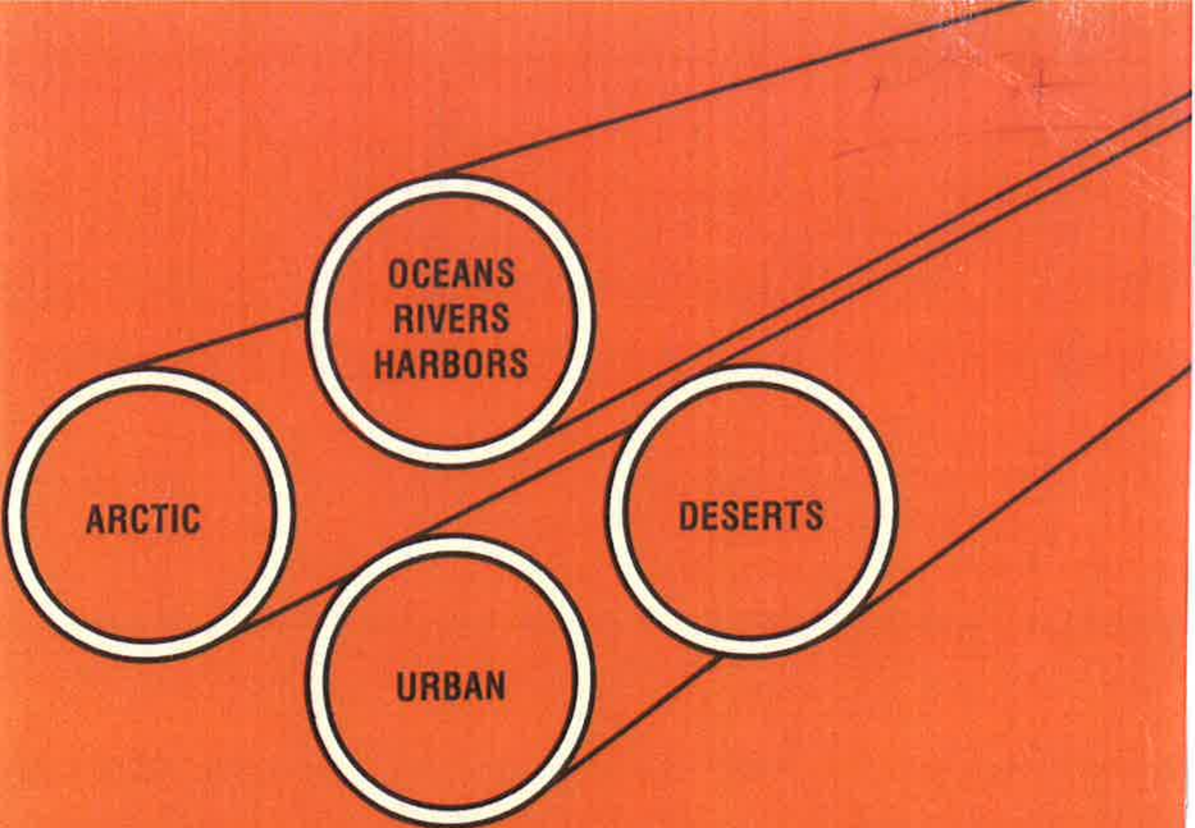

Pipelines In Adverse Environments II

Mark B. Pickell, Editor

Case Histories:
Construction on Canyon Wall Terrain

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ABSTRACT

Sections of two gravity flow irrigation flumes built on steep canyon walls in Washington State were replaced by pipe. Design and construction methods had to be tailored for hand tools and material deliverey by helicopter only, because of the extremely difficult rocky terrain. The lifting capability of the helicopters controlled the size and weight of materials and limited the prefabrication units (span and number of supports). One replacement project was necessary because of imminent failure of an old, high-maintenance wood flume. The other project was the emergency replacement of a 350 cfs, fully operating, concrete flume. Construction of the exposed replacement pipelines involved similar problems and solutions.

INTRODUCTION

Many gravity-flow irrigation flumes were built near the turn of the century in Washington State, placed along steep canyon walls with hand labor and tools. Sections of two of these irrigation flumes, both located in the Eastern foothills of the Cascade mountains, were replaced with pipe in 1980. This paper presents case histories of the replacement projects and a discussion of the construction methods used successfully on these two difficult projects.

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Some construction problems encountered at these canyon wall sites were:

- Limited access
- Small work area, if any
- Dangerous conditions for workers
- Atypical geotechnical investigation
- Potential of surveying error due to difficult terrain
- Susceptability of work to inclement weather

The major difference between the two projects was the time available for design and construction. The Icicle Irrigation District (I.I.D.) project included the standard preparation of contract documents, bidding by the contractor, and construction during the irrigation off-season with sufficient time for completion. The repair work done by the Yakima-Tieton Irrigation District (Y.T.I.D.) was the emergency replacement of a washed-out section of the main feeder canal, at the height of the irrigation season. Because service had to be restored within three weeks, the district hired an engineer and contractor to begin work immediately. Despite this difference many construction methods and constraints were common to both projects. This paper addresses the similarities in design and construction of the two projects, as well as the differences related to the time constraint on the Y.T.I.D. emergency repair.

One of the authors, F. W. Pita, was one of the two lead design engineers and construction supervisors for the Y.T.I.D. project and geotechnical engineer/designer for the I.I.D. Project. The co-author, B. L. Woodward, provided technical support for the designs.

CASE HISTORY I: ICICLE IRRIGATION DISTRICT FLUME REPLACEMENT

The project location is on the northern valley wall above the Wenatchee River near the City of Dryden, Washington. The site is approximately 400 feet above the valley floor on an exposed sandstone rock slope dipping at a 35° angle. Figure 1 is a cross-section showing the wooden flume that was replaced by 1550 feet of elevated steel pipe. The flume had required continual maintenance and was in danger of imminent failure. The design of the replacement pipe was tailored for small helicopter installation and working with hand tools. Because of previous small rock falls and winter avalanches the pipe is elevated above the rock face so that slides can pass beneath the pipe without damage. Figure 2 shows a typical fitting and column support for the 30-inch diameter spiral-weld steel pipe. The supports range in height from 2-feet to 15-feet and are positioned at 30-foot intervals. Custom-designed concrete footings with rock anchors allow for irregular rock formations and varying grades of steepness on the face of the cliff. The steel supports were bolted down to ensure a solid foundation for the pipeline.

The survey crew had to be extremely precise in laying out footings so that all of the prefabricated material would fit together properly. Components of the new pipeline were designed to allow field adjustment at the base of each footing and at each cradle during final alignment.

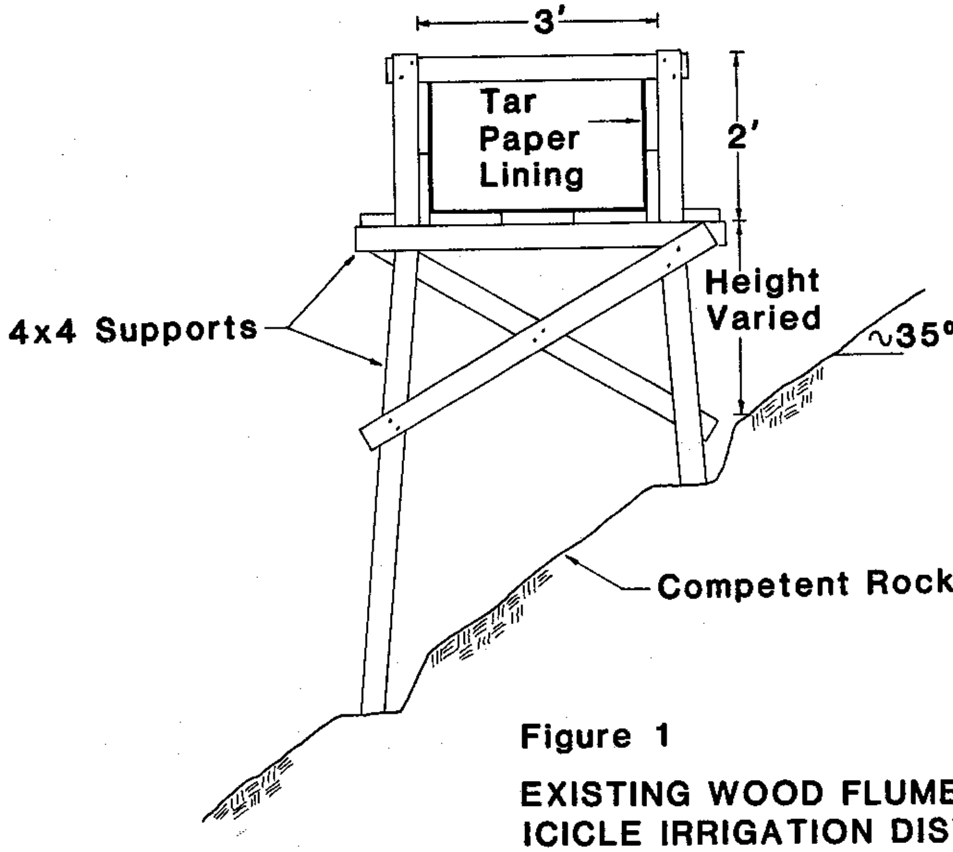


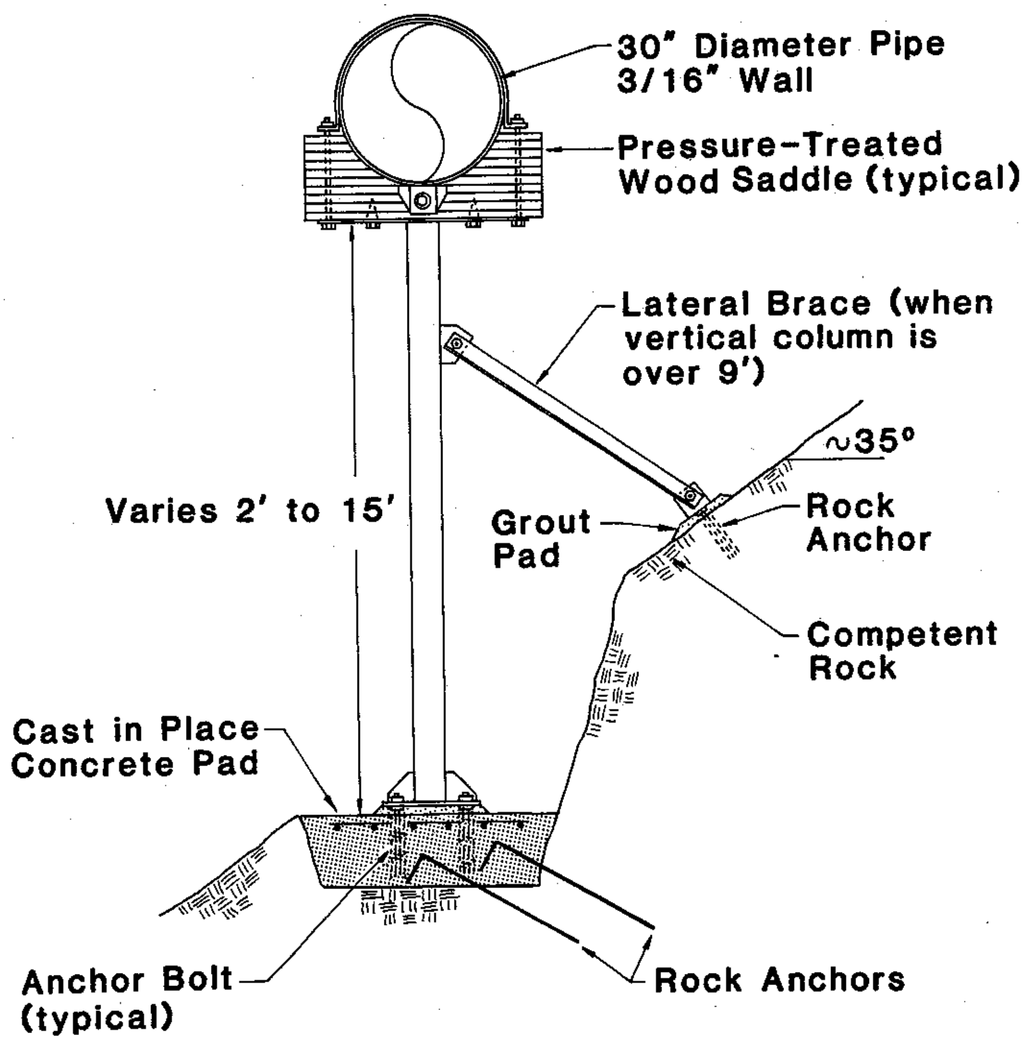
Figure 1

EXISTING WOOD FLUME
ICICLE IRRIGATION DISTRICT

The base plates of the steel supports were adjustable, and mortar was hand placed beneath the plate after final alignment of the entire pipeline. Significant savings were made by limiting the weight of the sections to 1800 pounds so that a small, locally based helicopter could be used for lifting and placing them. All of the prefabricated metal pieces were moved and set in place by helicopter as were three-quarter yard concrete buckets used for placing the concrete footings. The pipe sections were connected by using compression collars which were hand-placed and tightened. No field welding was performed on the pipe. Exact fabrication and field surveying were key elements in the success of the project.

The contract required that when the delivery system was taken out of service it must be during off-season time. In the State of Washington, this is the fall, winter and early spring. To avoid inclement weather it was imperative that the contractor be allowed to perform material fabrication during the irrigation season. At the time of shutdown the contractor was then able to mobilize quickly, remove the existing flume, and begin construction of the new facility. This plan enabled the contractor to use the good fall weather for the major portion of his construction.

The construction went according to plan and the contractor completed the work well before the deadline. The cost of the construction was approximately $400,000.



Note:
Support spacing at 30' interval.

Figure 2

TYPICAL PIPE SUPPORT
ICICLE IRRIGATION DISTRICT

CASE HISTORY II: YAKIMA-TIETON IRRIGATION DISTRICT'S EMERGENCY REPAIRS

Site and Failure Description

The main feeder canal of the Y.T.I.D. begins on the Tieton River at a diversion dam approximately five miles downstream from Rimrock Lake, and flows southeasterly along a moderate to steep mountain slope above the Tieton River and U.S. Route 12. The canal was constructed in 1906 by the Bureau of Reclamation. Throughout most of its 13-mile length, the canal is a horseshoe-shaped pre-cast reinforced concrete flume about 8-feet wide and 7-feet deep (Figure 3). The flume wall thickness is approximately 4 inches. The canal carries approximately 350 cubic feet per second of irrigation water to the 26,000 acres of orchards and farmland which make up the district.

The rock formations in which the Tieton Valley has been eroded range from andesite, basalt, conglomerate, mud flows, to tuff in the eastern portions to predominantly Yakima Basalt in the western portion. Loose talus is the primary surface material in the area of the canal break, forming a uniform slope of 1.3H:1V. Most of the canal is accessible only by foot (or by air) because of the steep slopes and loose talus.

Volcanic ash from the May 18, 1980, eruption of Mt. St. Helens covered the drainage basins upslope from the canal and was probably a major contributing factor to the canal break. The ash cover reduced the porosity of the soil, effectively preventing the ground-absorption of rainfall. Apparently, rainfall on June 16th caused a much greater volume of runoff than would normally be expected from a storm of that magnitude.

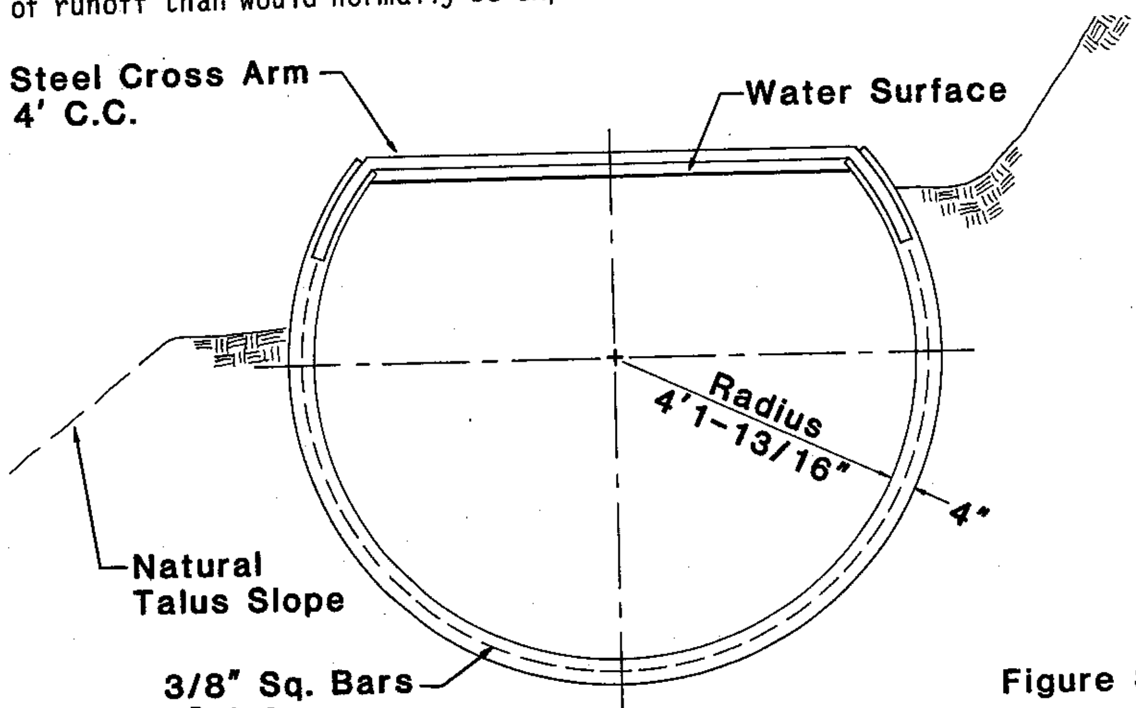


Figure 3

EXISTING CONCRETE CANAL
YAKIMA-TIETON IRRIGATION DISTRICT

The increased runoff caused erosion-debris-slides which filled the canal with rock, ash, trees, brush, and other upslope debris in many locations. Because the canal was in operation at the time, the blockage caused immediate overtopping of the canal.

The most severe damage occurred between canal-mile 9.13 and 9.15, where the overtopping eroded the loose talus slope on the downhill side of the canal, undermining a portion of the flume. A section approximately 100-feet long collapsed and the continued flow of water from upstream caused further erosion, resulting in a 300-foot wide by 100-foot deep plunge pool basin carved immediately below the flume alignment (Figure 4). At the canal level, the loose talus had not been eroded under the remaining exposed ends of the broken flume, although a 40-foot wide area where the water exited the upstream end of the old flume had been eroded down to bedrock. The bottom of the plunge pool area (approximately 100 feet below canal level) was relatively flat and the talus side walls were vertical and even undercut in some areas. Nearer to the valley floor (river level) the basin narrowed into a gully clogged with eroded talus rock. The broken remains of the collapsed 100 feet of flume were scattered and intermixed with trees and other debris down the slide area.

The complete interruption of the District's water supply endangered $100,000,000 worth of crops. Remedial efforts began immediately. Because time was so critical to the design and construction processes, a chronology table has been provided showing the sequence of events that followed the failure (Appendix A).

Design Approach in June 1980 for Emergency Repair

Within four days following the failure, the District and it's engineer, CH_2M-Hill, had accomplished the following:

- Inspected the site
- Met with Y.T.I.D. board to discuss problems and solutions
- Began mapping site by photogrametry
- Hired contractor, Turzillo, and helicopter service
- Began site cleanup - by District and volunteer crew
- Ordered 102" (9 feet) diameter CMP replacement pipe

The District had determined that the farmland it served would sustain severe crop damage if the canal was not repaired within three weeks. Because a repair engineered and constructed so quickly might not be sufficiently permanent, the design scope included both short-term repair and a more permanent solution. Many engineering risks were involved, such as lack of geotechnical data. The design could not be finalized until site conditions were better revealed by the completion of cleanup and scaling (loose rock removal) operations.

The replacement pipe had been ordered following the consolidation of several alternative solutions. The only economically feasible solution, and the only one possible within the time limit, was to bridge over the eroded area with a concrete-and-steel supported large diameter pipe. The 9-foot-diamter CMP was ordered before design of the supporting structure was final, to allow time for fabrication and delivery. The supporting structure was designed at the site, while hand-scaling was in progress. General design bases for the emergency pipe foundations are listed below:

- From Station 0+25 to 1+32.5 (the downstream end) permanent footings could be founded on the exposed bedrock, if reinforced with rock bolts.

- At station 0+00, the talus slope supporting the intact upstream end of the flume after the break was assumed to be stable on a short-term basis, even though the supporting slopes were not in a long-term stable condition. This assumption was a known risk, undertaken in order to complete the initial repair in a short period of time.

- Bedrock formations downstream of Station 1+32.5 that were supporting undamaged portions of the flume were assumed to be sound and not in danger of failure.

Because the upstream bridge footing on talus (Station 0+00) was considered adequate for the 1980 irrigation season only, a modification to stabilize it was planned for the winter of 1980-1981, and the design proceeded based on temporary stability.

The design allowed for the following constraints:

- The few feet of broken and cracked flume at each end of the break must be cut off and "squared".

- All steel and concrete components and welds must be designed to withstand the static and dynamic loadings imposed by the CMP pipe and maximum flow of irrigation water.

- Materials used must be readily available (e.g., in stock at suppliers in local cities).

- Repair must be constructable under extremely difficult access and work conditions (foot paths only).

- Size of components would be limited by lifting capacity (10,000 pounds) of the available helicopter.

- All site work must be done with hand or air tools.

- Invert elevations of the new pipe should match the existing canal inverts at each end of the break.

- Allowances must be made for thermal movement.

- No walkway would be available during the phase 1 emergency repair.

- The emergency portion of project must be complete by July 5, 1980.

Two important tasks were to be completed by the District during the irrigation off-season. These were coating the steel for protection from rust and lining the CMP flume to reduce the hydraulic headloss due to the increase in hydraulic roughness.

Emergency Construction

Repair work commenced with cleanup and scaling operations while the design was in progress. Two CH_2M-Hill senior design engineers supervised two shifts of design and construction onsite while many other engineers and Y.T.I.D. representatives supported the work as needed. Appendix A describes the mobilization and construction process.

The initial plan was to place a CMP pipe directly on steel columns anchored in grout-bag-formed foundations designed to support three welded steel bridge spans. Steel saddles were installed on the spans to cradle the pipe. Figures 5 and 6 show cross-sections of the repair at two key locations.

Field fabrication, helicoptor delivery of materials, and concurrent design and construction were successful and the emergency repair was completed before the three-week time limit, and irrigation resumed. The repair had cost approximately $600,000.

Off-Season Final Repair

The construction division of the Y.T.I.D. acted as the general contractor for the off-season repair work and hired the necessary specialty contractors for pipe fabrication and welding. CH_2M-Hill was engineer and construction manager for the project.

The talus material at the original failure site continued to erode as the slope approached it's natural angle of repose. This dictated an upstream extension of the steel-supported CMP flume. Exploratory hand-excavation was done by the Y.T.I.D. staff to a depth of about 7 feet, adjacent to the canal and approximately 20 feet upstream of the inlet end of the summer-placed CMP (Figure 2). Bedrock could not be located by hand-digging so drilling was done under the observation of CH_2M-Hill. Rock was encountered at varying depths in five bore holes. The borings showed that the depth to solid rock beneath the alignment of the flume was similar to that depth found at Station 0+25. The flume was not actually resting on bedrock until a point 110 feet upstream from Station 0+00 was reached. Analysis showed that as the unstable vertical talus slopes eroded to become stable again they would undermine approximately 100 feet of canal upstream from Station 0+00. To achieve stability, all of the loose talus material 110 feet upstream of Station 0+00 had to be removed down to bedrock. A replacement section was designed similar to the emergency repair section from Station 0+00 to 1+31.

A small Caterpillar-D3 bulldozer was winched up the slope to the site to excavate the loose material down to bedrock. A small Bobcat loader with a small backhoe attachment was driven through the canal to do scaling along the rock face. The construction that followed is

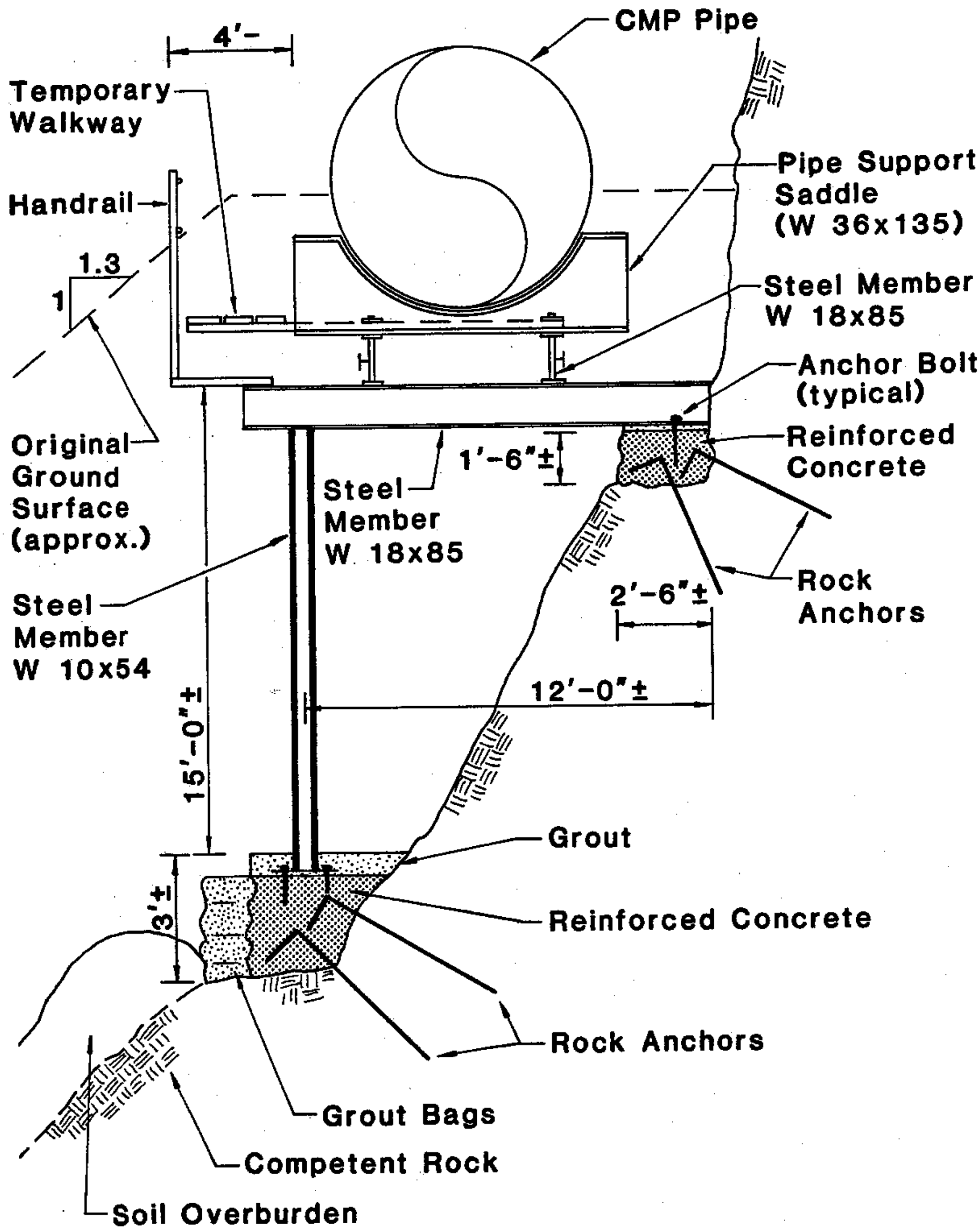


Figure 5

TYPICAL BRIDGE SUPPORT SECTION
YAKIMA-TIETON IRRIGATION DISTRICT

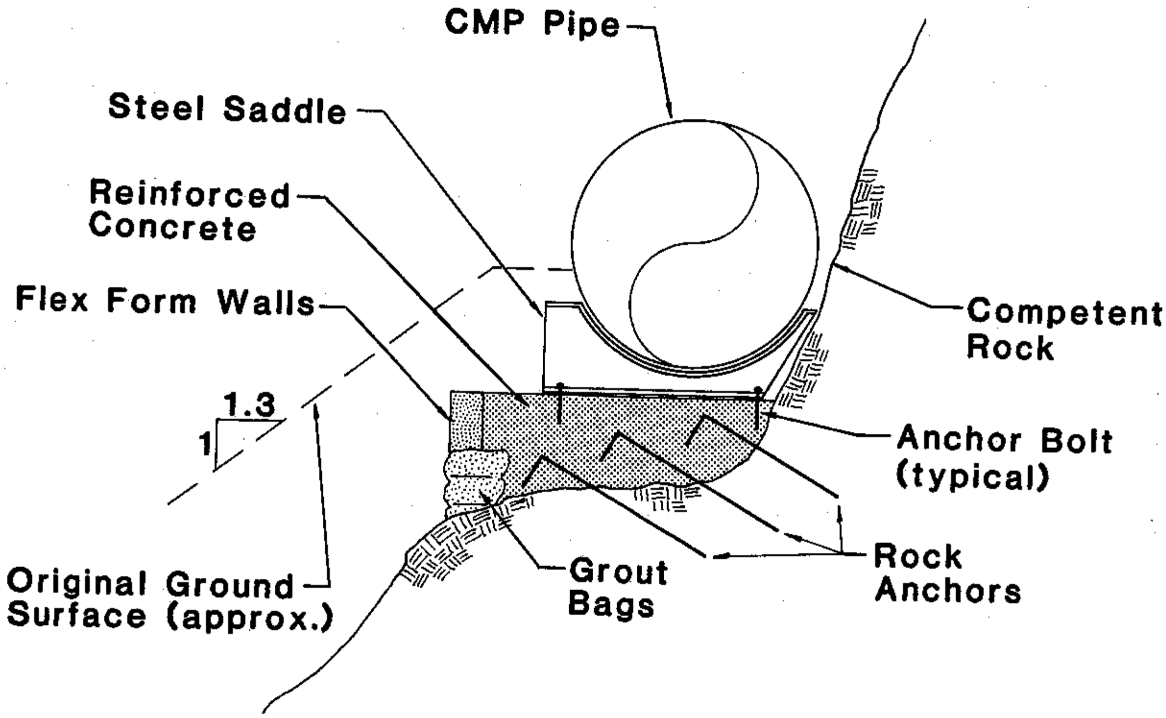


Figure 6

**CONCRETE SUPPORT SECTION
YAKIMA-TIETON IRRIGATION DISTRICT**

described in the appendix. Water was turned into the canal in April 1981, and the system functioned with no unforeseen problems.

During the following year's off-season the Y.T.I.D. staff has made additional repairs and tests to make the old and new repairs permanent. The additional pipe extention cost approximately $400,000.

APPENDIX A
CHRONOLOGY OF SIGNIFICANT EVENTS; Y.T.I.D. EMERGENCY REPAIR

DATE	EVENT
5-18-80	Mt. St. Helens volcano eruption leaves ash layer on hillsides surrounding canal.
6-16-80	Late afternoon thunderstorm and heavy rain triggers debris slides. Ninety-foot section of canal collapses down mountainside. Deep "plunge pool" and gully formed by erosion from broken canal water. Irrigation water delivery totally interrupted to all of Y.T.I.D. District manager, Warren Dickman, sees site in late p.m., calls Haapala, (CH_2M-Hill Irrigation Engineer), in p.m.
6-17-80	Haapala sees site a.m., calls Pita, (CH_2M-Hill Geotechnical Civil Engineer in Seattle office) in p.m.
6-18-80	Haapala, Pita and Y.T.I.D. board meet after site inspection, to discuss problem, solutions, risks, and funding. Concrete specialty contractor (Turzillo) and helicopter firm are contacted in p.m. CH_2M-Hill surveyors start setting air photo premarks for mapping (also 6-19-80).
6-19-80	Turzillo and helicopter representatives, (Columbia) arrive and plan lower staging area and repair. Pipe-bridge design selected by District and engineers.
6-20-80	102" dia CMP pipe (ARMCO) ordered. District and volunteer crews walk to site and work to clean plugged canal downstream of break.
6-21-80	Hand scaling of loose rock and debris begins. Turzillo moves in. Helicopter arrives and flies equipment in. Cole (CH_2M-Hill Senior Geotechnical Engineer), inspects site with Pita. High scalers expose bedrock suspended by ropes. ARMCO begins to roll pipe in Davis, California plant.
6-22-80	Explosives used to remove broken and undermined flume sections. Some sections lifted away by helicopter. Crews work to clear loose debris and talus. Grout bags placed and filled for lower footing at Station 0+50.
6-23-80	Crews continue scaling and cleaning slope. Two 1-yard concrete buckets delivered. Backup air compressor delivered.
6-24-80	Steel fabricator chosen, Erickson (CH_2M-Hill Senior Structural Engineer) designs steel with material which is readily available in Seattle supply yards and easily fabricated.

6-25-80 Contour site map completed (by photogrametry). DOE and USBR inspect site and review design concepts. Rock anchors drilled to anchor concrete foundation from Station 0+73 to Station 1+10.

6-26-80 Erickson arrives at site, designs footing rebar layout on site, and verifies steel design adequacy. Marker (CH_2M-Hill Senior Civil Engineer) inspects site and contributes to closure collar design.

6-27-80 Closure collar system design finalized on site, material ordered. Steel erection foreman arrives. Structural steel delivered to lower work site.

6-28-80 Steel erection crew prepares lower staging area work site; support bents fabricated. Pipe leaves Davis, California, by truck.

6-29-80 Flexform wall begins from Station 0+75 to Station 1+20. Pipe delivered to lower site. Bridge bents and bridge span sections placed by helicopter. All rock bolts and all rebar from Station 0+75 to 1+20 is placed.

6-30-80 Reinforcing steel placed for concrete downstream foundation (Station 1+20 to 1+32.5). Concrete (56 cubic yards) is placed in 2 hours from Station 0+75 to 1+32.51414. Three sections of pipe placed on bridge section. Upstream closure collar begun in p.m.

7-1-80 Pile support saddles placed on concrete (Station 0+75 to 1+32.5), aligned and bolted in place. Final pipe placed. Concrete form for upstream collar begun.

7-2-80 Upstream collar poured. Downstream collar formed and poured. Pipe joints sealed on inside pipe. Cleanup begun.

7-3-80 System inspected. Removal of equipment and cleanup completed.

7-4-80 Pipe tested. Flow increased gradually to 100 cfs then to 322 cfs by 50-cfs increments. Minor leaks, not considered severe enough to cause concern. System operating.

7-6-80 10" headloss measured through pipe.

7-7-80 Feasibility of adding freeboard upstream is studied and district decides to install it, so 350 cfs could pass through system without overtopping existing flume.

9-16-80 Site inspected by Pita, Haapala and Y.T.I.D. manager. Relatively minor leak in upstream closure collar.

10-1-80 Water turned off. End of season.

10-27 to 11-4-80	Y.T.I.D. excavates test hole by hand to locate bedrock upstream of Station 0+00.
11-4-80	Pita inspects test hole. Bedrock not found at 7 foot depth. Decision made by Pita and Y.T.I.D. manager to drill to locate rock and to establish foundation conditions.
11-22-80	Drilling begins in canal invert. Pita inspects.
11-24 : 26 & 12-1-80	Drilling continued. Shorey (CH_2M-Hill Engineering Geologist) inspects.
Mar 1981	Y.T.I.D. excavates all loose material to bedrock with D-3 bulldozer. Steel ordered and fabricated in Yakima shops.
3-19-81	Structural steel delivered to lower site.
3-23-81	Helicopter arrives. Pita and Beieler (CH_2M-Hill) act as onsite construction manager. Four columns and one bridge set in place. All remaining steel arrives.
3-24-81	All bridges and pipe in place. Final field welding continues. All large equipment removed by helicopter. Helicopter leaves.
3-28-81	Y.T.I.D. completes construction of structural steel and closure collars.
3-30-81	Structural inspection by CH_2M-Hill structural engineer.
4-7-81	Geotechnical engineering and geology inspection by Pita.
4-9-81	<u>Irrigation water turned on for 1981 season.</u>
1981-82	Y.T.I.D. staff mortar-lines pipe and coats steel for rust protection in next off-season.