R-89-13

# CONCRETE PERFORMANCE AT PUEBLO DAM, COLORADO

# 15-YEAR CORE REPORT

December 1989

U.S. DEPARTMENT OF THE INTERIOR
Bureau of Reclamation
Denver Office
Research and Laboratory Services Division
Concrete and Structural Branch

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16. ABSTRACT

Physical properties of cores extracted at approximately 15 years' age from the dam and river plug at Pueblo Dam, Colorado, indicate a good quality, uniform, well-consolidated concrete. This study is part of a series in the long-term evaluations of strength and elastic properties of concrete in various dams. Results of the tests on the cores from the river plug showed the average compressive strength of the concrete to be about 5,920 $lb/in^2$ (40.8 MPa). The average compressive strength of the dam concrete was about 4,390 $lb/in^2$ (30.3 MPa). The modulus of elasticity for the river plug concrete was about 4.79 $lb/in^2 \times 10^6$ (33 GPa), and the dam concrete modulus of elasticity was 4.41 $lb/in^2 \times 10^6$ (30.4 GPa). Poisson's ratio, density, mix design, and tensile strengths are also discussed.

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a. DESCRIPTORS--

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by

**William F. Kepler**

Concrete and Structural Branch
Research and Laboratory Services Division
Denver Office
Denver, Colorado

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UNITED STATES DEPARTMENT OF THE INTERIOR ★ BUREAU OF RECLAMATION

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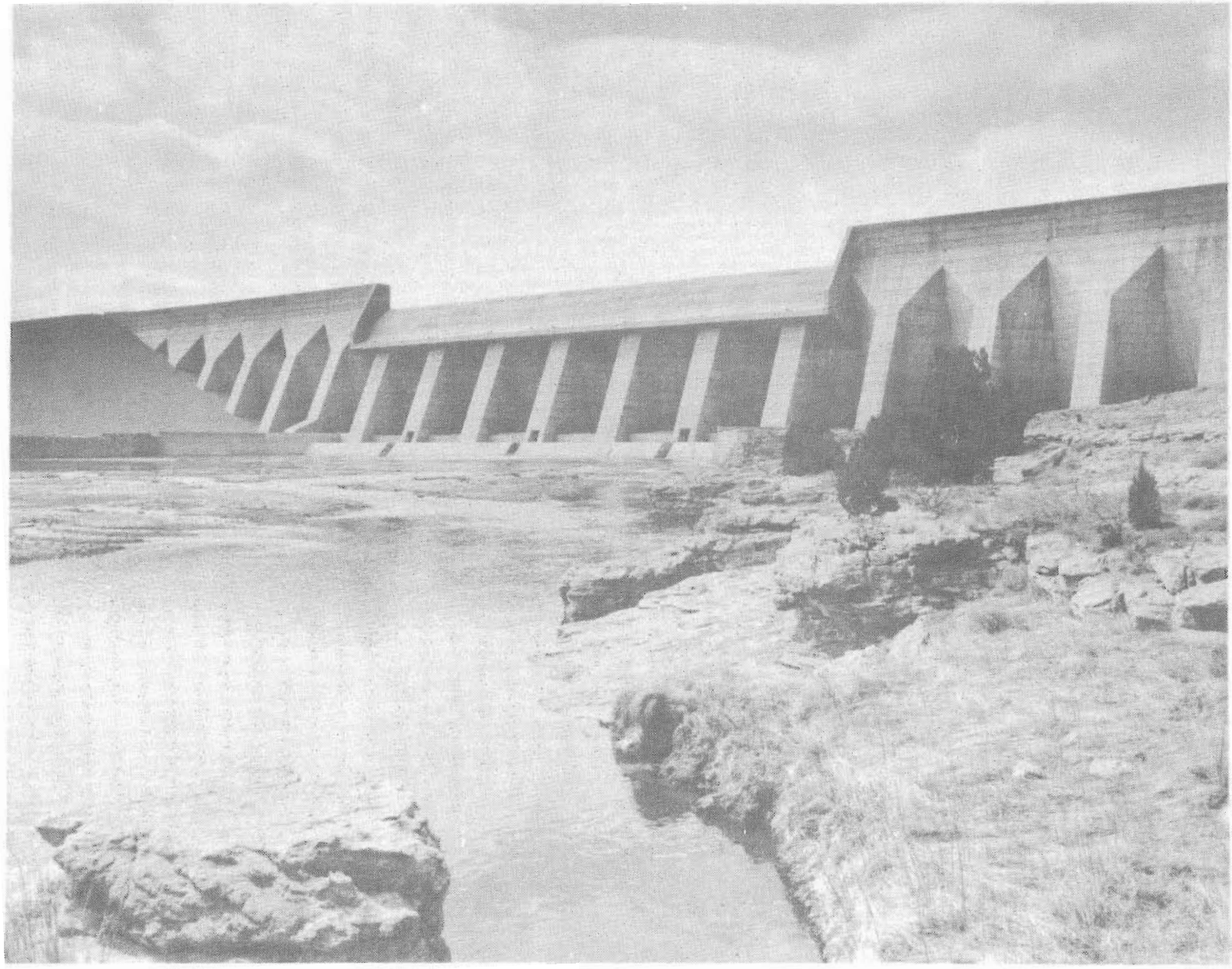


Pueblo Dam. P382-706-16857NA.

## CONTENTS



## TABLES



## FIGURES

## CONTENTS - Continued

### APPENDIX

## INTRODUCTION

Pueblo Dam is located on the Arkansas River in Pueblo County of southern Colorado, about 8 miles (12.8 km) west of the city of Pueblo. This earthen and concrete gravity dam, 190 feet (58 m) high and 10,200 feet (3110 m) long, has a 1,750-foot (533-m) long concrete spillway consisting of 23 massive head buttresses 175 feet (53 m) high. The buttresses rest on a concrete river plug foundation. The mass concrete for the river plug was placed in 1971; the mass concrete of the dam buttresses was placed in 1973 and 1974. Over 540,000 $yd^3$ (413 000 $m^3$) of concrete were placed in the structure.

In July 1987 as part of the longtime concrete dam studies, 6-inch (150-mm) diameter and 10-inch (250-mm) diameter cores were extracted to evaluate the strength and elastic properties of the concrete. These values were compared to those of earlier studies to evaluate the effects of age on various physical properties of the concrete.

This report presents the results from the physical properties testing. At testing, the average age of the cores was about 16 years for the river plug concrete and about 13 years for the dam concrete. The cores were evaluated for:

- Compressive strength
- Modulus of elasticity
- Poisson's ratio
- Direct tensile strength
- Density

Plan and profile of the Pueblo Dam spillway are shown on figures 1 and 2. Plan and profile of the Pueblo Dam river plug are shown on figure 3.

## CONCLUSIONS

The overall quality of the concrete in the cores from Pueblo Dam indicates a durable concrete having a compressive strength exceeding the design requirements.

The elastic properties of the concrete are normal for mass concrete of this strength and age.

The direct tensile strength of the plug concrete was 3.2 percent of the compressive strength while for the dam concrete it was 4.1 percent of the compressive strength. The normal expected range for mass concrete is 4 to 6 percent of the compressive strength (Harboe, 1961).

In comparison to the initial core report, there has been little change in any of the physical properties in either the river plug concrete or the dam concrete.

## PUEBLO DAM CONCRETE

Concrete placed in the river plug and dam contains type II, low-alkali cement, class F fly ash, 3-inch (75-mm) maximum-size aggregate, a WRA (water-reducing, set-controlling admixture), and an AEA (air-entraining admixture). Calcium chloride was added to the mix as an accelerator during the cold weather placements at a rate of 1 percent by weight of cementitious material. Concrete aggregate

for the dam and river plug was obtained from the Walking "O" borrow area, a flood plain deposit in the reservoir area 2 miles (3.2 km) upstream from the dam (see app. A for aggregate analysis).

Two different mass concrete mix designs were used in the river plug. In areas of severe exposure, a high cement content (low water to cement plus pozzolan ratio) was used to increase the durability of concrete; in the areas of more moderate exposure, a lower cement content was used. The higher cement content mix was designated as "exterior" and the lower cement content was designated as "interior." Only one principal mass concrete mix design was used in the dam buttresses (see table 1 for typical yield quantities).

## DRILLING AND HANDLING

Nine 10-inch (250-mm) diameter cores and four 6-inch (150-mm) diameter cores were extracted from Pueblo Dam during 1987 to furnish specimens for physical properties testing. The 10-inch-diameter cores were extracted from the dam mass concrete in blocks 7, 9, 15, 16, 17, 19, and 22. The 6-inch-diameter cores were extracted from river plug mass concrete in blocks 3, 5, 6, and 7. All cores were drilled vertically.

For economic reasons, only a representative selection of cores was shipped to Denver for testing. At the jobsite, the moist cores were wrapped in plastic and shipped in wooden crates packed with sawdust to the Bureau of Reclamation's Denver laboratories. In Denver, the core specimens were selected, logged, photographed, and tested.

ASTM C 42, "Standard Method of Obtaining and Testing Drilled Cores and Sawed Beams of Concrete" (ASTM, 1987), specifies that the diameter of concrete core extracted for compressive strength testing should preferably be at least three times the nominal maximum size of coarse aggregate used in the concrete, and must be at least twice the maximum nominal aggregate size of the coarse aggregate in the core sample. Therefore, since the mass concrete contained 3-inch (75-mm) maximum-sized aggregate, the diameter of the core by ASTM standards preferably should have been at least 9 inches (225 mm) but an absolute minimum of 6 inches. The cores extracted from the dam were 10 inches in diameter; the cores extracted from the river plug were 6 inches in diameter.

## TESTING

### Compressive Strength and Elastic Properties

The compressive strength testing was performed according to ASTM C 39, "Compressive Strength of Cylindrical Concrete Specimens" (ASTM, 1987). The ends of 10-inch-diameter compressive strength specimens were lapped plane to a tolerance of 0.002 inch (0.05 mm). The 6-inch-diameter compressive strength specimens were capped with a sulfur compound to achieve end tolerances. The compressive strength values were adjusted according to ASTM C 42 for the specimens not having a length to diameter ratio equal to 2. After removal from the fog room, specimens were sealed in plastic to prevent moisture loss.

Values for the modulus of elasticity (E) and Poisson's ratio (r) were computed according to Bureau of Reclamation test method, USBR 4469, Procedure for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression" (in preparation). For a comparison of the two methods, both the USBR 4469 and ASTM C 469, "Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression" were used to determine E and r for the river plug concrete. USBR 4469 computes E and r to 1,000 lb/in$^2$ (689 to 6895 KPa). ASTM C 469 computes E and r from a strain of 0.000050 in/in to a stress equal to 40 percent of the ultimate compressive strength.

The modulus of elasticity and Poisson's ratio were determined using epoxied strain gauges with computer readout. Lines of strain gauges were placed around the cylinder, two along either side of the long axis and two around the middle. Each line consisted of two strain gauges connected in series. The manufacturer recommended that the total length of the strain gauges be between 2.5 and 3 times the size of the maximum-size aggregate. The maximum-size aggregate was 3 inches (75 mm); therefore, the total length of the strain gauges should have been at least 7.5 inches (190 mm). The two 4-inch (100-mm) long strain gauges connected in series developed a total length of 8 inches (200 mm).

### Direct Tensile Strength

The direct tensile strength testing was performed according to Bureau of Reclamation test method, USBR 4914, "Direct Tensile Strength, Static Modulus of Elasticity, and Poisson's Ratio of Cylindrical Concrete Specimens in Tension" (in preparation). The core specimens for direct tension testing were saw cut to provide a length to diameter ratio equal to 2. Double end plates, 4-1/2 inches (115 mm) thick designed to minimize deformation, were bonded to each end of the core with epoxy and then cured for 24 hours. The specimens were sealed to prevent moisture loss. The test specimens were then placed in a hydraulic testing machine and loaded to failure in tension at 200 lb/in$^2$ per minute (1380 kPa/min).

### Density

Density of the concrete was determined by dividing the "as is" weight of the concrete specimen by the volume of the water the specimen displaced.

## TEST RESULTS

A summary of the test results is given in tables 2 and 3.

### Compressive Strength and Elastic Properties

The average compressive strengths for both the river plug concrete and the dam concrete were significantly higher than the specified 3,000 lb/in$^2$ (20.7 MPa). The excess strength was due to the increased paste volume required to place the concrete and to ensure adequate bond at the construction joints. The average compressive strength for the river plug concrete was 5,920 lb/in$^2$ (40.8 MPa), with a standard deviation of 1,100 lb/in$^2$ (7.6 MPa). The average compressive strength for the dam concrete was 4,390 lb/in$^2$ (30.3 MPa), with a standard deviation of 590 lb/in$^2$ (4.1 MPa). The higher compressive strength of the river plug concrete compared to the dam concrete is

primarily due to the higher cement content required for durability of the river plug and partially due to the smaller size of the river plug concrete test specimens.

The average compressive strength for the river plug concrete at 6 months was 6,280 lb/in$^2$ (43.3 MPa); at 3 years it was 5,840 lb/in$^2$ (40.3 MPa). The average compressive strength for the dam concrete at 6 months was 3,520 lb/in$^2$ (24.3 MPa); at 1 year it was 4,370 lb/in$^2$ (30.1 MPa).

The modulus of elasticity for the dam concrete averaged 4.41 x $10^6$ lb/in$^2$ (30.4 GPa) with a standard deviation of 1.04 x $10^6$ lb/in$^2$ (7.2 GPa). The modulus of elasticity for the river plug concrete averaged 4.79 x $10^6$ lb/in$^2$ (33.0 GPa) with a standard deviation of 0.80 x $10^6$ lb/in$^2$ (5.5 GPa). Poisson's ratio for the dam concrete averaged 0.21 with a standard deviation of 0.05. Poisson's ratio for the river plug concrete averaged 0.20 with a standard deviation of 0.03. Test results for the compressive strength and elastic properties are shown in table 2.

### Direct Tensile Strength

It appears that the direct tensile strength of the dam and especially of the river plug concrete is low. For mass concrete, the direct tensile strength is normally between 4 and 6 percent of the compressive strength. The dam mass concrete was 4.1 percent and the river plug concrete was 3.2 percent of their respective compressive strengths. Only four direct tensile test specimens contained construction joints, only one of these failed at the joint.

The direct tensile strength of the of the initial core testing showed a similar low comparison to the compressive strength (Mogck and Dunstan, 1982). At 6 months the direct tensile strength of the river plug concrete averaged 3.2 percent of the compressive strength; at 3 years it averaged 3.9 percent. At 6 months the direct tensile strength of the dam concrete averaged 5.4 percent of the compressive strength; at 1 year it averaged 4.2 percent.

The direct tensile strength of the dam concrete averaged 180 lb/in$^2$ (1240 KPa), with a standard deviation of 64 lb/in$^2$ (440 KPa). The direct tensile strength of the river plug concrete averaged 190 lb/in$^2$ (1310 KPa) with a standard deviation of 63 lb/in$^2$ (435 KPa).

The average direct tensile strength of the dam concrete at 6 months was 185 lb/in$^2$ (1275 KPa); at 1 year it was 180 lb/in$^2$ (1240 KPa). The average direct tensile strength of the river plug concrete at 6 months was 200 lb/in$^2$ (1380 KPa); at 3 years it was 220 lb/in$^2$ (1520 KPa). Test results for the direct tensile strength can be found in table 3.

### Density

The densities, shown in tables 2 and 3, vary little from sample to sample and are normal for mass concrete. The average density of the dam concrete was 152.4 lb/ft$^3$ (2442 kg/m$^3$), with a standard deviation of 2.0 lb/ft$^3$ (32 kg/m$^3$) The average density of the river plug concrete is 151.5 lb/ft$^3$ (2427 kg/m$^3$) with a standard deviation of 1.75 lb/ft$^3$ (28 kg/m$^3$). The average density of the cores taken at 6 months was 154.0 lb/ft$^3$ (2467 kg/m$^3$).

## BIBLIOGRAPHY

ASTM, *1987 Annual Book of ASTM Standards*, Concrete and Mineral Aggregates, vol. 04.02, American Society for Testing and Materials, Philadelphia, Pennsylvania, 1987.

Bureau of Reclamation, *Concrete Manual*, vol. II, U.S. Government Printing Office, U.S. Department of the Interior, Bureau of Reclamation, Washington, D.C., (in preparation).

_____, *Design Considerations for Construction of Pueblo Dam*, Denver, Colorado, March 1972.

Harboe, E. M., *Properties of Mass Concrete in Bureau of Reclamation Dams*, Concrete Laboratory Report No. C-1009, Bureau of Reclamation, Denver, Colorado, December 1961.

Mogck, L. G., and E. R. Dunstan, *Concrete Performance at Pueblo Dam, Colorado, Initial Core Report*, Report No. GR-80-7, Bureau of Reclamation, Denver, Colorado, March 1982.

**Table 1. - Pueblo Dam mass concrete - typical yield quantities per $yd^3$ (per $m^3$)**

| Material | Weight | Source |
|---|---|---|
| | *River plug exterior concrete* | |
| Water | 187 lb (84.3 kg) | |
| Cement | 330 lb (149.7 kg) | Ideal, Florence CO |
| Pozzolan | 82 lb (37.2 kg) | Walter Handy, Ladue MO |
| Sand | 859 lb (390 kg) | Borrow Walking "O" |
| Coarse aggregate | 2,554 lb (1160 kg) | Borrow Walking "O" |
| AEA | 2.8 oz (108 mL) | Protex Industries |
| WRA | 21.3 oz (825 mL) | Protex Industries |
| Concrete temperature | = 49 °F (9.4 °C) | |
| Slump | = 2.25 inches (57 mm) | |
| Unit weight | = 148.6 lb/$ft^3$ (2379 kg/$m^3$) | |
| W/(C+P) | = 0.45 | |
| Air content: | | |
| Gravimetric | = 3.4 percent | |
| Pressure meter | = 4.0 percent | |
| Sand content | = 27 percent of total aggregate | |
| Coarse aggregate | = 34.6 percent No. 4 to 3/4-inch (4.75- to 19.0-mm) | |
| | 34.7 percent 3/4- to 1-1/2-inch (19.0- to 37.5-mm) | |
| | 30.7 percent 1-1/2- to 3-inch (37.5- to 75-mm) | |
| Design compressive strength at 28 days | = 3,000 lb/$in^2$ (20.7 MPa) | |



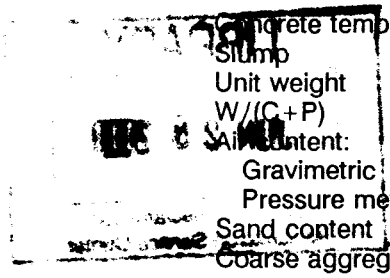
Note: From March 1971 L-29 construction report for concrete placed on March 17, 1971.

| | | |
|---|---|---|
| | *River plug interior concrete* | |
| Water | 174 lb (78.9 kg) | |
| Cement | 247 lb (112.0 kg) | Ideal, Florence CO |
| Pozzolan | 83 lb (37.6 kg) | Walter Handy, Ladue MO |
| Sand | 932 lb (443 kg) | Borrow Walking "O" |
| Coarse aggregate | 2,557 lb (1156 kg) | Borrow Walking "O" |
| AEA | 2.5 oz (97 mL) | Protex Industries |
| WRA | 17.2 oz (666 mL) | Protex Industries |
| Concrete temperature | = 48 °F (8.9 °C) | |
| Slump | = 2.25 inches (57 mm) | |
| Unit weight | = 147.6 lb/$ft^3$ (2363 kg/$m^3$) | |
| W/(C+P) | = 0.53 | |
| Air content: | | |
| Gravimetric | = 4.2 percent | |
| Pressure meter | = 4.3 percent | |
| Sand content | = 27 percent of total aggregate | |
| Coarse aggregate | = 34.9 percent No. 4 to 3/4-inch (4.75 to 19.0-mm) | |
| | 35.0 percent 3/4- to 1-1/2-inch (19.0- to 37.5-mm) | |
| | 30.1 percent 1-1/2- to 3-inch (37.5- to 75-mm) | |
| Design compressive strength at 90 days | = 3,000 lb/$in^2$ (20.7 MPa) | |

Note: From March 1971 L-29 construction report for concrete placed on March 12, 1971.

**Table 1. - Pueblo Dam mass concrete - typical yield quantities per $yd^3$ (per $m^3$) - Continued**

| Material | Weight | Source |
|---|---|---|
| | *Dam exterior concrete* | |
| Water | 158 lb (72 kg) | |
| Cement | 210 lb (95 kg) | Ideal, Florence CO |
| Pozzolan | 70 lb (32 kg) | Walter Hardy, Ladue, MO |
| Sand | 985 lb (447 kg) | Borrow Walking "O" |
| Coarse aggregate | 2,584 lb (1172 kg) | Borrow Walking "O" |
| AEA | 3.0 oz (116 mL) | Protex Industries |
| WRA | 11.7 oz (453 mL) | Sika Chemicals |



Concrete temperature = 55 °F (12.8 °C)
Slump = 1.75 inches (44 mm)
Unit weight = 148.4 lb/$ft^3$ (2376 kg/$m^3$)
W/(C+P) = 0.57
Air content:
  Gravimetric = 4.4 percent
  Pressure meter = 3.0 percent
Sand content = 27 percent of total aggregate
Coarse aggregate = 34.5 percent No. 4 to 3/4-inch (4.75- to 19.0-mm)
  32.0 percent 3/4- to 1-1/2-inch (19.0- to 37.5-mm)
  33.5 percent 1-1/2- to 3-inch (37.5- to 75-mm)
Design compressive strength at 180 days = 3,000 lb/$in^2$ (20.7 MPa)

Note: From August 1973 L-29 construction report for concrete placed on August 1, 1973.

**Table 2. - Compressive strength and elastic properties - Pueblo Dam concrete cores (in-lb units)**

| Block | Station | Elevation (ft) | Date placed | Testing age (yr) | Density ($lb/ft^3$) | Compressive strength ($lb/in^2$) | USBR 4469 | | ASTM C 469 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Modulus of elasticity ($lb/in^2 \times 10^6$) | Poisson's ratio | Modulus of elasticity ($lb/in^2 \times 10^6$) | Poisson's ratio |
| *River plug concrete (6- by 12-inch-diameter specimens)* | | | | | | | | | | |
| 3 | 4+51.9 | 4740.7 | 4/71 | 16.18 | 151.0 | 5,240 | 4.23 | 0.20 | 4.00 | 0.20 |
| 3 | 4+51.9 | 4745.2 | 4/71 | 16.18 | 149.8 | 7,250 | 4.82 | 0.20 | 4.60 | 0.20 |
| 3 | 4+51.9 | 4747.8 | 4/71 | 16.18 | 149.4 | 6,480 | 6.94 | 0.35 | 6.85 | 0.35 |
| 3 | 4+51.9 | 4749.4 | 4/71 | 16.18 | 145.1 | 4,960 | 4.31 | 0.16 | 4.10 | 0.15 |
| 5 | 5+77.2 | 4731.6 | 4/71 | 16.18 | 152.0 | 4,540 | 3.93 | 0.13 | | |
| 5 | 5+77.2 | 4743.1 | 4/71 | 16.18 | 149.7 | 7,790 | 5.82 | 0.23 | 5.30 | 0.22 |
| 5 | 5+77.2 | 4744.3 | 4/71 | 16.16 | 152.5 | 7,930 | 4.57 | 0.21 | 4.35 | 0.22 |
| 5 | 5+77.2 | 4747.3 | 4/71 | 16.18 | 153.7 | 6,670 | 4.68 | 0.15 | 4.55 | 0.18 |
| 6 | 4+48.0 | 4732.4 | 4/71 | 16.18 | 150.5 | 4,610 | 5.60 | 0.26 | 5.40 | 0.28 |
| 6 | 4+48.0 | 4737.0 | 4/71 | 16.18 | 153.0 | 6,000 | 4.69 | 0.19 | 4.60 | 0.21 |
| 6 | 4+48.0 | 4741.6 | 4/71 | 16.18 | 155.6 | 5,340 | 4.49 | 0.23 | 4.50 | 0.26 |
| 6 | 4+48.0 | 4746.3 | 4/71 | 16.18 | 151.6 | 6,680 | 4.38 | 0.18 | 4.20 | 0.19 |
| 6 | 4+48.0 | 4734.5 | 4/71 | 16.18 | 149.4 | 4,460 | 4.17 | 0.20 | 4.00 | 0.20 |
| 7 | 5+47.9 | 4734.5 | 4/71 | 16.18 | 152.8 | 4,970 | 6.09 | 0.28 | 6.45 | 0.32 |
| 7 | 5+47.9 | 4736.9 | 4/71 | 16.18 | 154.2 | 4.680 | 1.91 | 0.26 | 2.25 | 0.28 |
| 7 | 5+47.9 | 4738.9 | 4/71 | 16.18 | 150.4 | 5,540 | 5.01 | 0.22 | 4.80 | 0.22 |
| 7 | 5+47.9 | 4739.9 | 4/71 | 16.18 | 151.1 | 6,500 | 6.12 | 0.25 | 6.10 | 0.28 |
| 7 | 5+47.9 | 4742.7 | 4/71 | 16.16 | 154.8 | 7,220 | 5.11 | 0.18 | 5.05 | 0.20 |
| 7 | 5+47.9 | 4745.3 | 4/71 | 16.18 | 152.0 | 5,660 | 4.13 | 0.11 | 4.10 | 0.14 |
| Averages | | | | 16.18 | 151.5 | 5,920 | 4.79 | 0.21 | 4.73 | 0.23 |

Note: The river plug stationing is perpendicular to the dam stationing.

**Table 2. - Compressive strength and elastic properties - Pueblo Dam concrete cores (in-lb units) - Continued**

| Block | Station | Elevation (ft) | Date placed | Testing age (yr) | Density ($lb/ft^3$) | Compressive strength ($lb/in^2$) | USBR 4469 Modulus of elasticity ($lb/in^2 \times 10^6$) | USBR 4469 Poisson's ratio |
|---|---|---|---|---|---|---|---|---|
| | | | | *Dam concrete (10- by 12-inch-diameter specimens)* | | | | |
| 7 | 56+69.5 | 4912.6 | 5/74 | 13.12 | 151.2 | 4,480 | 5.14 | 0.22 |
| 7 | 56+69.5 | 4918.1 | 5/74 | 13.12 | 152.4 | 4,490 | 5.25 | 0.20 |
| 9 | 58+51.0 | 4773.7 | 11/73 | 13.62 | 154.4 | 4,440 | 2.42 | 0.09 |
| 9 | 58+51.0 | 4777.7 | 11/73 | 13.62 | 153.9 | 4,470 | 4.69 | 0.21 |
| 9f6 | 57+83.7 | 4753.9 | 11/73 | 13.62 | 160.4 | 5,130 | | |
| 15a | 62+77.9 | 4777.7 | 9/73 | 13.79 | 151.5 | 3,990 | 4.20 | 0.22 |
| 15b | 62+77.9 | 4773.4 | 9/73 | 13.79 | 150.0 | 4,550 | 4.92 | 0.22 |
| 15b | 62+77.9 | 4777.7 | 9/73 | 13.79 | 152.2 | 3,410 | 4.58 | 0.19 |
| 16 | 63+69.0 | 4916.0 | 9/74 | 12.79 | 150.2 | 4,400 | 4.88 | 0.22 |
| 17 | 64+44.0 | 4915.0 | 6/74 | 13.05 | 152.5 | 4,560 | 3.16 | 0.22 |
| 19 | 65+94.0 | 4919.6 | 6/73 | 14.05 | 150.8 | 3,760 | 4.21 | 0.18 |
| 22 | 68+15.0 | 4915.6 | 10/73 | 13.71 | 150.9 | 5,500 | 4.52 | 0.18 |
| 22 | 68+15.0 | 4920.0 | 10/73 | 13.71 | 151.2 | 3,460 | 4.94 | 0.21 |
| | Averages | | | 13.52 | 152.4 | 4,390 | 4.41 | 0.20 |

**Table 2. - Compressive strength and elastic properties - Pueblo Dam concrete cores (SI units) - Continued**

| Block | Station | Elevation (m) | Date placed | Testing age (yr) | Density (kg/m$^3$) | Compressive strength (MPa) | USBR 4469 Modulus of elasticity (GPa) | USBR 4469 Poisson's ratio | ASTM C 469 Modulus of elasticity (GPa) | ASTM C 469 Poisson's ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *River plug concrete (150- by 300-mm-diameter specimens)* | | | | | | |
| 3 | 4+51.9 | 1445.0 | 4/71 | 16.18 | 2420 | 36.1 | 29.2 | 0.20 | 27.6 | 0.20 |
| 3 | 4+51.9 | 1446.3 | 4/71 | 16.18 | 2400 | 50.0 | 33.2 | 0.20 | 31.7 | 0.20 |
| 3 | 4+51.9 | 1447.1 | 4/71 | 16.18 | 2390 | 44.7 | 47.8 | 0.35 | 47.2 | 0.35 |
| 3 | 4+51.9 | 1447.6 | 4/71 | 16.18 | 2320 | 34.2 | 29.7 | 0.16 | 28.3 | 0.15 |
| 5 | 5+77.2 | 1442.2 | 4/71 | 16.19 | 2440 | 31.3 | 27.1 | 0.13 | | |
| 5 | 5+77.2 | 1445.7 | 4/71 | 16.18 | 2400 | 53.7 | 40.1 | 0.23 | 36.5 | 0.22 |
| 5 | 5+77.2 | 1446.1 | 4/71 | 16.16 | 2440 | 54.7 | 31.5 | 0.21 | 30.0 | 0.22 |
| 5 | 5+77.2 | 1447.0 | 4/71 | 16.18 | 2460 | 46.0 | 32.3 | 0.15 | 31.4 | 0.18 |
| 6 | 4+48.0 | 1442.4 | 4/71 | 16.18 | 2410 | 31.8 | 38.6 | 0.26 | 37.2 | 0.28 |
| 6 | 4+48.0 | 1443.8 | 4/71 | 16.18 | 2450 | 41.4 | 32.3 | 0.19 | 31.7 | 0.21 |
| 6 | 4+48.0 | 1445.2 | 4/71 | 16.18 | 2490 | 36.8 | 31.0 | 0.23 | 31.0 | 0.26 |
| 6 | 4+48.0 | 1446.7 | 4/71 | 16.18 | 2430 | 46.1 | 30.2 | 0.18 | 29.0 | 0.19 |
| 6 | 4+48.0 | 1447.6 | 4/71 | 16.18 | 2350 | 30.8 | 28.8 | 0.20 | 27.6 | 0.20 |
| 7 | 5+47.9 | 1443.1 | 4/71 | 16.18 | 2450 | 34.3 | 42.0 | 0.28 | 44.5 | 0.32 |
| 7 | 5+47.9 | 1443.8 | 4/71 | 16.18 | 2470 | 32.3 | 13.2 | 0.26 | 15.5 | 0.28 |
| 7 | 5+47.9 | 1444.4 | 4/71 | 16.18 | 2410 | 38.2 | 34.5 | 0.22 | 33.1 | 0.22 |
| 7 | 5+47.9 | 1444.7 | 4/71 | 16.18 | 2420 | 44.8 | 42.2 | 0.25 | 42.1 | 0.28 |
| 7 | 5+47.9 | 1445.6 | 4/71 | 16.16 | 2480 | 49.8 | 35.2 | 0.18 | 34.8 | 0.20 |
| 7 | 5+47.9 | 1446.4 | 4/71 | 16.18 | 2440 | 39.0 | 28.5 | 0.11 | 28.3 | 0.14 |
| | Averages | | | 16.18 | 2430 | 40.8 | 33.0 | 0.21 | 32.6 | 0.23 |

Note: The river plug stationing is perpendicular to the dam stationing.

**Table 2. - Compressive strength and elastic properties - Pueblo Dam concrete cores (SI units) - Continued**

| Block | Station | Elevation (m) | Date placed | Testing age (yr) | Density ($kg/m^3$) | Compressive strength (MPa) | USBR 4469 Modulus of elasticity (GPa) | USBR 4469 Poisson's ratio |
|---|---|---|---|---|---|---|---|---|
| | | | | *Dam concrete (250- by 500-mm-diameter specimens)* | | | | |
| 7 | 56+69.5 | 1497.4 | 5/74 | 13.12 | 2420 | 30.9 | 35.4 | 0.22 |
| 7 | 56+69.5 | 1499.0 | 5/74 | 13.12 | 2440 | 34.1 | 36.2 | 0.20 |
| 9 | 58+51.0 | 1455.0 | 11/73 | 13.62 | 2470 | 30.6 | 16.7 | 0.09 |
| 9 | 58+51.0 | 1456.2 | 11/73 | 13.62 | 2470 | 30.8 | 32.3 | 0.21 |
| 9f6 | 57+83.7 | 1449.0 | 11/73 | 13.62 | 2570 | 35.4 | | |
| 15a | 62+77.9 | 1456.2 | 9/73 | 13.79 | 2430 | 27.5 | 29.0 | 0.22 |
| 15b | 62+77.9 | 1454.9 | 9/73 | 13.79 | 2400 | 31.4 | 33.9 | 0.22 |
| 15b | 62+77.9 | 1456.2 | 9/73 | 13.79 | 2440 | 23.5 | 31.6 | 0.19 |
| 16 | 63+69.0 | 1498.4 | 9/74 | 12.79 | 2410 | 30.3 | 33.6 | 0.22 |
| 17 | 64+44.0 | 1498.1 | 6/74 | 13.05 | 2440 | 31.4 | 21.8 | 0.22 |
| 19 | 65+94.0 | 1499.5 | 6/73 | 14.05 | 2420 | 25.9 | 29.0 | 0.18 |
| 22 | 68+15.0 | 1498.3 | 10/73 | 13.71 | 2420 | 37.9 | 31.2 | 0.18 |
| 22 | 68+15.0 | 1499.6 | 10/73 | 13.71 | 2420 | 23.9 | 34.1 | 0.21 |
| | Averages | | | 13.52 | 2440 | 30.3 | 30.4 | 0.20 |

**Table 3. - Direct tensile strength - Pueblo Dam concrete cores (in-lb units)**

| Block | Station | Elevation (ft) | Date placed | Testing age (yr) | Density ($lb/ft^3$) | Direct tensile strength ($lb/in^2$) |
|---|---|---|---|---|---|---|
| | | *River plug concrete (6- by 12-inch-diameter specimens)* | | | | |
| 3 | 4+51.9 | 4733.4 | 4/71 | 16.13 | 151.1 | 180* |
| 3 | 4+51.9 | 4734.4 | 4/71 | 16.13 | 152.1 | 160 |
| 3 | 4+51.9 | 4737.4 | 4/71 | 16.15 | 150.8 | 200 |
| 3 | 4+51.9 | 4738.4 | 4/71 | 16.15 | 152.7 | 210 |
| 3 | 4+51.9 | 4739.4 | 4/71 | 16.13 | 149.6 | 230 |
| 3 | 4+51.9 | 4746.5 | 4/71 | 16.15 | 151.1 | 160 |
| 3 | 4+51.9 | 4744.2 | 4/71 | 16.13 | 153.3 | 270 |
| 5 | 5+77.2 | 4732.6 | 4/71 | 16.13 | 151.9 | 190 |
| 5 | 5+77.2 | 4735.2 | 4/71 | 16.13 | 150.6 | 330 |
| 5 | 5+77.2 | 4736.3 | 4/71 | 16.13 | 151.4 | 220* |
| 6 | 4+48.0 | 4735.0 | 4/71 | 16.15 | 149.6 | 120 |
| 6 | 4+48.0 | 4740.6 | 4/71 | 16.13 | 148.9 | 80 |
| 6 | 4+48.0 | 4742.7 | 4/71 | 16.13 | 146.6 | 220 |
| 6 | 4+48.0 | 4744.4 | 4/71 | 16.15 | 151.7 | 110* |
| 6 | 4+48.0 | 4743.0 | 4/71 | 16.13 | 150.1 | 160 |
| 7 | 5+47.9 | 4732.5 | 4/71 | 16.13 | 152.8 | 110 |
| 7 | 5+47.9 | 4735.5 | 4/71 | 16.13 | 151.6 | 230 |
| 7 | 5+47.9 | 4737.9 | 4/71 | 16.15 | 154.2 | 70 |
| 7 | 5+47.9 | 4741.7 | 4/71 | 16.15 | 152.6 | 230 |
| 7 | 5+47.9 | 4744.0 | 4/71 | 16.13 | 152 2 | 260 |
| 7 | 5+47.9 | 4747.5 | 4/71 | 16.15 | 149.9 | 220 |
| | Averages | | | 16.14 | 151.2 | 190 |

* These test specimens contain construction joints. Dam concrete in block 15b at elevation 4769.2 failed at the construction joint. River plug concrete in block 3 at elevation 4733.4, in block 6 at elevation 4742.7, and in block 7 at elevation 4732.5 did not fail at the construction joint.

Note: The river plug stationing is perpendicular to the dam stationing.

**Table 3. - Direct tensile strength - Pueblo Dam concrete cores (in-lb units) - Continued**

| Block | Station | Elevation (ft) | Date placed | Testing age (yr) | Density ($lb/ft^3$) | Direct tensile strength ($lb/in^2$) |
|---|---|---|---|---|---|---|
| | | | *Dam concrete (10- by 20-inch-diameter specimens)* | | | |
| 7 | 56+69.5 | 4916.3 | 5/74 | 13.14 | 150.7 | 220 |
| 9 | 58+51.0 | 4775.6 | 11/73 | 13.64 | 150.7 | 180 |
| 9f6 | 57+83.7 | 4751.6 | 11/73 | 13.64 | 152.2 | 200 |
| 15b | 62+77.9 | 4769.2 | 9/73 | 13.82 | 150.5 | 90* |
| 15b | 62+77.9 | 4771.4 | 9/73 | 13.82 | 149.9 | 320 |
| 15b | 62+77.9 | 4775.5 | 9/73 | 13.81 | 150.3 | 250 |
| 17 | 64+44.0 | 4912.4 | 6/74 | 13.07 | 150.7 | 110 |
| 17 | 64+44.0 | 4918.1 | 6/74 | 13.05 | 150.8 | 140 |
| 19 | 65+94.0 | 4913.5 | 6/73 | 14.05 | 153.2 | 140 |
| 19 | 65+94.0 | 4916.8 | 6/73 | 14.07 | 151.1 | 150 |
| 22 | 68+15.0 | 4917.7 | 10/73 | 13.73 | 150.9 | 180 |
| | Averages | | | 13.62 | 151.0 | 180 |

* These test specimens contain construction joints. Dam concrete in block 15b at elevation 4769.2 failed at the construction joint. River plug concrete in block 3 at elevation 4733.4, in block 6 at elevation 4742.7, and in block 7 at elevation 4732.5 did not fail at the construction joint.

**Table 3. - Direct tensile strength - Pueblo Dam concrete cores (SI units) - Continued**

| Block | Station | Elevation (m) | Date placed | Testing age (yr) | Density ($kg/m^3$) | Direct tensile strength (kPa) |
|---|---|---|---|---|---|---|
| | | *River plug concrete (150- by 300-mm-diameter specimens)* | | | | |
| 3 | 4+51.9 | 1442.7 | 4/71 | 16.13 | 2420 | 1240* |
| 3 | 4+51.9 | 1443.0 | 4/71 | 16.13 | 2440 | 1100 |
| 3 | 4+51.9 | 1444.0 | 4/71 | 16.15 | 2420 | 1380 |
| 3 | 4+51.9 | 1444.3 | 4/71 | 16.15 | 2450 | 1450 |
| 3 | 4+51.9 | 1444.6 | 4/71 | 16.13 | 2400 | 1590 |
| 3 | 4+51.9 | 1446.7 | 4/71 | 16.15 | 2420 | 1100 |
| 3 | 4+51.9 | 1446.0 | 4/71 | 16.13 | 2460 | 1860 |
| 5 | 5+77.2 | 1442.5 | 4/71 | 16.13 | 2430 | 1310 |
| 5 | 5+77.2 | 1443.3 | 4/71 | 16.13 | 2410 | 2280 |
| 5 | 5+77.2 | 1443.6 | 4/71 | 16.13 | 2430 | 1520* |
| 6 | 4+48.0 | 1443.2 | 4/71 | 16.15 | 2400 | 830 |
| 6 | 4+48.0 | 1444.9 | 4/71 | 16.13 | 2390 | 550 |
| 6 | 4+48.0 | 1445.6 | 4/71 | 16.13 | 2350 | 1520 |
| 6 | 4+48.0 | 1446.1 | 4/71 | 16.15 | 2430 | 760* |
| 6 | 4+48.0 | 1447.2 | 4/71 | 16.13 | 2400 | 1100 |
| 7 | 5+47.9 | 1442.5 | 4/71 | 16.13 | 2450 | 760 |
| 7 | 5+47.9 | 1443.4 | 4/71 | 16.13 | 2430 | 1590 |
| 7 | 5+47.9 | 1444.1 | 4/71 | 16.15 | 2470 | 480 |
| 7 | 5+47.9 | 1445.3 | 4/71 | 16.15 | 2440 | 1590 |
| 7 | 5+47.9 | 1446.0 | 4/71 | 16.13 | 2440 | 1790 |
| 7 | 5+47.9 | 1447.0 | 4/71 | 16.15 | 2400 | 1520 |
| | Averages | | | 16.14 | 2420 | 1310 |

* These test specimens contain construction joints. Dam concrete in block 15b at elevation 1453.7 failed at the construction joint. River plug concrete in block 3 at elevation 1442.7, in block 6 at elevation 1445.6, and in block 7 at elevation 1442.5 did not fail at the construction joint.

Note: The river plug stationing is perpendicular to the dam stationing.

**Table 3. - Direct tensile strength - Pueblo Dam concrete cores (SI units) - Continued**

| Block | Station | Elevation (m) | Date placed | Testing age (yr) | Density ($kg/m^3$) | Direct tensile strength (kPa) |
|---|---|---|---|---|---|---|
| | | | *Dam concrete (250- by 500-mm-diameter specimens)* | | | |
| 7 | 56+69.5 | 1498.5 | 5/74 | 13.14 | 2410 | 1520 |
| 9 | 58+51.0 | 1455.6 | 11/73 | 13.64 | 2410 | 1240 |
| 9f6 | 57+83.7 | 1448.3 | 11/73 | 13.64 | 2440 | 1380 |
| 15b | 62+77.9 | 1453.7 | 9/73 | 13.82 | 2410 | 620* |
| 15b | 62+77.9 | 1454.3 | 9/73 | 13.82 | 2400 | 2210 |
| 15b | 62+77.9 | 1455.6 | 9/73 | 13.81 | 2410 | 1720 |
| 17 | 64+44.0 | 1497.3 | 6/74 | 13.07 | 2410 | 760 |
| 17 | 64+44.0 | 1499.0 | 6/74 | 13.05 | 2420 | 970 |
| 19 | 65+94.0 | 1497.6 | 6/73 | 14.05 | 2450 | 970 |
| 19 | 65+94.0 | 1498.6 | 6/73 | 14.07 | 2420 | 1030 |
| 22 | 68+15.0 | 1498.9 | 10/73 | 13.73 | 2420 | 1240 |
| | Averages | | | 13.62 | 2420 | 1240 |

* These test specimens contain construction joints. Dam concrete in block 15b at elevation 1453.7 failed at the construction joint. River plug concrete in block 3 at elevation 1442.7, in block 6 at elevation 1445.6, and in block 7 at elevation 1442.5 did not fail at the construction joint.

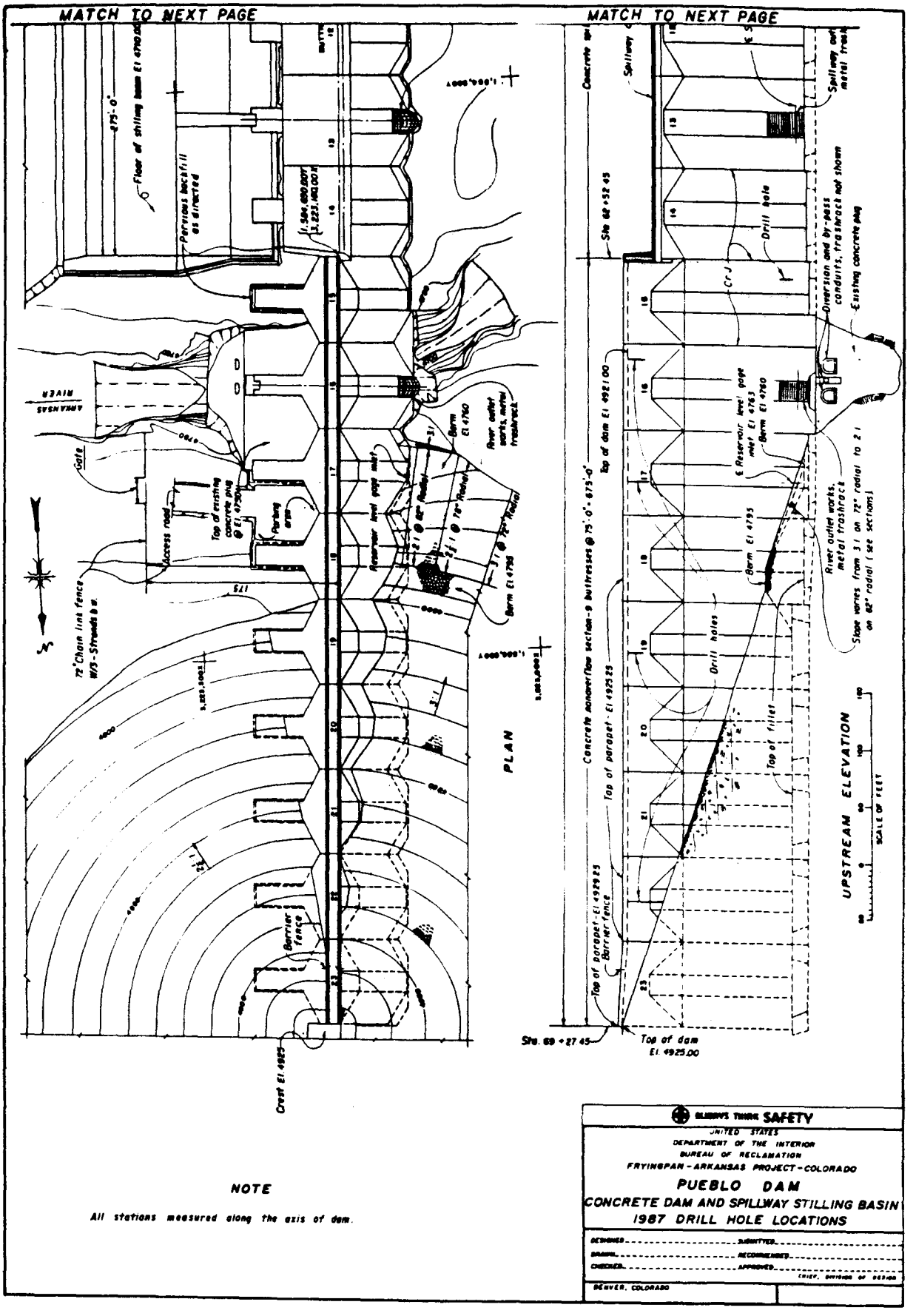



Figure 1. - Pueblo Dam - concrete dam spillway stilling basin plan and elevation, left side - 1987 drill hole locations.

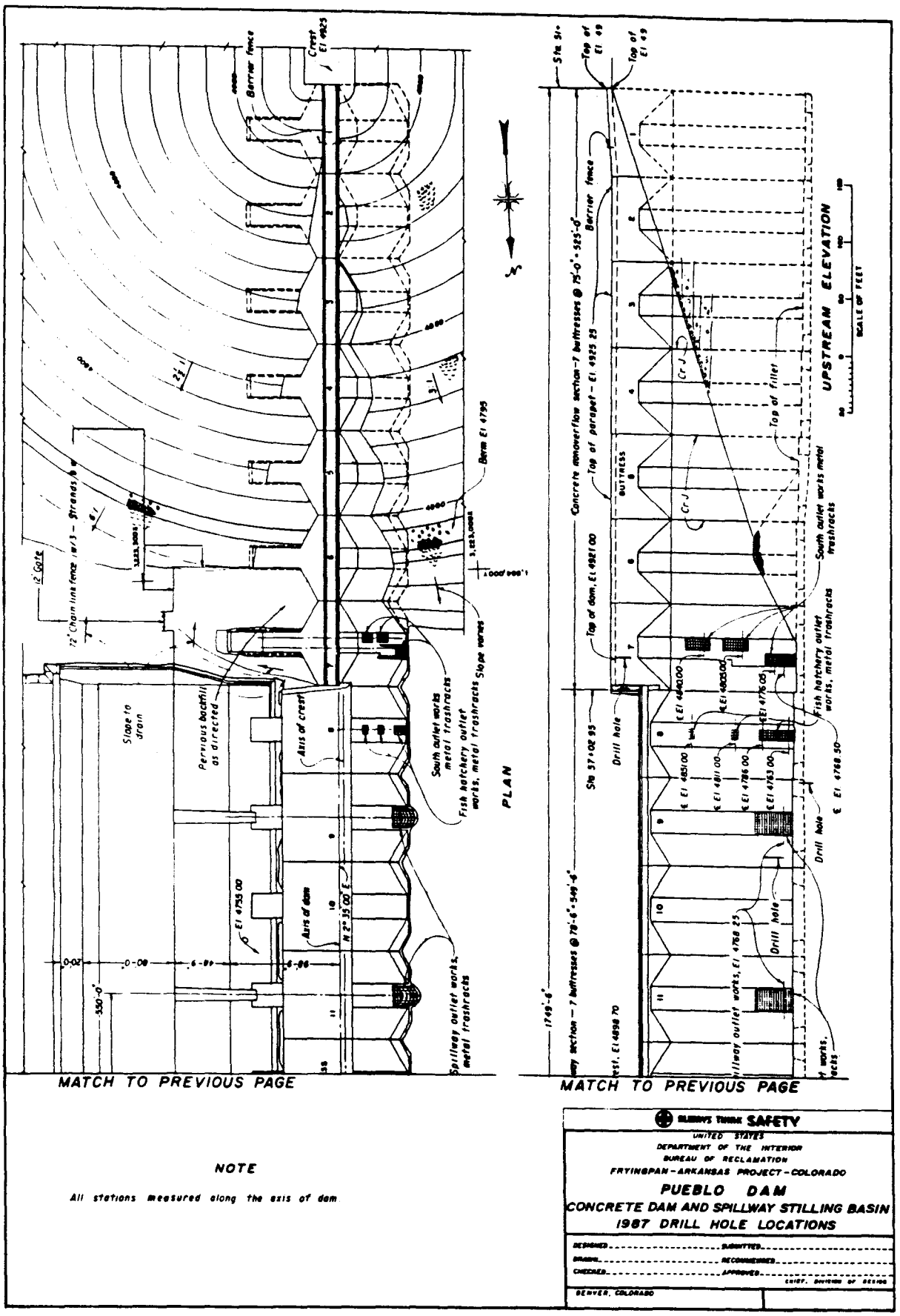



Figure 2. - Pueblo Dam - concrete dam spillway stilling basin plan and elevation, right side - 1987 drill hole locations.

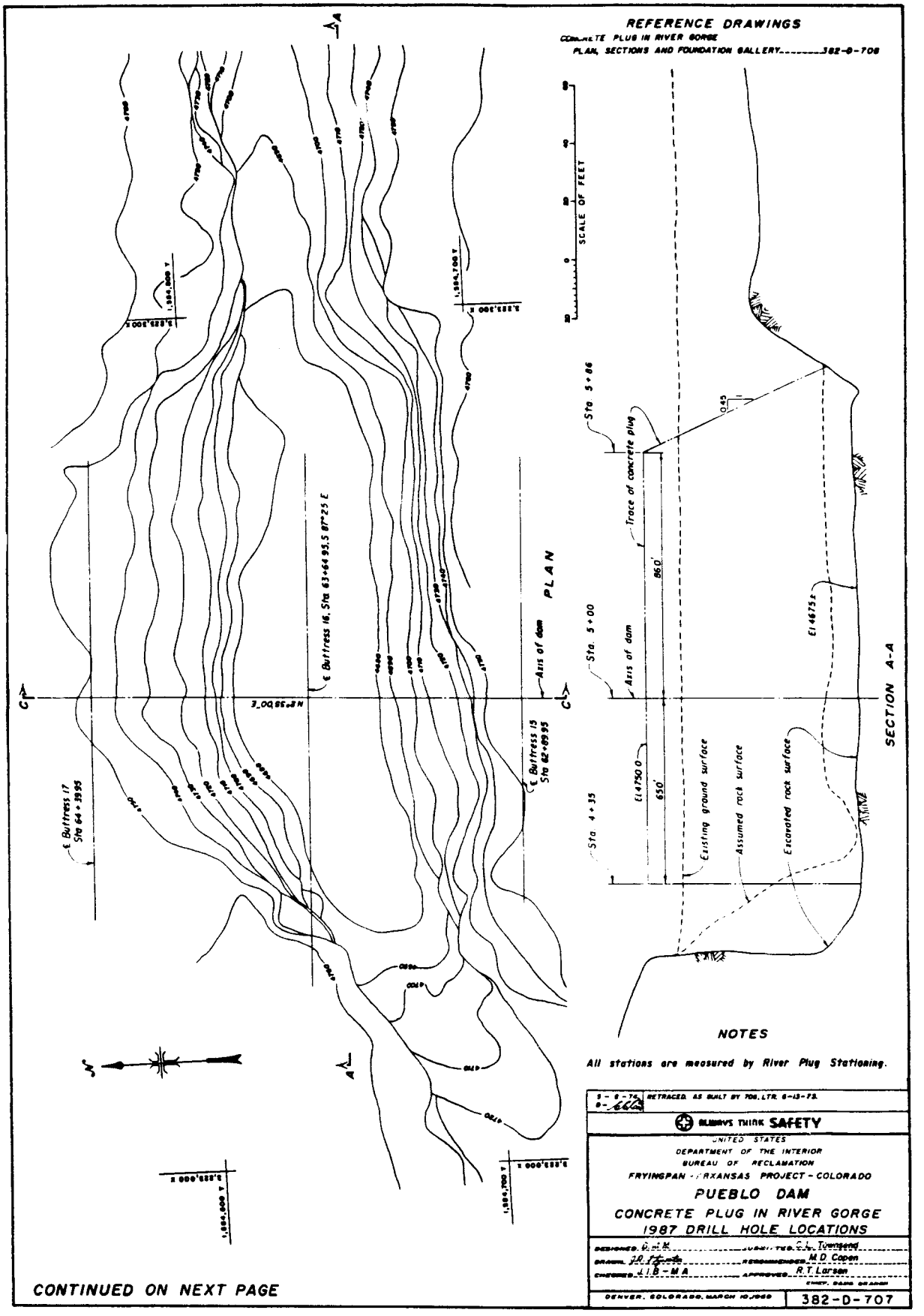


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Figure 3. - Pueblo Dam - concrete plug in river gorge - 1987 drill hole locations.

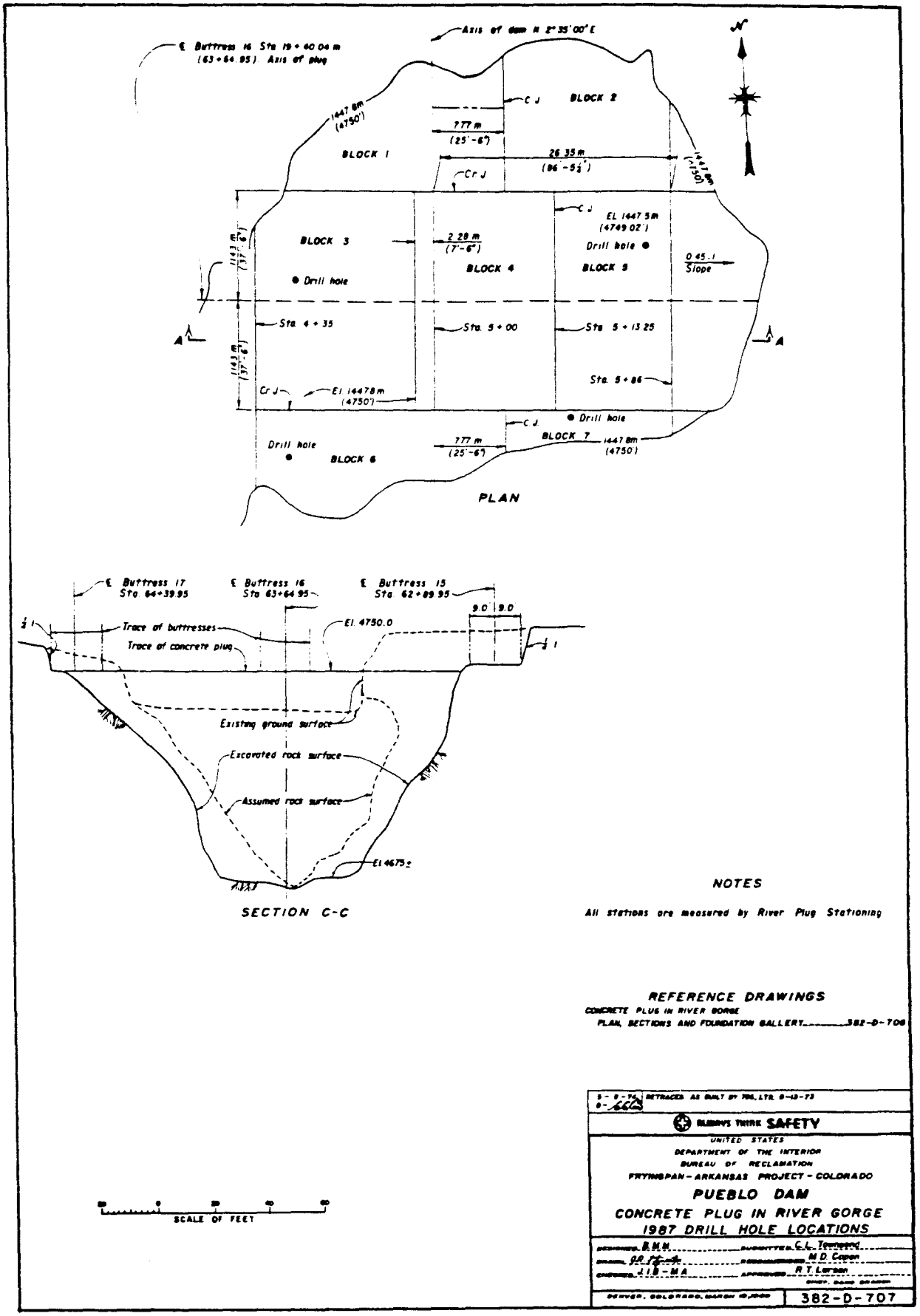


Figure 3. - Pueblo Dam - concrete plug in river gorge - 1987 drill hole locations. - Continued

# APPENDIX

## Aggregate analysis

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

OFFICE OF CHIEF ENGINEER
DIVISION OF RESEARCH
CONCRETE AND STRUCTURAL BRANCH
DENVER, COLORADO 80225
DATE

REPORT NO. C-1165 J
COMPILED BY
CHECKED BY
REVIEWED BY
SUBMITTED BY

# AGGREGATE QUALITY EVALUATION

| | | | | |
|---|---|---|---|---|
| STATE Colorado | REG. 7 | SOURCE NO. | LAT. 38° N | LONG. 104° W |
| SAMPLE NO. M-5780 | MATERIAL Sand and gravel | | | DATE REC'D. 5-16-68 |
| DEPOSIT NAME Walking "O" Area | | | OVERBURDEN 7.7 feet average | |
| OWNERSHIP Howard Brass and W. A. Mays | | | VOLUME 5,500,000 cu yds | |
| LOCATION 1/ Deposit located in parts of | | | | |
| SEC. 34 & 35 | T 20S | R 66 W | MERIDIAN Sixth Principal | |
| FEATURE Pueblo Dam | | | | |
| PROJECT Fryingpan-Arkansas | | | | |
| REMARKS | | | | |
| | | | DATE LTR. TRANS. 5-14-68 | |

GRADING (DES. 4,5,6) CUM. % RETAINED

| SIEVE | PIT RUN | 3"-1½" | 1½"-¾" | ¾"-#4 | FINE AGG | WASHED FINE AGG |
|---|---|---|---|---|---|---|
| 6 IN | 0 | | | | | |
| 3½ IN. | – | | | | | |
| 3 IN | 0 | | | | | |
| 2½ IN | – | | | | | |
| 1¾ IN | – | | | | | |
| 1½ IN | 27 | | | | | |
| 1¼ IN | – | | | | | |
| ⅞ IN | – | | | | | |
| ¾ IN | 57 | | | | | |
| ⅝ IN | – | | | | | |
| ⅜ IN | 82 | | | | | |
| 5/16 IN | – | | | | | |
| NO. 4 | 100 | | | | 0 | 0 |
| NO. 5 | | | | | – | – |
| NO 8 | | | | | 11 | 11 |
| NO 16 | | | | | 23 | 24 |
| NO 30 | | | | | 42 | 45 |
| NO 50 | | | | | 69 | 73 |
| NO 100 | | | | | 89 | 92 |
| PAN | | | | | 100 | 100 |
| F M | 7.66 | | | | 2.34 | 2.45 |
| %SAND | 51 | | | | | |

TEST RESULTS 2/

| | 6"-3" | 3"-1½" | 1½"-¾" | ¾"-⅜" | ⅜"-#4 | FINE AGG | WASHED FINE AGG |
|---|---|---|---|---|---|---|---|
| SP. GR., S.S.D. (DES. 9,10) | | 2.64 | 2.65 | 2.63 | 2.61 | | 2.64 |
| ABSORPTION, % (DES. 9,10) | | 0.5 | 1.0 | 1.6 | 1.8 | | 0.9 |
| ORGANIC IMPURITIES, (DES. 14) | —— | —— | —— | —— | —— | No.1 | |
| PERCENT SILT (DES. 16) | | | | | | 8.2 | |
| % LIGHTER - SP. GR. (DES. 17,18,42) | | | | | | | |
| CLAY LUMPS, % (DES. 13) | | | | | | | |
| SAND EQUIVALENT | —— | —— | —— | —— | —— | 45 | 96 |
| $NA_2SO_4$ LOSS, 5 CYC. WGT'D. % LOSS (DES. 19) | | | | 3.1 | | —— | 2.5 |
| L.A. ABRASION (DES. 21) GRADING "A" "B" "C" "D" | | | | | | | |
| % LOSS, 100 REV. | | 6.4 | | | | | |
| % LOSS, 500 REV. | | 29.6 | | | | | |

FREEZING AND THAWING DATA

| CONCRETE | | | | | | | RIPRAP | |
|---|---|---|---|---|---|---|---|---|
| W/C RATIO | SLUMP INCHES | % AIR METER | $H_2O$ LBS/YD³ | 28-DAY STRENGTH 3"x6" CYL'S | WEIGHT LOSS, % | CYCLES | WEIGHT LOSS, % 3 INCH CUBE | CYCLES |
| 0.51 | 4.3 | 6.2 | 250 | 3,740 | 25 | 600 | | |

ALKALI - AGGREGATE REACTIVITY DATA

| MATERIALS | SAND | | | | GRAVEL | | | |
|---|---|---|---|---|---|---|---|---|
| CEMENT NO. | Petro only | | | | Petro only | | | |
| SODA EQUIVALENT | | | | | | | | |
| TEST AGG. % | 100 | 100 | 50 | 25 | 100 | 100 | 50 | 25 |
| EXP % - 6 MO. | | | | | | | | |
| EXP % - 12 MO. | | | | | | | | |

PETROGRAPHIC DESCRIPTION MEMORANDUM NO. 68-75 2/ DATE 11-20-68 BY C. A. Bechtold

The gravel, subrounded to angular in shape with about 25 percent flat particles, is composed mainly of granite, schist, gneiss, limestone and dolomite with lesser amounts of sandstone, altered volcanics, glassy volcanics, and chert. About 3 percent of the gravel is physically unsound and 4 percent is alkali-reactive. The sand, subangular to angular in shape, is composed of the same rock types found in the gravel plus quartz, feldspar, amphibole, epidote, garnet, sphene, magnetite, mica, and a few miscellaneous minerals. Some carbonaceous material, clay, and soluble sulfate (gypsum), removable by washing, are present in the sand. About 5 percent of the sand is physically unsound and 2 percent is alkali-reactive.

Conclusions: Aggregate comparable to Sample No. M-5780 is suitable for use in concrete provided the sand is washed to remove excess silt and proper gradings are obtained.

1/ Deposit located in the NW1/4 and NW1/4 SW1/4 and NW1/4 SW1/4 NE1/4 and SW1/4 NW1/4 NE1/4 Sec. 35; NE1/4 SE1/4 and S1/2 NE1/4 Sec. 34, T 20 S, R 66 W, Sixth Principal Meridian.

2/ Test data for a composite of material from test pits No. TP-123, AP-131A, AP-133A, AP-135A, AP-136A, TP-140, and AP-140A.

GPO: 1990—774-127

**Mission of the Bureau of Reclamation**

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*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-use organizations, and other concerned groups.*

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