installations. These conditions are present primarily due to inadequate understanding of the complex operating principals of the valves, and subsequent poor level of maintenance.

A May 17, 1985 memorandum from the Commissioner of the Bureau of Reclamation established a program for the systematic replacement of the Bureau-designed needle valves by 1991. For the interim operating period, existing external features of the needle valve operating systems are being modified, and new step-by-step operating instructions are being developed, both intended to reduce the possibility of operator error.

* * * * *

DETERIORATED REINFORCED CONCRETE CANAL LINING
GRANITE REEF AQUEDUCT
CENTRAL ARIZONA PROJECT

Applied Sciences Referral Memorandum No. 86-1-8

Authored by: Harry Uyeda

Background

Severe deterioration of the reinforced concrete canal lining on the left bank, panel No. 146, at Milepost 50 of the Granite Reef Aqueduct, Reach 3, was noted by project personnel in March 1986, about 7 years after construction. This reinforced section of this reach extends from station 316+00 to station 365+00. L. D. Klein (D-1523) and T. E. Rutenbeck (D-1512) inspected the damage on April 3, 1986, and H. Uyeda, O. Uhlmeyer, and L. Mellott visited the site on April 16, 1986. Both trips resulted in the conclusion that the distress was the result of corrosion of the embedded steel reinforcement.

Following the latter trip, project personnel conducted tests for reinforcement electrochemical potential and for concrete cover over reinforcement on 41 panels, 19 from the left bank and 22 on the right bank within this reach. The results of this survey were submitted by memorandum dated May 16, 1986, and indicated a general problem within this 4,900-foot section.

Subsequently, the project provided twelve 1-foot square samples of the reinforced lining, samples of soil removed from beneath the concrete samples, and samples of both the well water used for mixing the concrete and canal water.

This report summarizes the results of testing on the samples received to determine the cause for the corrosion activity.

Introduction

Concrete provides protection from corrosion to the embedded steel by formation of a stable (passive) ferric (iron) oxide film on its surfaces. This passive oxide layer is formed by exposure to the highly alkaline (pH 12.5) environment provided by concrete. Passivated steel exhibits noble potentials very similar to that of copper or about -200 millivolts versus a copper/copper sulfate reference (CSE). However, if the steel is not in intimate contact with sound concrete, the passive film is not formed. When this passive film is not formed, the steel in the presence of moisture and oxygen exhibits more active potentials similar to steel exposed in neutral solutions of about -500 millivolts (CSE) or more negative. Thus, when some of the steel is adequately embedded and other surfaces are not in contact with the highly alkaline environment, such as opposite voids or cracks, a cell (battery) develops between the two attributable to pH concentration effects, wherein the exposed steel corrodes. The velocity (rate) of the corrosion reaction then becomes a function of the driving potential, the relative surface areas of the anode and cathode, and the circuit resistance. The driving potential is the difference in potential between the passive steel (cathode) and the active steel (anode). The circuit resistance is largely controlled by degree of saturation with water, the concrete cover, and the soluble salt content. Wetting and drying can also accelerate the activity by concentrating salts with each cycle.

The chloride ion can, if accompanied by moisture and oxygen, depassivate steel in sound concrete. The threshold concentration for this to occur is generally accepted to be 0.20 percent by weight of cement.

Corrosion of steel is accompanied by a volume change. This is because rust occupies a greater volume than the alloy. Thus, if confined, such as in concrete, the volume change, which may be as high as 800 percent, results in high tensile and shear stresses and strains on the confining material. If the confining material will not accommodate tensile strain (e.g., concrete), cracking and spalling result.

Test Results

Table 1 merely identifies the origin of the 12 concrete and soil samples received.

Table 2 exhibits the analyses of the two water samples. Of particular interest insofar as corrosion is concerned are the concentrations of the sulfate and chloride ions and the water conductivities. The concentrations of the sulfate ions are within the range considered to result in a positive degree of sulfate attack on concrete which is normally accommodated by the use of Type II cement. The chloride ion content in the mixing (well) water is high and, assuming a water/cement ratio of 0.58, would result in a uniform distribution of the chloride ion within the concrete of 0.010 percent by weight of cement. Both the canal water and the well water would be considered moderately conductive and would result in low circuit resistance within corrosion cells and consequently a high rate of attack.

Table 3 displays the results of the analyses of the soil samples. The soluble sulfate contents indicate a negligible degree of attack to concrete. Although the soils are alkaline, they exhibit highly variable chloride contents and conductivities. Chloride contents of 100 p/m, and conductivities above 1000 μs/cm are unusually high.

Table 4 shows the results of analyses for chloride at different layers within the concrete. The chloride contents are extremely variable and in some cases exceed the threshold level required to initiate corrosion in sound concrete (0.20 percent by weight of cement).

Table 5 covers the inspection of the reinforced concrete samples for cover, consolidation, and intensity of corrosion activity. Cover above the steel varies considerably but is satisfactorily consolidated. The cover below the steel varies greatly and in all cases was poorly consolidated. The intensity of the corrosion activity is related to the cover below the reinforcement, i.e., the soil-side cover. The four, badly deteriorated samples with severe corrosion of the steel were from the left bank (north side) of the canal.

Table 6 relates the intensity of corrosion to the chloride content in the concrete and soil-side concrete cover and the chloride in the concrete to that of the underlying soil. Except for a few anomalies, the following general relationships are observed:

1. Intensity of corrosion increases with decrease in cover
2. Intensity of corrosion increases with increasing chloride content in the concrete
3. Chloride content in the concrete increases with increasing chloride content in the soil

Figures 1 through 10 are views of the reinforced concrete samples. Figure 1 depicts the concrete consolidation on the surface of sample No. 11, which was found to be satisfactory and typical of surface consolidation on other samples.

Whereas figure 2 depicts satisfactory consolidation throughout the thickness of the lining on sample No. 11, figure 3 shows a large void beneath the longitudinal reinforcement on sample No. 12. The void is the result of inadequate consolidative effort on concrete below the steel. The void and the steel appear to have formed a weakened plane for the subsequent contraction cracking above the bar.

Figure 4 is the opposite end of the sample shown in figure 3. Note that the crack completely penetrates the thickness of the concrete.

Figure 5 generally typifies the soil-side concrete of all samples. The concrete generally is poorly consolidated, and the consolidation appears to be worse directly under the reinforcement. Some of these voids from the bottom completely penetrate to the steel as shown in figures 6 and 7. If well consolidated, a vivid impression of the reinforcement bar including deformations would be clearly visible. From these photographs, one cannot determine if deformed bars were installed.

Figures 8 and 9 show the active corrosion on the reinforcement opposite voids which completely penetrated the concrete cover. Again no vivid imprint of the steel configuration can be seen.

Figures 10 and 11 display severe corrosion of the steel and cracking and spalling of the concrete such that the degree of consolidation above and below the reinforcement cannot be determined.

Analyses of the Test Results

1. Initiation of the Corrosion Activity

Table 6 shows that four of the samples (No. 3, 4, 5, and 6) are disrupted so extensively that the degree of consolidation and cover thickness cannot be determined. Thus, these four samples do not provide any clues as to the cause for the corrosion.

Of the remaining eight samples, only the three containing voids completely penetrating the soil-side concrete cover were actively corroding. The other five had a minimum soil-side cover of 1 inch and displayed corrosion barely visible macroscopically.

Thus, the corrosion was initiated by pseudo-galvanic effects attributable to cover concrete thicknesses as low as 0.

It is reasonable to assume that the degree of consolidation exhibited by the 12 samples is typical for this reinforced canal lining section. Thus, it would seem that other panels would have a similar propensity to corrode.

2. Intensity of the Corrosion Reaction

Table 6 also shows that the intensity (velocity, rate) of the corrosion activity is largely a function of the cover thickness and the chloride concentration in the concrete. The chloride content in the concrete generally reflects the chloride concentration within the underlying soils.

Thus, the intensity was controlled by cover and chloride content of the soil.

It is suspected that the severely disrupted samples, No. 3, 4, 5, and 6, contained areas where no concrete cover, such as opposite voids or cracks, was obtained over the reinforcing steel. These samples all were removed from the left bank of the canal. The reason for experiencing greater deterioration on one bank as opposed to another is not clearly understood. However, the left bank of a canal which runs from west to east, would be exposed to somewhat greater insolative effects. This may have resulted in greater degree of cracking from drying shrinkage and daily heating and cooling thermal gradients.

Conclusions

1. The corrosion activity was initiated by no or inadequate cover under the steel reinforcement. The failure to achieve adequate cover is the result of poor consolidation beneath the reinforcement mat.

2. The intensity of the corrosion activity is directly related to the thickness of cover as well as the chloride concentration of the underlying soil.

3. Other panels, other than those which have already exhibited visual signs of distress, are subject to premature failure provided that the degree of consolidation determined for the 12 samples is typical. However, since the corrosion activity is attributable to soil-side effects, those showing only incipient corrosion after 7 years' exposure may provide satisfactory service lives.

Recommendations

1. The bottom cover requirements should be increased to 2 inches minimum with sound concrete. Two inches of concrete cover has been found to be normally adequate even in highly aggressive exposure such as to seawater.

2. Since cracking of the concrete can also result in diminution of concrete cover, all practicable measures should be taken to minimize this effect including:

   a. Saturate subgrade immediately prior to placement of concrete

b. When rapid drying shrinkage is experienced, augment membrane curing with 24 hours of moist curing prior to application of the curing compound as discussed on page 380 of the Concrete Manual.

Table 1
Sample Identification
Soil and Concrete Samples
Reach 3, Granite Reef Aqueduct, Central Arizona Project

Concrete/ Soil Sample No.	Origin of Sample				
	Milepost	Panel No.	Bank of Canal	Origin Station (ft.)	Elevation (ft.)
1	50	145L	Left	351+88	1295.52
2	50	145L	Left	351+83	1297.84
3	50	145L	Left	351+82	1300.05
4	50	145L	Left	351+69	1300.60
5	50	145L	Left	351+75	1299.60
6	50	145L	Left	351+72	1294.60
7	50	145R	Right	351+87	1299+50
8	50	145R	Right	351+85	1291+10
9	50	145R	Right	351+80	1295.40
10	50	145R	Right	351+71	1293.70
11	50	145R	Right	351+69	1296.50
12	50	145R	Right	351+73	1298.70

Table 2
Test Results
Water Samples
Reach 3, Granite Reef Aqueduct, Central Arizona Project

Analysis	Canal Waters	Well Water
pH	7.90	8.30
Conductivity (µs/cm @ 25 °C)	865	1170
Suspended solids (mg/L)	1.47	20.1
Dissolved solids (mg/L) 105 °C	535	847
Sum of cations & anions (mg/L)	598	691
Calcium (mg/L)	58.5	9.60
Magnesium (mg/L)	26.3	20.6
Sodium (mg/L)	81.8	221
Potassium (mg/L)	4.43	2.16
Carbonate (mg/L)	0.00	0.00
Bicarbonate (mg/L)	147	140
Sulfate (mg/L)	222	137
Chloride (mg/L)	57.8	180

Table 3
Test Results
Soil Samples Removed from Behind Concrete Samples
Reach 3, Granite Reef Aqueduct, Central Arizona Project

Soil Sample No.	Associated Concrete Sample No.	pH	Soluble Chloride (p/m)	Soluble Sulfate (p/m)	As Received			Dehydrated		Paste		
					Conduc-tivity (µs/cm)	Density (g/cc)	Moisture (%)	Conduc-tivity (µs/cm)	Density (g/cc)	Conduc-tivity (µs/cm)	Density (g/cc)	Saturation (%)
1	1	10.4	50.3	22.4	81.97	1.37	11.0	2.658	1.25	588.2	1.91	37.1
2	2	10.5	53.7	35.0	149.3	1.57	9.81	2.251	1.27	571.4	1.76	34.5
3	3	10.2	356	24.0	344.8	1.59	10.3	2.841	1.32	1383	1.94	36.5
4	4	10.3	447	18.0	500.0	1.59	10.9	6.158	1.26	2174	1.93	35.3
5	5	9.46	183	16.8	307.7	1.60	9.47	6.523	1.25	1497	1.92	35.4
6	6	10.3	102	28.7	190.5	1.55	10.5	6.662	1.34	1111	1.94	36.7
7	7	10.1	96.2	17.2	138.7	1.49	7.24	5.831	1.42	1250	1.97	32.3
8	8	9.92	84.4	20.9	144.9	1.60	8.42	7.123	1.33	625.0	1.94	33.3
9	9	10.2	51.9	34.3	113.8	1.58	8.00	6.592	1.32	628.9	1.93	35.9
10	10	10.3	79.7	27.6	363.6	1.73	10.6	8.467	1.21	1111	1.93	37.5
11	11	10.1	57.5	26.5	192.3	1.67	9.97	12.26	1.24	793.7	1.97	33.1
12	12	10.0	45.3	29.2	232.6	1.80	10.1	12.03	1.25	526.3	1.92	26.3

Table 4
Chloride Analyses
Reinforced Concrete Samples
Reach 3, Granite Reef Aqueduct, Central Arizona Project

Sample	Chloride Ion Concentration								
	% by weight of concrete				% by weight of cementitious material[1]				
No.	Top	Middle	Bottom	Average	Top	Middle	Bottom	Average	Remarks
1	0.003	0.008	0.012	0.008	0.03	0.07	0.10	0.07	
2	0.001	0.013[2]	0.014	0.009	0.001	0.11	0.12	0.08	[2] Average of 2 analyses
3	0.137[3]	0.162	0.224	0.174	1.18	1.40	1.94	1.51	[3] Avg. of 5 analyses on on 2 samples
4	0.078	0.303	0.279	0.220	0.68	2.63	2.42	1.91	
5	0.091	0.106	0.114	0.137	1.65	0.92	1.19	1.25	
6	0.024	0.062	0.100[2]	0.062	0.21	0.54	0.87	0.54	[2]
7	0.004	0.009	0.024	0.012	0.03	0.08	0.21	0.11	
8	0.002	<0.001	0.012	0.005	0.02	<0.01	0.10	0.04	
9	0.002	0.003	0.013[4]	0.006	0.02	0.03	0.11	0.05	[4] Average of 2 samples
10	0.002	0.004	0.021[4]	0.009	0.02	0.03	0.18	0.08	[4]
11	0.006	0.000[4]	0.009	0.005	0.05	0.00	0.08	0.04	[4]
12	0.004	0.000	0.003	0.002	0.03	0.00	0.03	0.02	

[1] Assuming 450 lbs. cementitious material (cement + pozzolan)/yd^3 of concrete and concrete density of 3900 lbs./yds.

Table 5
Examination Results
Reinforced Concrete Cores
Reach 3 Granite Reef Aqueduct, Central Arizona Project

Sample	Minimum cover (in.) over Reinforcement Top	Bottom	Consolidation	Corrosion of Reinforcement
1	1.0	1.3	Voids at bottom surface only	Incipient, both bars
2	0.9	1.0	Voids at bottom surface only	Incipient, both bars
3	(1)	(1)	(1)	Sever, both bars
4	(1)	(1)	(1)	Severe, both bars
5	(1)	(1)	(1)	Severe, both bars
6	(1)	(1)	(1)	Severe, transverse bar; active, longitudinal bar
7	1.9	0	Voids to steel from bottom	Active opposite voids on on transverse bar
8	1.0	1.4	Voids at bottom surface only	Incipient, transverse bar only
9	1.5	1.1	Voids at bottom surfce only	Incipient, transverse bar only
10	1.5	0	Voids to steel from bottom	Active opposite voids on transverse bar
11	1.2	1.4	Voids at bottom surface only	Incipient, longitudinal bar
12	0.4	0	Voids to steel from bottom	Active opposite voids on both bars

(1) Sample severely cracked and spalled such that cover and degree of consolidation could not be determined

Table 6
Summary of Test Results
Test Samples
Reach 3, Granite Reef Aqueduct, Central Arizona Project

Sample No.	Corrosion Activity	Minimum Bottom Cover (in.)	Chloride (% by wt. of cement, ave.)	Soil (p/m)
1	Incipient	1.3	0.07	50.3
2	Incipient	1.0	0.08	53.7
3	Severe	(1)	1.51	356
4	Severe	(1)	1.91	447
5	Severe	(1)	1.25	183
6	Severe	(1)	0.54	102
7	Active	0	0.11	96.2
8	Incipient	1.4	0.04	84.4
9	Incipient	1.1	0.05	51.9
10	Active	0	0.08	79.7
11	Incipient	1.4	0.04	57.5
12	Active	0	0.02	45.3

(1) Sample severely cracked and spalled such that cover and degree of consolidation could not be determined.

Figure 1. Upper surface of Sample No. 11. Consolidation of the concrete on the exposed surfaces was generally satisfactory.

Figure 2. Side view of Sample No. 11. This edge shows generally satisfactory consolidation.

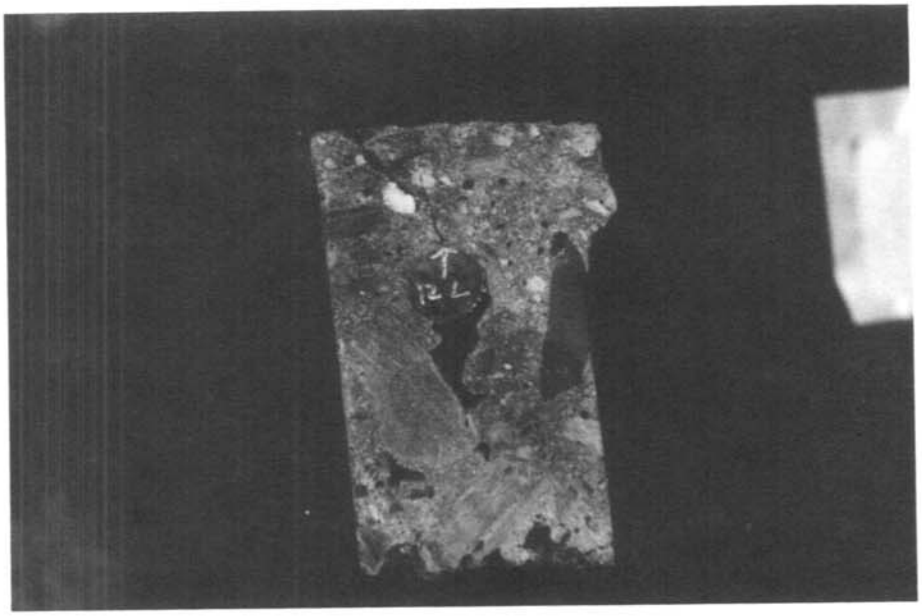

Figure 3. Edge view of Sample No. 12 showing longitudinal No. 4 (1/2-inch diameter) reinforcement. Note large void beneath the steel and crack from the surface of the concrete to the steel.

Figure 4. Opposite end of view shown in Figure 3 above. Note cracking completely through section containing the longitudinal reinforcement.

Figure 5. Bottom surface (soil side) of Sample No. 10. Concrete is not completely consolidated.

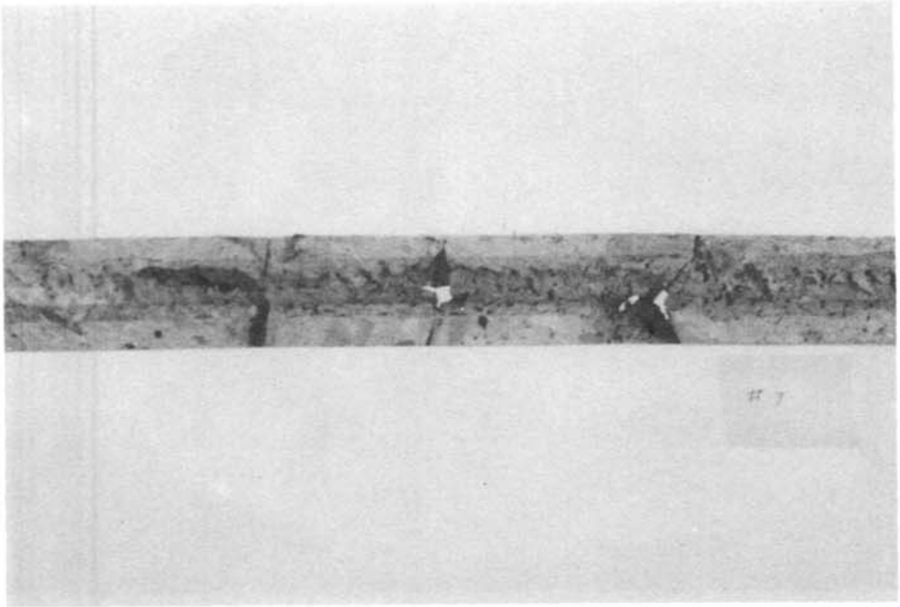

Figure 6. Slice of concrete below transverse reinforcement on Sample No. 7. In some cases, voids are continuous from the bottom surface to the steel reinforcement.

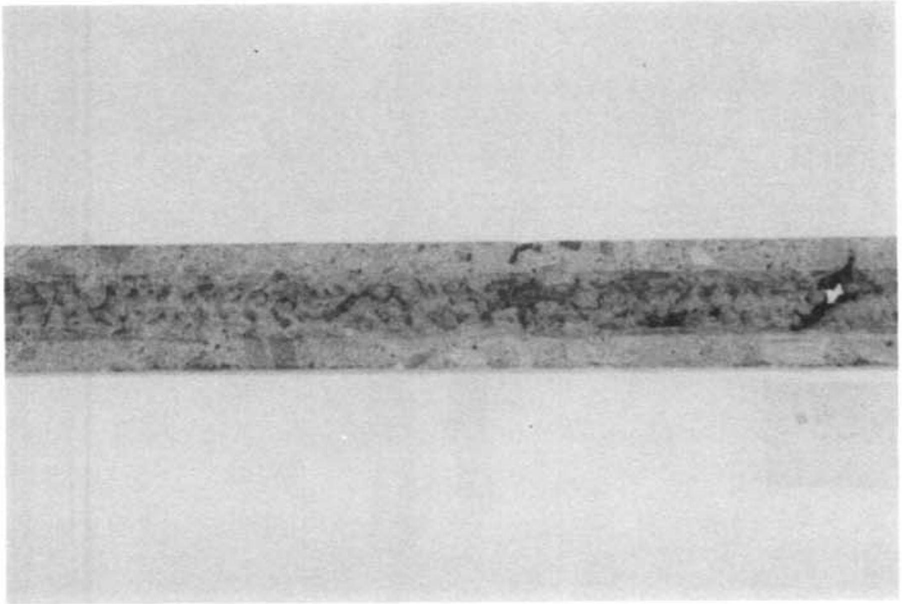

Figure 7. Concrete removed from below transverse reinforcement on Sample No. 12. Note hole and voids beneath reinforcement.

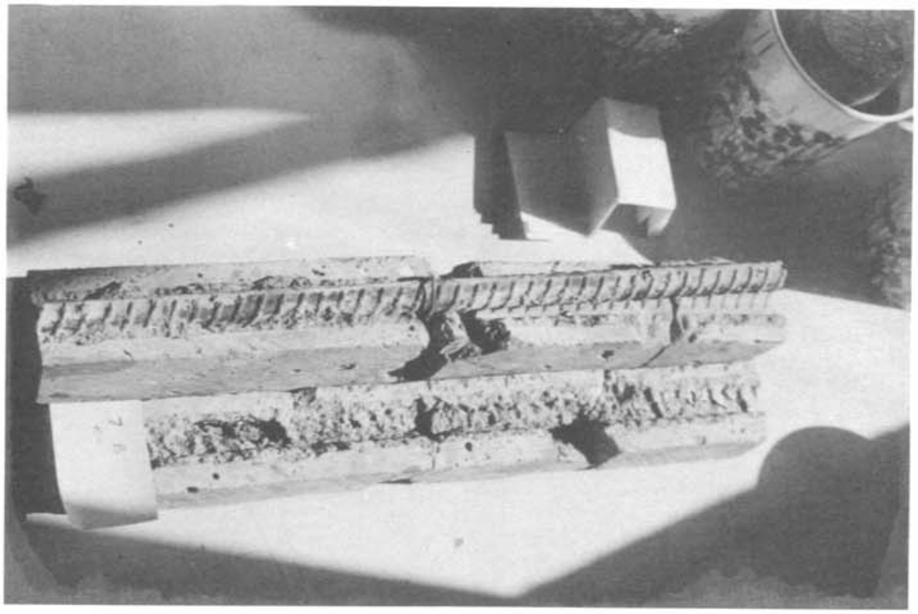

Figure 8. Slice of concrete containing the transverse reinforcement on Sample No. 7. Note poor consolidation and active corrosion of the steel.

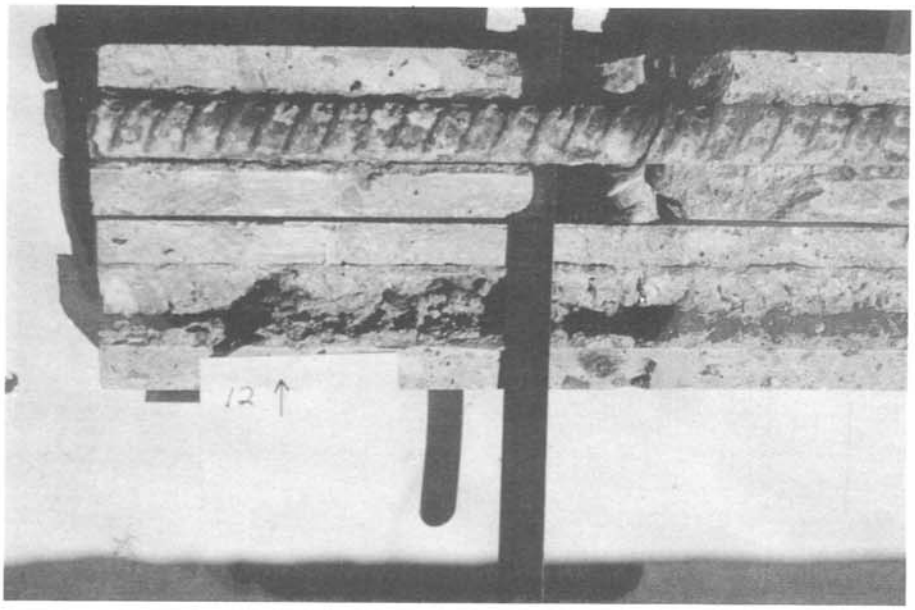

Figure 9. Slice of concrete containing the transverse reinforcement on Sample No. 12. Again note poor consolidation and active corrosion of reinforcement.

Figure 10. Underside of Sample No. 3. Steel is severely corroded and concrete is severely cracked and spalled.

Figure 11. Underside of Sample No. 5. Again steel is severely corroded and concrete is severely cracked and spalled.

IMPROVING WATER PRODUCTION FROM WELLS

By

Walt Hinz

Improving water production from a well is important, especially in Arizona where maximum production from a farmer's wells is crucial to efficient water use.

Improving production includes knowing the drawdown level of the well, which is the distance that the water level is lowered below static level when the pump is operating. After a well is drilled, tests are usually made at different pumping rates to determine the relationship between discharge and drawdown.

Wells drilled in locations where the water bearing formations are thin may show very substantial decreases in discharge per foot of drawdown as the drawdown increases.

Wells drilled in locations where the water bearing material is thick may show discharges per foot of drawdown that decrease very little as the drawdown increases.

Perforations are generally located in well casings only where the water bearing formations are found. Drillers keep records of the formations encountered as drilling progresses to enable them to locate perforations properly.

These logs can be quite valuable for supplying information needed in rehabilitating old wells but are often unavailable.

Well conditions will change with time. Aquifers may narrow and perforations may plug, causing water to travel greater distances and enter the well through other perforations. The results may be an increase in drawdown, a decrease in discharge, and higher pumping costs.

A well on property owned by Farmers Investment Company at Sahaurito produced a flow of only about 500 gallons per minute last year (1984). Although early records were not available, the farm manager thought the discharge was about 1,000 gpm in 1956, soon after the well was deepened to the present 1,046-foot depth.

Layne-Western Co., Inc., Tempe, Arizona, was contracted to rehabilitate the well and Well Scan Video Surveys, Phoenix, was hired to make a TV inspection. The inspection showed the casing to be in bad condition with deposits covering most perforations. It was recommended that cleaning be done using Sonar-Jet.

A 400-foot section of the well, considered to be in the best water bearing formation, was cleaned. A catch basket placed on the end of the Sonar Jet line was used to bring up samples of the deposits loosened by the operation.

Since a new pump was installed after the cleaning was completed, the improvement could be attributed to the well cleaning alone. However, the well discharge was increased

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The author is an irrigation engineering consultant. The article is reprinted, with permission from the editor, from the July 1986 Arizona Farmer-Stockman.

to approximately 775 gallons per minute. Because the perforations were so badly clogged, it is likely that much of this increase was due to cleaning.

Steve Starr, water division supervisor for Chandler, also had two wells rehabilitated recently. Both were videotaped before and after cleaning.

Steel brushes were used to clean the well casings to loosen deposits. The report by Well-Scan made after the cleaning stated that almost all perforations above the 800-foot level appeared to be open.

Although the overall pumping efficiency before and after cleaning could not be determined, Starr said the discharge was increased by about 400 gpm.

Pumping plant performance and well conditions will change with time. Periodic testing for overall efficiency will reveal the changes taking place. A good maintenance program will assure high pumping plant efficiencies, maintain dependability, and increase life of pumping plant components.

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SPOTLIGHT ON THE NORTH PLATTE PROJECT

Originating in the Rocky Mountains, the North Platte River flows northward from Colorado into central Wyoming, then loops in a southeasterly direction through Wyoming to Nebraska. Its basin covers 32,000 square miles. It is the most important river in southeastern Wyoming and western Nebraska. Bureau of Reclamation facilities on the river furnish water for irrigation, power, municipal, industrial, recreation, and wildlife use, and provide flood control.

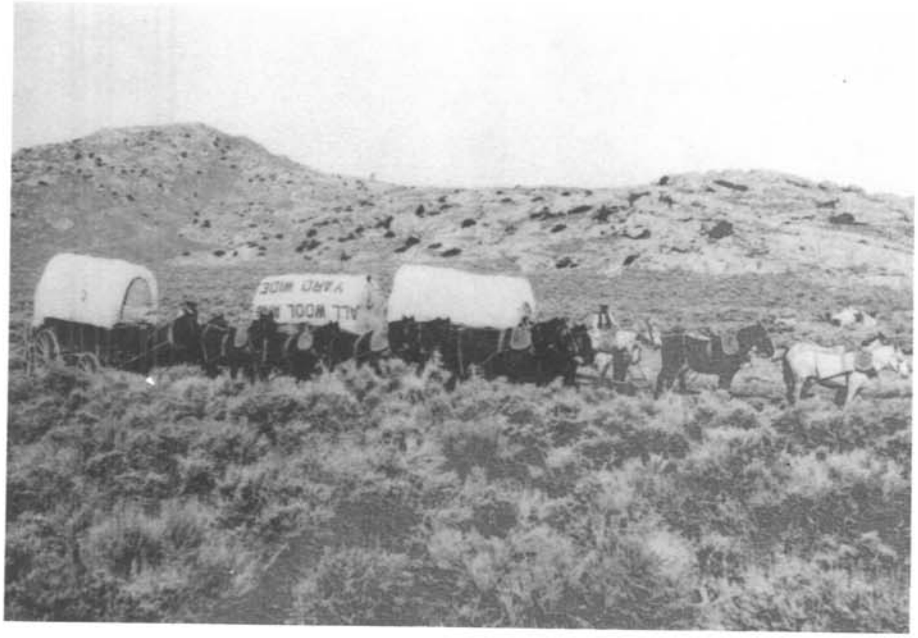
There are three Bureau of Reclamation projects on the river; the North Platte Project, the Kendrick Project, and two units (Kortes and Glendo) of the Pick-Sloan Missouri Basin Program. In this issue, we will focus on the North Platte Project.

The North Platte Project is one of the first constructed under the Reclamation Act of 1902. Major features include Pathfinder and Guernsey Dams and Reservoirs; Guernsey Powerplant; Whalen Diversion Dam; and the Interstate, Fort Laramie, and Northport Canals; and distribution laterals.

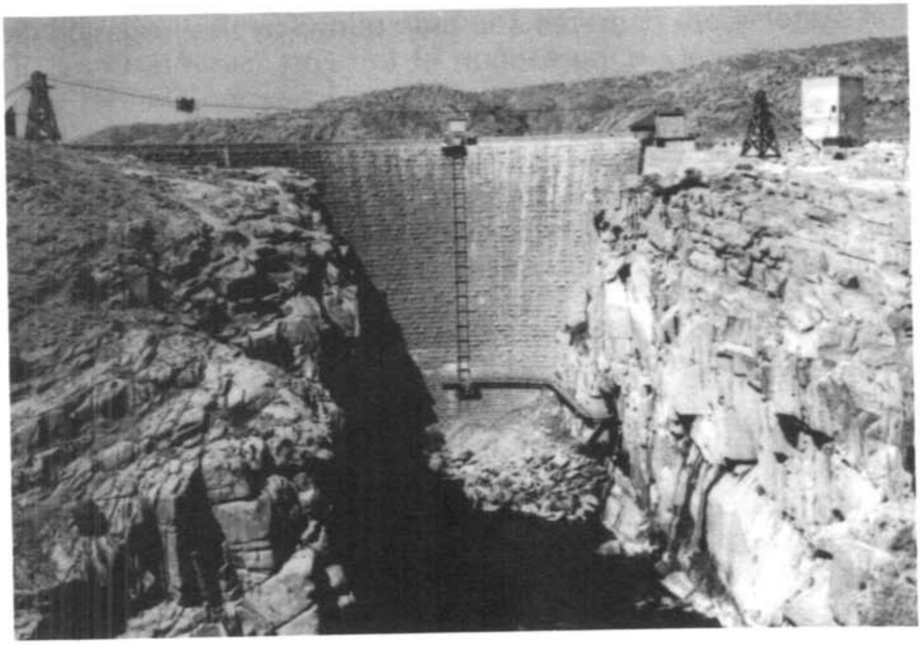
History

Early settlers in the North Platte Basin built crude individual irrigation systems which soon proved inadequate due to lack of storage facilities. Bureau of Reclamation engineers investigating the region in 1903 found a suitable dam and reservoir site near the narrow canyon where the Sweetwater and the North Platte Rivers met.

Construction of Pathfinder Dam, 47 miles southwest of Casper, Wyoming, began in 1905 and was largely built by hand labor. The dam was completed in 1909. The masonry dam is the principal storage structure of the North Platte Project and its reservoir was, in 1909, the world's largest manmade reservoir. Cement was hauled from Casper by horse freighters, and the granite for the structure was quarried from hills near the damsite. The dam itself has been designated as a National Historic Place.



Pathfinder Construction Supply Train, 1906



Pathfinder Dam

Approximately 165 miles downstream is another major feature of the project, Guernsey Dam and Powerplant. The earth and rockfill dam was the final project feature constructed. The dam and its reservoir and powerplant were completed in 1927.

Whalen Diversion Dam is about 10 miles downstream from Guernsey. The dam, consisting of a concrete overflow section, sluice gates, headworks, and an earth dike, was completed in February 1909. It diverts water into the Fort Laramie and Interstate Canals. Construction of the Interstate Canal, started in July 1905, was the first undertaking of the North Platte Project. The canal transports irrigation water to farmland and to the offstream reservoirs of Lake Alice and Lake Minatare, located northeast of Scottsbluff, Nebraska.

Irrigation

Water released from Pathfinder Reservoir for winter power generation is stored again in Glendo Reservoir for future delivery to North Platte Project lands.

A full water supply is provided to the four irrigation districts whose distribution systems were built by Reclamation. These districts include Pathfinder, Goshen, Gering-Fort Laramie, and Northport.

Pathfinder Irrigation District is served by the Interstate Canal and lateral system. Goshen and Gering-Fort Laramie Irrigation Districts are served by the Fort Laramie Canal and lateral system.

Water diverted near the Wyoming-Nebraska State line is carried 80 miles through the privately owned Tri-State Canal to the headgate of the Northport Canal and lateral system. This system serves the Northport Irrigation District near the easterly end of the project.

Project irrigation systems are operated and maintained by the irrigation districts served, with the exception of the Wyoming section of the Fort Laramie Canal. This stretch of canal is operated and maintained by the Goshen Irrigation District with the Gering-Fort Laramie District sharing the cost.

A supplemental water supply is provided to nine water user associations having a combined irrigable area of 109,000 acres. These districts are known as Warren Act contractors and have privately built distribution systems.

The area irrigated by the North Platte Project is an important source of the nation's food supply. Sugar beets, dry beans, corn, and alfalfa hay are all grown on project-irrigated land.

There has never been a crop failure since the project began operation. The project has returned many times its cost through the value of crops produced. Since 1908, North Platte Project lands have produced crops values at over $2 billion.

Power

Guernsey is the only powerplant operating on the North Platte Project. It provides approximately 4,800 kilowatts of power to the interconnected system via two generators.

Flood Control

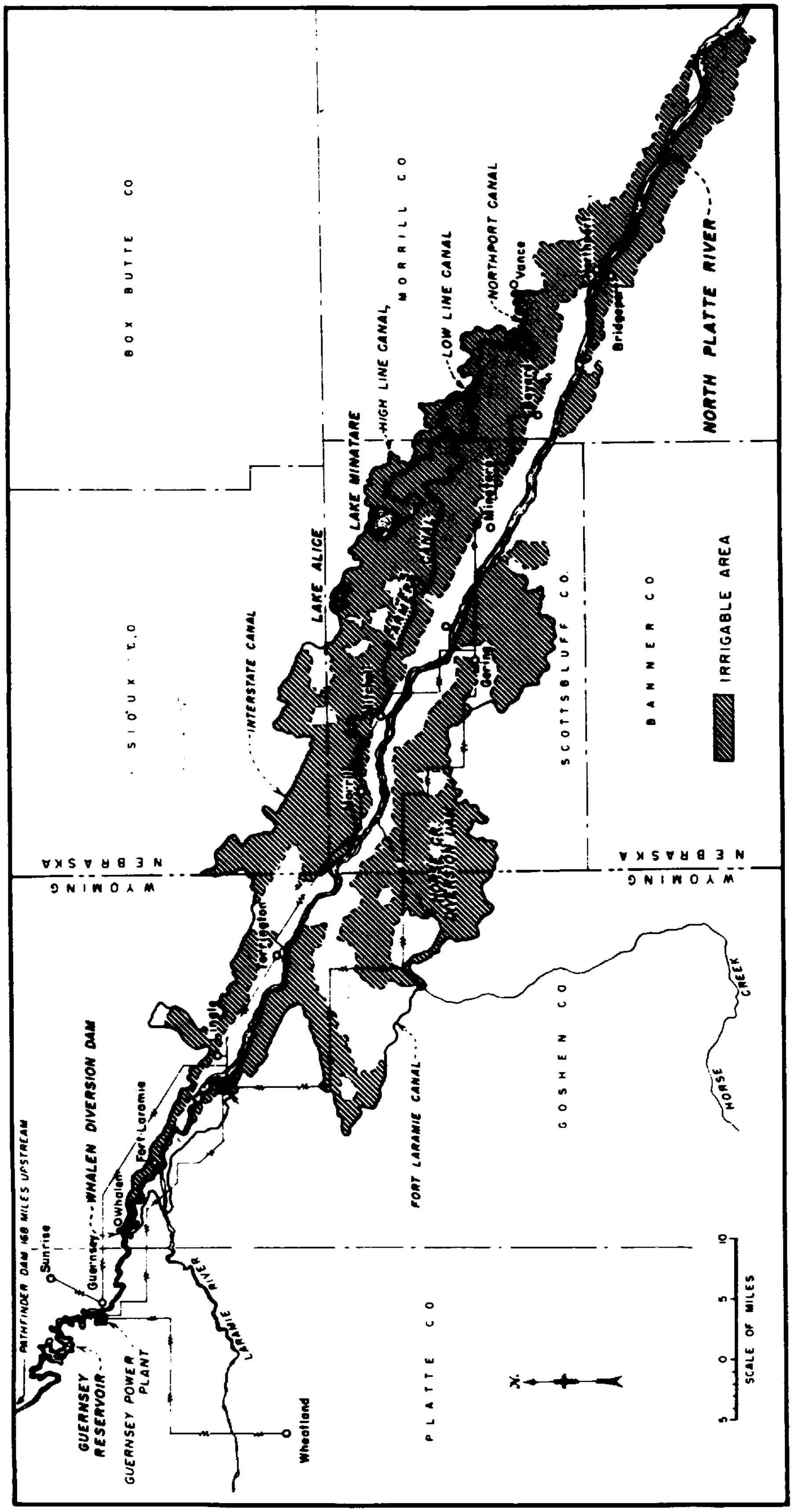
The cumulative benefits from flood control on the North Platte River have amounted to over $35 million. In 1984 alone the flood control benefit was $9.5 million.

Recreation

North Platte Project reservoirs are prime recreation areas providing fishing and boating for the inhabitants of communities bordering the river, and for tourists from other areas.

Fish and Wildlife

The North Platte Project encompasses two National Wildlife Refuges; the Pathfinder, established in 1928; and the North Platte, established in 1916. The reservoirs themselves, in addition to the nearby land around the reservoirs, provide habitat for a variety of species including warm and cold water fish, large game, migratory birds, and waterfowl.



North Platte Project

DIGEST STATEMENT

BARTLETT DAM-EROSION BELOW SPILLWAY

Dam: Bartlett
Project: Salt River Project
State: Arizona
Type: Concrete multiple-arch
Completed: 1939
Function(s): Irrigation, power
Crest length: 800 feet
Hydraulic height: 189.5 feet
Active capacity: 178,000 acre-feet
Surface area: 2,815 acres

Design Characteristics: Bartlett Dam, a feature of the Salt River Project, is located in central Arizona. The spillway has three gates, is located at the right abutment, and has a capacity of 175,000 ft^3/s. It consists of a curved concrete-lined channel 170 feet wide and 420 feet long. The concrete-lined channel terminates in a deflector sill 10 feet high. It was designed to force the water to leap clear of the downstream cutoff wall. The facility is operated and maintained by the Salt River Project.

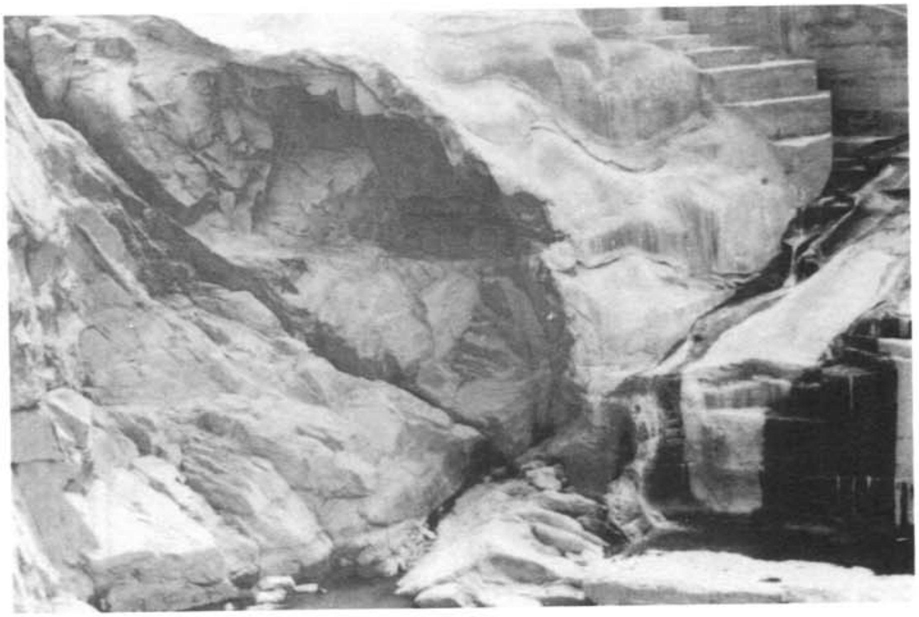
Evidence: Erosion which exposed open rock formation joints in the canyon wall and floor, located downstream and in line with the lower end of the spillway chute.

Incident: During the first moderate spill of 28,000 ft^3/s, in December 1965 and January 1966, considerable damage occurred in the discharge channel below the spillway chute flip structure. Undermining of the chute was occurring. Continued massive erosion of the discharge channel could undermine and cause the spillway to fail completely. Criticality is high.

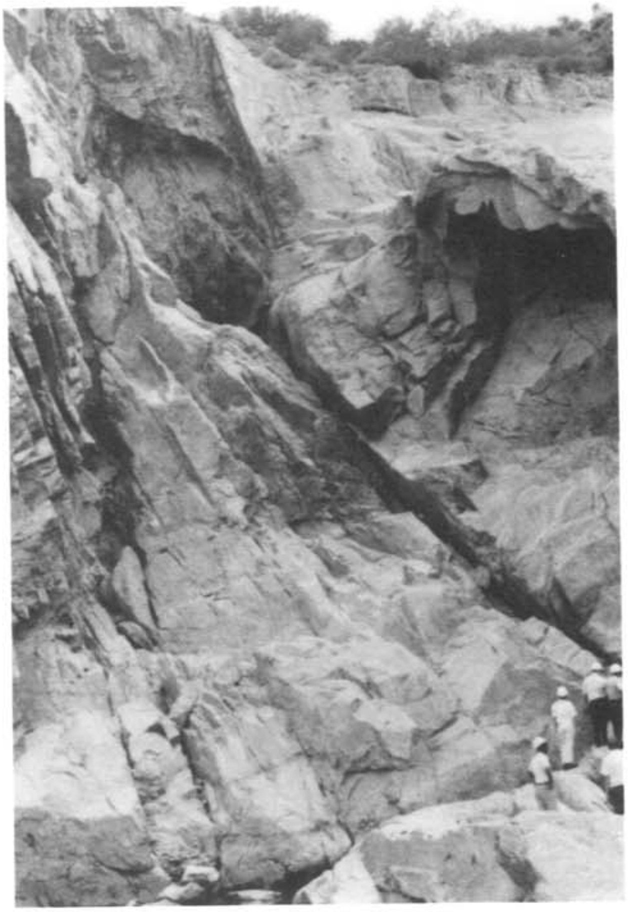
Causes: An abrupt turn in the channel and the open joints in the weathered rock of the channel contributed to the damage. A shotcrete repair program was implemented in 1966-68. The entire outlet channel for a distance of about 100 feet downstream from the end of the spillway was paved with a 9- to 12-inch thickness of shotcrete. Frequent discharges for a few years caused no detrimental effect. Major storms in early 1978 necessitated large releases peaking at 98,000 ft^3/s during March 1 to 8. Major damage occurred to the armored area. A 50-foot-deep and 100-foot-long hole was eroded in the canyon wall. The reinforced gunite was undercut. More storms in December 1978 resulted in spillway discharges up to 65,000 ft^3/s which further enlarged the plunge pool. High flows in January 1979 caused further damage.

Remedy: The rock slopes on the channel sides were scaled back for rock bolts and concrete. A cyclopean masonry wall was constructed to protect the nearly vertical rock below the spillway flip structure.

The effectiveness of the spillway channel was tested during the occurrence of numerous extremely improbable flooding incidences and has not been damaged.

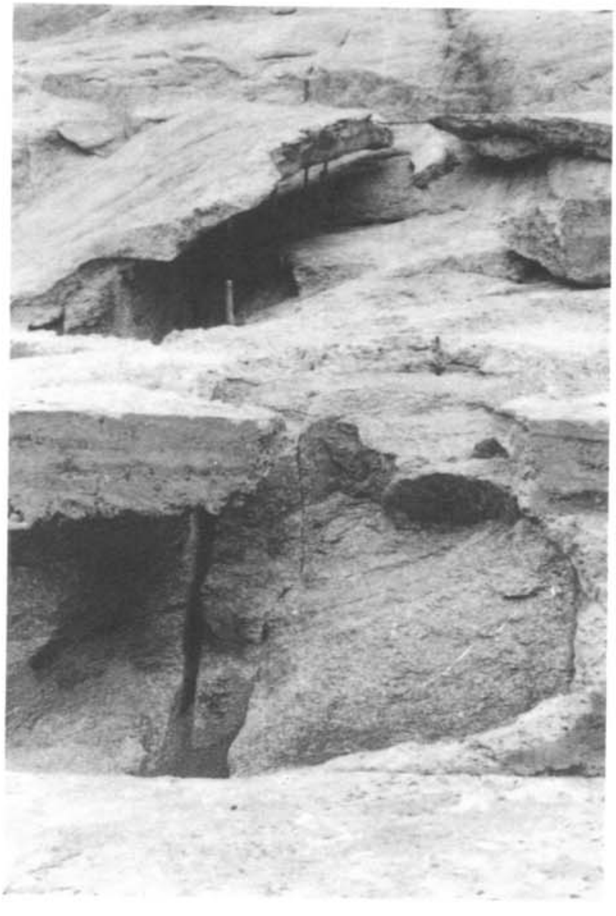


Bartlett Dam – General view of damage downstream of spillway chute. Note open joints and overhanging rock and concrete. Photo taken April 25, 1978.



Bartlett Dam – Damage downstream of spillway chute, showing open joints and overhanging rock and concrete. Photo taken April 25, 1978.

Bartlett Dam – Downstream end of spillway chute and channel armoring. Photo taken October 10, 1984.



Bartlett Dam – Damage concrete and gunite and open joints in rock foundation. Photo taken April 25, 1978.

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