



An Evaluation of Water Jetting For Bureau of Reclamation Use In Cleaning Concrete Dam Foundation Drains

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FOR
BUREAU OF RECLAMATION USE
IN
CLEANING CONCRETE DAM FOUNDATION DRAINS

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INTRODUCTION:

High pressure water jetting with pump pressures of 10,000 to 25,000 pounds/square inch, and ultra-high pressure water jetting with pump pressures up to about 35,000 (and sometimes as high as 60,000) pounds/square inch, have been used for many industrial and construction applications in recent years. The technology has developed from the Russian invention of a water cannon that could fracture hard rock in 1937, to hand held water blasting equipment for cleaning surfaces in the 1950's, to the use of abrasives and improved pump pressures for concrete removal in the 1960's, to later improvements including even higher pressures, remotely operated equipment, hole boring, rotating heads, waste water collection systems, and increased removal rates and thus lower costs.

In the 1980's, the benefits of this technology for hydrodemolition of concrete for repair projects became recognized. Deteriorated concrete could be removed without damaging the remaining sound concrete and without damaging the reinforcement. The resulting surface was ideal for bonding to the new repair concrete.

The use of water jetting to clean concrete dam foundation drains was also developing in the 1980's. This technology seemed to have the potential for solving problems with existing methods--the economical methods were often not effective, and the effective methods were very expensive.

The purpose of this report is to examine possible increased use of water jetting technology for cleaning foundation drains in concrete dams maintained by the Bureau of Reclamation. A Reclamation Drain Cleaning Seminar was held January 20-21, 1998, in Denver, and a summary report of the seminar lists drain cleaning needs and goals, as well as concerns about the water jetting method. By comparing the seminar information with current literature on water jetting for drain cleaning, this report attempts to assess the potential for increased use of water jetting for Reclamation drain cleaning work.

The technical information in this report was taken directly, paraphrased, or consolidated from sources listed in the Bibliography.

DRAIN CLEANING AND STRUCTURAL STABILITY:

Clogged drains in concrete dam foundations or abutments are not merely an inconvenience, but can be a threat to the stability of the dam. Many Reclamation concrete dams were designed on the assumption that drains will remain functional for the life of the dam to control seepage and to control uplift forces under the base of the dam. Reclamation maintains about 60 significant storage concrete dams that have some form of foundation drainage system. Concrete dam failures usually develop in the foundation area and controlling seepage and uplift forces can be critical to foundation and dam stability. At many concrete dams, periodic cleaning of foundation drains has not been done and instrumentation data indicate that drainage has decreased at some dams because of drain plugging with calcium carbonate and bacterial or other deposits. While decreased drainage flows are not proof of dam stability problems, they do indicate the potential for increased uplift forces.

CURRENT METHODS FOR CLEANING FOUNDATION DRAINS:

There are many methods available. Both the effectiveness and the cost varies widely from method to method. Success of a method at one dam is no guarantee of success at other sites. Conditions that vary widely at different sites include: hardness of deposits, chemical composition of deposits, bond strength of deposits to sidewalls, difficulty of access to drain openings, number of drains, rate of deposit buildup, percentage of cross-section plugged, length of plug, straightness of drain hole, length of drain hole, diameter of hole, soundness of hole walls, and level of experience of the crew. In considering increased use of water jetting on Reclamation drain cleaning projects, it is important to understand other available methods. Water jetting has the potential to overcome problems associated with some other methods, but like any method, it has some limitations. There is no intention to discontinue use of other effective methods. By understanding and using the latest water jetting technology, Reclamation can add a new tool to its list of frequently used methods and gain new benefits in economy and effectiveness.

The following is a list and brief description of some currently available methods:

Sulfamic, Sulfuric, and Hydrochloric Acid Rehabilitation

Sulfamic acid has been field tested to chemically dissolve calcium carbonate in clogged foundation drains. In pelletized or granular form the acid was applied in quantities equivalent to 2 to 8 percent of the unobstructed drain volume.

Other acids have been used in liquid form with limited success due to dilution and health problems related to their use.

While acids are time and energy efficient, they are usually unable to clear fully clogged drains, produce noxious odors and fumes, and can cause environmental problems. Acids work best as a maintenance procedure to prevent clogging by dissolving small amounts of calcium carbonate

before complete plugging occurs.

Carbon Dioxide Treatment

In theory, this process can dissolve calcium carbonate because adding carbon dioxide under pressure can acidify water in the drain. The zone being treated is isolated using packers. An attempt to use the method at Folsom Dam was not successful because foundation rock joints made it impossible to pressurize the drain.

Rodding

Rodding consists of breaking through drain plugs with a steel rod or with a star drill or other metal head attached to a line and dropped down the hole. If the blockage is not too hard or too thick, rodding can be very effective--especially for blockages near the surface. Rodding does not completely clean the drain walls and is therefore more effective in opening plugged areas and restoring flow through the drain hole length than it is in restoring drain walls for good flow into the drain. Rodding is economical and uses simple equipment. It is most effective when plugs high in the drain must be broken, but where lower areas still have good flow through the drain hole walls. Rodding is frequently followed by flushing.

Flushing and Air Lifting

Soft and loose deposits can be flushed out of drain holes by placing the end of a water line at the bottom of the drain and using water pressures of up to 250 psi and flows up to 60 gpm. Air lifting is done in a similar manner, but uses compressed air to force debris out of the drain.

Over-Coring or Reaming and Drilling of New Holes

During over-coring or reaming a drill is used to increase the original hole diameter by 1/4 to 1 inch using various plug, rock, or impregnated diamond bits. Drill and bit alignment with the upper pipe or casing are critical in this operation. Binding of the drill rods occurs quite easily if correct alignment is not achieved. This operation is one of the more costly methods of drain remediation.

The first cleaning using this method appears to achieve the most noticeable and economical results. Subsequent re-drillings yield smaller improvements in drainage and in many cases replacement drains are drilled at a nearby location. High cost, difficult access for large equipment, and the fact of continually enlarging the hole are the obvious drawbacks to this method. It is, however, one of the most effective methods.

Rotary Tube Cleaners or Mechanical Abraders

This method involves flexible tools with rotating mechanical cutters capable of removing soft to moderately hard deposits restoring the original diameter of the drain.

Wilson Tube Cleaner:

Wilson tube cleaners are flexible shaft, air driven, and use expandable rotating cutting heads.

Payne and Arnholtz:

This unit is an electrically driven (110 volt) flexible shaft, that incorporates carbide cutters on a rotating cutter head.

Goodway Reaming Tool:

This unit is an air-operated cleaning tool with a flexible hub that centrifugally activates the cutting head blades. It incorporates an automatic water flush to remove cuttings from the hole.

Roto Rooter:

This unit is an electrically driven flexible shaft with a variety of cutting heads.

Coleman Tool:

This device is unique in that it operates on hydrostatic water pressure, with a head that oscillates back and forth. The Coleman water-activated tip is attached to a hose and lowered down hole, while the oscillating head removes encrustations from the sidewall of the drain hole. Varying hydrostatic head pressures at gallery elevations and individual drain depth limit the effectiveness of this system.

In general the above mentioned methods are usable in areas where the holes are reasonably straight, total plugging is not encountered, and soft to moderately hard deposits are present. These methods have been effective on deep drains, use easily portable equipment, and are cheaper than over-coring.

High Pressure and Ultra-High Pressure Water Jetting

This technology consists of two levels of pressure and volume. High pressure peaks near 25,000 psi and 10 to 20 gpm. Ultra-high pressure approaches 35,000 psi, and uses less water with flows of 3 to 10 gpm. A high pressure pump is set above ground and is connected to a filtered water supply. Hoses are pulled to the work location and a tripod is set above the hole and used for transporting tools in and out of the hole. A jetted nozzle is attached to a flexible lance and the unit is lowered down the hole to depth and then removed slowly to complete cleaning and flushing. The force of jetting propels the nozzle and hose into the drain, so horizontal drains are as easily cleaned as vertical drains.

Current water jetting methods appear to overcome many of the shortcomings of the other methods listed above. In 1989, when the Bureau of Reclamation published GR-89-1, "Foundation Drain Maintenance Methods", Reclamation had limited experience using water jet technology for foundation drain cleaning. The equipment was prone to failure, bulky and cumbersome. Current technology is vastly more advanced, streamlined and user friendly. It is adjustable, flexible, economical, and effective for a variety of conditions. The technology is still advancing rapidly. Water jetting will not replace all of the above methods for all jobs, but will be a valuable additional method whose use will likely increase as Reclamation gains field experience with the latest technology.

RECENT USE OF WATER JETTING FOR FOUNDATION DRAIN CLEANING:

Friant Dam, California

In December of 1997, VPS Inc. undertook water jet cleaning of foundation drain holes at Friant Dam for the Bureau of Reclamation. A total of 198 holes ranging from 12 to 100 feet in depth were cleaned for a cost of about \$59,000. Lowering a 4-inch plumb bob into each hole confirmed that the entire cross-section was cleaned to full depth. Drops in monitored pressures and increases in gutter flows indicated a successful job. The amount of any erosion occurring outside the original hole diameter was not determined. Friant dam is a concrete dam constructed on bedrock, and hydraulic pressures in the foundation are monitored.

A 20,000 psi water pump rated at 17 gallons per minute was used for the power unit. Several hundred feet of 20,000 psi hose ran from the pump to the cleaning tool. Lengths of over 1000 feet can be used, if necessary. A mole with proprietary rotating head design was used because it can cut through solid blockages and scrub the walls clean in one operation. A portable derrick with electric winch was used to lower and raise the cleaning tool (mole) in the drain holes. In holes with minor faults in the foundation rock, a 1" lance mole with a ridged stinger was used to prevent problems with jamming. The tool was energized both during lowering and raising in the drain hole to achieve efficient cleaning and debris removal.

All indications were that this was a successful operation. At some drains, foundation pressures fell quickly during drain cleaning, as gage hands visibly moved to lower readings during hydro blasting operations. Another indication of success was the increased drain depth measured at most locations after cleaning obstructions.

Lower Monumental Dam, Washington

In June of 1998, VPS Inc. cleaned 15 foundation drain holes for the U.S. Army Corps of Engineers at Lower Monumental Dam. The Corps of Engineers wrote a detailed Scope of Work for the project covering cleaning, testing, and recording performance data for the drains. The Corps provided drain hole information sheets for field data recording by the contractor. The Scope of Work included controls to prevent air or water pressure buildup in drain holes. The use of a packer system or other device that could contain pressure was prohibited. Flow rates of water into the hole and out of the hole were required to be monitored to assure they were approximately equal. The cleaning head was required to be small enough to allow space for water returns--head diameter was limited to 2 inches for the 3-inch diameter drain holes. Either high pressure or ultra-high pressure water jetting would be approved, but the Scope of Work asked for pressures between 10,000 and 20,000 psi with a maximum water flow rate of 20 gpm. The original drain depths were known, and the contractor was to attempt to open all holes to original depth, but re-drilling would not be required. Hole depth, and depth to water (or flow rate if flowing water) were required to be measured before and after cleaning each drain hole. The Corps would monitor the cleaning process using a borehole camera for inspection before and after cleaning. Drain holes consist of a 3.5-inch I.D. steel standpipe through the concrete of the dam down to the top of foundation rock where the hole becomes a 3-inch diameter unlined drain

hole through the basalt rock foundation. The Scope of Work included standard Corps of Engineers requirements for environmental protection and safety.

VPS Inc. used a 20,000 psi, 17 gpm pump and 400 feet of 20,000 psi hose to power the cleaning head. The cleaning head was a speed governed reaction-jet rotating mole with a proprietary head designed and developed by VPS. A portable derrick with electric winch was used to insert and retract the mole at a controlled rate. Sandbags were used to retain debris. Water jetting was done at a pressure of 12,500 psi at 15 gpm on all 15 drains.

Measurements taken before and after drain cleaning indicated generally successful results. Drains were successfully cleaned to original depth, water flow increased from several of the drains, and foundation pressures dropped at several locations.

British Columbia Hydro Dams

B.C. Hydro has been testing various foundation drain cleaning methods since 1981. In terms of cost, they have found rodding and flushing to be the most inexpensive. High pressure water jetting and ultra-high pressure water jetting were in the middle price range. Reaming, over-coring, and re-drilling were the most expensive methods and can cost from 4 to 8 times as much as water jetting.

High pressure water jetting is less costly than ultra-high pressure water jetting, but B.C. Hydro concludes that the high water flow rates of high pressure jetting can cause erosion in a weak, fractured rock foundation. On some projects, the higher cost of ultra-high pressure equipment may be justified to obtain good results with lower water flow and reduce the possibility of rock erosion.

B.C. Hydro has used both high pressure and ultra-high pressure water jetting for drain cleaning at several dams in an effort to overcome shortcomings of more traditional methods. As might be expected, recent projects appear to be more successful than earlier water jetting projects. Improvements in equipment and techniques and a growing accumulation of field experience have combined to improve the success rate.

At Revelstoke Dam (completed in 1984), drains in the metamorphic rock foundation were first cleaned in 1987 to remove calcium carbonate deposits in an effort to relieve uplift pressures. A 10,000 psi pump was used and several nozzle designs were tested including rotating nozzles. Observations with a borehole camera determined that rotating nozzles with carbide jets were the best for removing calcium carbonate from the drain walls. Piezometric pressures were lowered from 3 to 12 meters in some blocks, while other blocks had no pressure change. The drains in blocks showing no pressure change were cleaned again in 1992, using a 15,000 psi pump to power the nozzle. Pressures were lowered in some blocks, but there was some caving of drain holes due to plucking of rock. This experience pointed out the need to assess rock soundness before drain cleaning and to consider the use of ultra-high pressure water jetting because of its use of lower water volume.

At Seven Mile Dam (completed in 1980), 120 drains in the granite rock foundation were first cleaned in 1989 when high piezometric pressures were measured at the power intake and spillway blocks after first filling of the reservoir in 1988. High pressure water jet cleaning similar to that used at Revelstoke Dam was used to remove calcite buildup. Because the holes were relatively clean initially, little material was removed and no reduction in piezometric pressure or increase in drain flows was accomplished. Drilling of 34 additional drain holes was necessary to get the needed decreases in pressure.

At Hugh Keenleyside Dam (completed in 1968), 55 drains in concrete and foundation rock were cleaned in 1990 with ultra-high pressure jetting to remove calcite. Pump pressures up to 35,000 psi were used. Drain blockages were cleared successfully, but piezometric pressures did not drop significantly. At this dam, it was found that softer deposits could be removed with low pressure water flushing, and that ultra-high pressure jetting was better for harder deposits and calcite filled fractures in rock.

At Ruskin Dam (completed in 1930), a concrete gravity dam with diorite foundation, the drains in concrete were constructed by embedding slotted sheet metal pipes. Drains in concrete are 4 inches in diameter and drains in rock are 2 inches. The first cleaning was in 1981 in an effort to remove tough calcium carbonate encrustations. High pressure water jetting was tested in 12 drains for a total length of 110 meters. The pump could supply 12,000 psi or 8,000 psi water. The jetting hose was hand fed and turned by hand to evenly distribute water impact on the drain wall. Camera inspection showed that the metal liner was effectively cleaned, but some deposits were left in the slots. The method was unable to clean the 2-inch drains in rock. During drain cleaning, there was no pressure buildup in the hole being cleaned or in adjacent holes.

By 1993, the drains at Ruskin Dam had new uniform calcite deposits up to 1 inch thick. This provided a good test site for ultra-high pressure jet testing. Camera inspection showed the method was effective in removing hard calcite deposits from the drains, and tests on small blocks of shale, granite, and concrete showed no damage. The experimental program was designed to evaluate different nozzles at various working pressures and to optimize the ultra-high pressure method. Before and after pictures of the metal lined drains were impressive. The before picture shows a rough calcite opening with no metal visible. The after picture shows a clean, bright slotted metal liner.

The maximum water pressure available was 35,000 psi with a maximum flow of 4.0 gpm. The system used has the ability to immediately stop flow at the drain location using a hand operated valve. Stainless steel pipe was used to carry jetting water to the gallery to minimize pressure loss. To reduce damage to concrete or rock, the nozzles tested did not have any jet angles of 90 degrees that would directly hit the drain hole walls. To clean joints in rock, a combination of forward and backward jets was used. Nozzle rotation was accomplished by rotating the last 50-foot section of hose at a cart in the drainage gallery. Nozzles for drain cleaning were first tested in the gallery. Calcite thickness of 2 inches was common on gallery walls near drain openings and various nozzles were put on the end of a lance and used to clean calcite from the walls. Wall

tests showed that all tested nozzles could effectively remove these hard calcite deposits.

Cleaning was performed so that there would be four passes over each portion of the drain hole. The cleaning rate was about 2 meters per minute. To assess pre-cleaning condition of the drains, the holes were flushed and inspected with a video camera prior to cleaning. Difficulty was encountered in passing the cleaning nozzle from the 4 inch diameter concrete drain sections into the 2 inch rock drain holes. Video inspection did not detect the cause of blockage at the rock and concrete interface, but penetration into the rock drain was successful at only four holes.

Because of concerns that ultra-high pressure jetting could damage jointed foundation rock by erosion or by lifting of layers, nozzles were tested on small blocks of rock. A block of shale with numerous seams, a block of granite, and a block of concrete were tested. Holes, 3 inches in diameter, were drilled in the blocks for nozzle access. In the shale, the holes were perpendicular to the seams. Even at water pressures of 35,000 psi, there was no significant erosion in the shale seams. There was some water seepage along the seams, but because of low flow rates to the nozzle, there was no lifting of the layers. No damage was done in jetting the granite. The concrete has some cement paste removal at 23,000 psi and some paste and sand removal at 35,000 psi. There was no deep erosion of concrete.

The general conclusion from Ruskin Dam work was that ultra-high pressure jetting has less risk of erosion in the drain hole because it uses low water flows. Both high pressure and ultra-high pressure jetting can be effective in removing calcite.

The experience at Ruskin Dam could be valuable information for Bureau of Reclamation drain cleaning projects. It demonstrates that site-specific choices in equipment can increase the success rate and minimize damage. Technical details of nozzles and equipment tested at Ruskin Dam deserve careful study prior to undertaking future Reclamation projects. A test program prior to drain cleaning can be a valuable part of any project.

ADDRESSING CONCERNS AND GOALS FROM THE JANUARY 1998 MEETING:

The January 20-21, 1998 Drain Cleaning Seminar held in Denver for Bureau of Reclamation personnel listed goals and concerns for future drain cleaning projects. This section attempts to address those items that pertain to high pressure and ultra-high pressure water jetting methods. While the numerous benefits of water jetting were discussed at the Seminar, the concerns and goals must be addressed.

One concern was that drain joint locations must be known and equipment must be manually guided through the joints. This concern can be met by good project planning. The first step is to review drawings and records for joint locations. The second and most effective measure is to use a borehole camera to locate and examine joints.

Another concern was that impurities in the water supply (often reservoir water) could clog nozzles causing an equipment-damaging pressure build-up in jet lines. Reclamation needs to work with contractors and equipment suppliers to minimize this danger. Strict requirements for water filtration, flow monitoring, pressure monitoring, automatic shut off devices, and operator training can reduce this danger.

During water jetting of drains, forward nozzle jets clean drain deposits, while rear facing jets force water and debris out of the hole. A concern often expressed is that the backwash could clog the drain hole behind the nozzle and create a pressure pocket that could damage the rock or concrete surrounding the drain hole or, even worse, could pressurize joints in the rock or cracks in the concrete and lift the structure. The thought of applying up to 35,000 psi pressure in these joints causes some to avoid using the method. In their report on drain cleaning at Friant Dam, VPS Inc. stated “Actual pressure transferred to the structure of the dam is very low. This is due to the fact that the hydroblast pressure is converted into velocity as the blast water creates the impact that does the actual cleaning. Exerting hydraulic pressure on the structure from hydroblast operations is virtually impossible.” As this statement indicates, under normal operating conditions, while there is high pressure in the hose behind the nozzle, the water exiting the jets is at atmospheric pressure and is traveling at high velocity. The only additional pressure is the static head of the backwash. While the hose pressure may be 35,000 psi, the drain pressure will typically be less than 50 psi. Getting high pressure in the drain hole would require complete blocking of the backwash, the forward drain section, and the drain walls. While theoretically possible, this situation seems unlikely to occur. If drain walls are fractured enough to allow a significant volume of water to enter to lift the structure, they may not be tight enough to retain pressure. It is also unlikely that the backwash and the forward drain would both be blocked sufficiently to retain 35,000 psi. Because, however, such damage is theoretically possible, precautions should be taken. Engineering analysis of some structures for potential damage could be performed. Operator training, pressure and flow monitoring, and automatic shut off devices are also important. As more field experience accumulates and equipment becomes more automated, Reclamation can work with equipment manufacturers and contractors to even further reduce the probability of this unlikely event.

Another concern is potential damage to lengths of weak or soft drain walls in rock or concrete. If the drain wall is weaker than the deposits being removed, it could easily be damaged. B.C. Hydro had some experience with “rock plucking” and concluded that this is less of a problem with ultra-high pressure jetting than with high pressure jetting because of the lower water volume used. At sites where zones of weak drain wall are prevalent, ultra-high pressure jetting could be specified. Other considerations might include initially limiting the jetting time and performing video inspection before further water jetting. In some cases, it may be necessary to simply accept the fact that certain short sections may be come enlarged and any resulting plugging must be removed. There may be a few extreme cases where water jetting is not the best method because of the weak drain walls. As field experience increases, such problems will be solved. Methods may even be developed to insert short sections of drain liners at depth down the existing drain hole to cross weak or jointed areas.

The Drain Cleaning Seminar notes also listed drain cleaning goals. Some of the goals pertaining to water jetting are: prioritize drain cleaning in budgets, get support throughout the regions, prioritize cleaning needs, establish an expert cleaning team, establish a centralized database on technology and field experience, have borehole camera capabilities, document before and after flows, have pressure monitoring devices to avoid foundation damage, purchase a water jetting unit to gain hands-on field experience, and communicate field findings to avoid duplication of effort.

Considering the Reclamation-wide interest and need, these goals could be met over the next several years.

WATER JETTING FOR BUREAU OF RECLAMATION USE:

Current (1999) water jet technology for drain cleaning is technically superior to the technology of the 1980's and early 1990's. Much of the earlier equipment was developed for use in the oil fields or other industries and was adapted for drain cleaning needs. The equipment was less effective and less durable than current technology. The need to rotate the nozzle for effective cleaning was recognized and early drain cleaning accomplished this by twisting the hoses by hand. The technology then moved to rotating heads that were not always reliable. Reliable, non-leaking, rotating heads are now available. Replaceable jets of gemstones or metal alloys with longer life are also available. Small diameter hoses and connections eliminate previous access limitations. Portable pump units now have higher pressures and higher horsepower allowing greater hose lengths and steady pressures at the nozzle. Steel and kevlar reinforced hoses with friction reducing linings and improved flexibility and abrasion resistance have improved operations.

During the development of water jetting for drain cleaning, there has been an increasing use of before and after documentation to measure cleaning success. Borehole cameras are effective in determining cleaning needs and in determining cleaning success. Lowering a ball or plumb bob of proper diameter after drain cleaning can confirm that the hole is open to full depth. Monitoring drops in piezometric pressures in concrete dam foundations is a direct indication that dam safety has been improved. Monitoring after-cleaning increases in drain flow rates is an indication of success. Measuring drain depth before and after cleaning and comparing to original drain depth gives another indication of degree of success. Pressure rebound can indicate drain efficiency--this test is performed by sealing with a packer near the drain opening and pressurizing the drain hole to make prescribed measurements.

Current water jet drain cleaning technology has advanced to the point that the Bureau of Reclamation could benefit by increasing its use of this technology.

This report can serve to deliver basic information to program managers who can arrange funding and set priorities.

The next step is to purchase a complete water jetting unit, develop guidelines for its use, and

begin accumulating field experience. A complete set of high pressure water jetting equipment can be purchased for approximately \$85,000. The majority of jetting needs will be for high pressure equipment. The occasional need for the more expensive ultra-high pressure equipment can be met by using contractors.

This would add a valuable tool for many drain cleaning problems. It does not mean that traditional methods would be abandoned. It does not mean that we would not still use contractors for specialized water jetting needs. Field trials with the new equipment should start at sites where the potential for success is greatest. Information gained should be quickly distributed. The new equipment should be made available for use throughout Reclamation. Problems encountered should be quickly investigated and solved. Investigations of related needed technology development should be undertaken. One possibility is to develop methods to open pores and fissures in concrete and rock after drain cleaning to ensure good water flow into the cleaned drain opening.

Critical to the success of the program is the establishment of a central point of contact for both equipment and transfer of technical information.

POSTSCRIPT:

After this report was first drafted in September 1998, the Bureau of Reclamation Great Plains Region purchased a high pressure water jetting machine for about \$89,000 that is rated to deliver 15,000 psi at 22 gpm. The manufacturer will provide two days of on-site training to Reclamation personnel. The Great Plains Region also purchased a trailer and accessories for the unit; and a new down-hole color video camera unit to monitor cleaning results. First use of the equipment is scheduled for summer of 1999, at Yellowtail Dam. Later in 1999, the equipment will be used at Canyon Ferry Dam. Great Plains Region will produce a comprehensive report on the method, costs, and results. Once they have trained their drill crew and operations are running smoothly, visitors from other Reclamation offices will be welcome on site to see operations. If results are satisfactory, GP personnel will be able to give assistance to other regions with this new capability.

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