Development of a Method for Detecting Debris at the Entrance to Submerged Orifices

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COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

Fingerling salmon and trout migrating down the Snake and Columbia River systems must pass a number of low-head dams (Figure 1). A high rate of mortality may occur as the fish pass through the turbines and the large populations of predators in the tailraces (Long et al. 1968). The discovery that the migrating fingerlings naturally concentrate in turbine intake gatewells has led to efforts to utilize this tendency as a means for increasing fingerling survival (Long 1968; Long and Krcma 1969). As a consequence, traveling screens are now in use to enhance the numbers of fish entering the intake gatewells where they are permitted to exit through an orifice into a fish bypass (Figure 2). A collection system at the terminal end of the bypass may be used to concentrate the fish for trucking or barging around the remaining dams or the fish may simply be released into the river downstream from the dam (Matthews et al. 1977).

The orifices that permit fish to pass from the intake gatewells to the bypass sometimes collect debris across their entrance that can injure fish. Although turbine intakes are protected by trash racks which exclude large debris, much small debris enters the intakes and the intake gatewells. Sticks frequently hang up at the entrances to the gatewell orifices and form a base upon which other materials may accumulate. When fingerlings are trapped by the velocity of the water flowing into an orifice, they cannot avoid contact with the debris and are often descaled or otherwise injured.

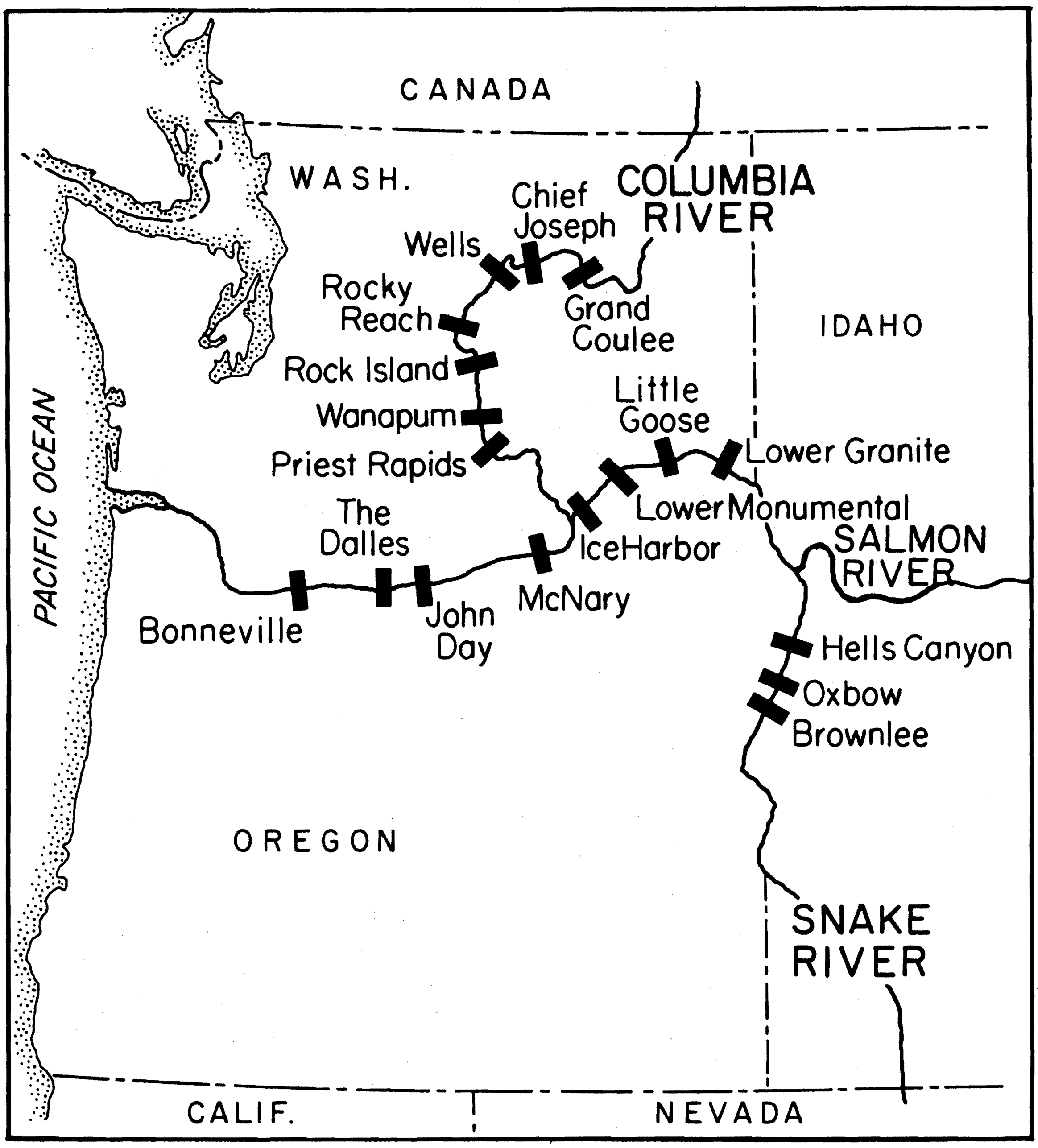


Figure 1.--Upriver stocks of fingerling salmon and steelhead trout must pass numerous dams on their migration to the Pacific Ocean.

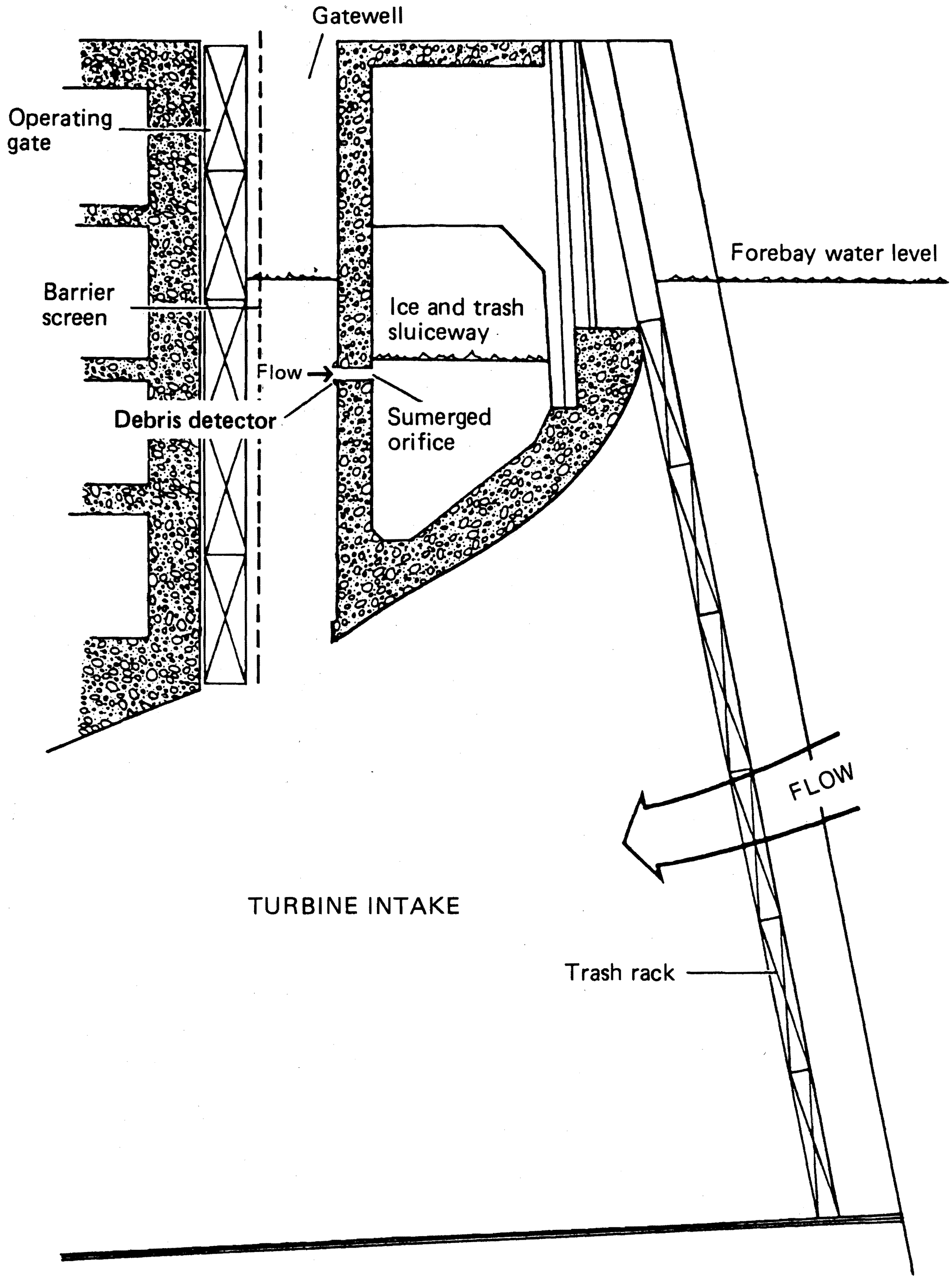


Figure 2.-- Transverse cross section through typical turbine intake of first powerhouse at Bonneville Dam showing location of submerged orifice and debris detector in gatewell.

At most dams, such as Bonneville and John Day, no simple method exists for determining when the orifices begin accumulating debris because both the entrances and exits of the orifices are submerged and cannot be seen. Divers must often be used to inspect the orifices and remove accumulated debris. This method is very expensive and does not provide for timely action.

To develop a simple, effective means of detecting debris at orifice entrances, the National Marine Fisheries Service, under contract to the U.S. Army Corps of Engineers, selected two techniques for detailed testing: paired aneroid sensors and circular flange load cells. The objectives were to test both techniques under controlled hydraulic conditions (laboratory study) to verify the general feasibility, and then test one or both techniques under actual field conditions (field trial).

DESCRIPTION OF TECHNIQUES

Both techniques were able to detect changes in pressure at the orifice entrance due to the presence of debris. The major problem was to distinguish pressure changes due to the presence of debris from pressure changes due to other factors, e.g., changes in water pressure due to fluctuations in orifice submergence and changes in pressure due to fluctuations in water velocity caused by changes in the hydraulic head on the orifice.

Paired Aneroid Sensors

Figure 3 shows the aneroid sensor rings as assembled for testing. A plastic orifice ring was grooved to accept two air-filled rings of 5/16-

A

B

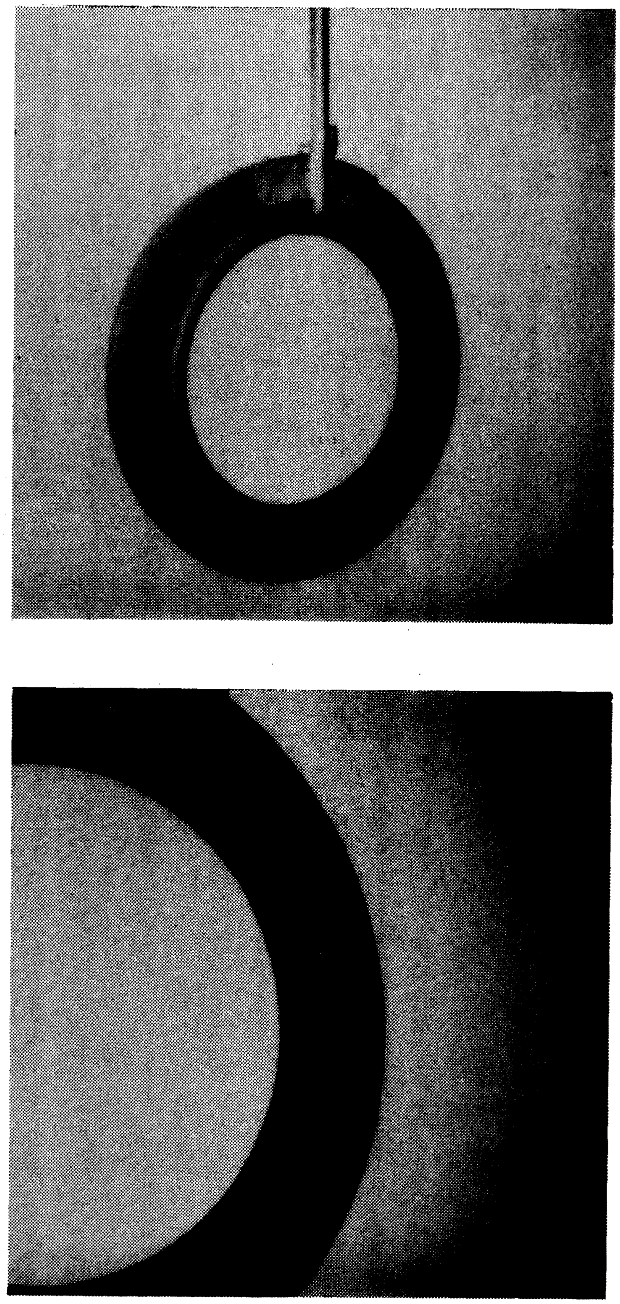


Figure 3.--Two views of paired aneroid sensor rings partly embedded in ring of plastic.

inch diameter surgical tubing. Each ring was connected via tubing to a differential pressure gauge. In principle, the pressure due to submergence or water velocity would affect both sensors the same, and only pressure differences caused by debris in contact with the front tube would be transmitted to the readout.

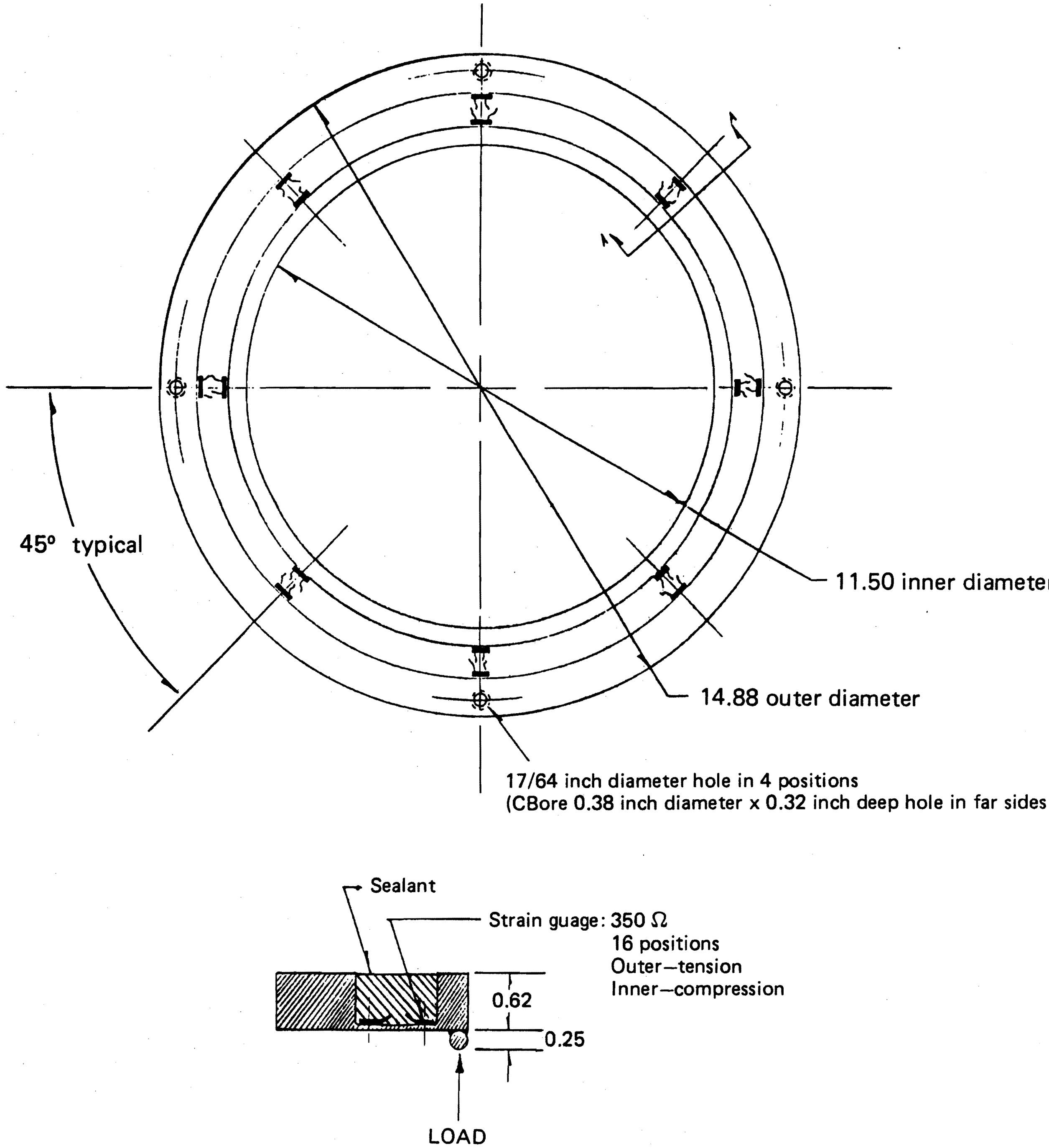
Circular Flange Load Cell

Figure 4 shows the design of the load cell and Figure 5 is the complete assembly. Strain gauges were mounted on a carefully machined area of a metal flange so that any deflection of the flange outputs an electrical signal.

We anticipated that deflection (signal output) caused by changes in water velocity due to changes in hydraulic head would occur slowly, whereas deflection due to impingement of debris would occur rapidly. These differences then, would be used to detect the presence of debris. In addition, we hoped that the baseline signal (when no debris is present) would always have a relatively narrow range for any given hydraulic head and submergence. The more discrete this baseline signal, the more certain the operator could be in determining that, after removal of the debris, all the debris was indeed removed.

LABORATORY STUDY

The objectives of the laboratory study were to examine the sensitivity of each technique for detecting debris; to verify that the presence of debris could be consistently detected; and to discover, if possible, any problems that might affect long-range reliability.



Capacity: 100 pounds (uniform load)
Output: 2.00 mV/V nominal
Terminal resistance: 350 Ω
Temperature range: 32° –100° F
Combined accuracy: ½ of 1° full scale

Figure 4.--Design of circular flange load cell.

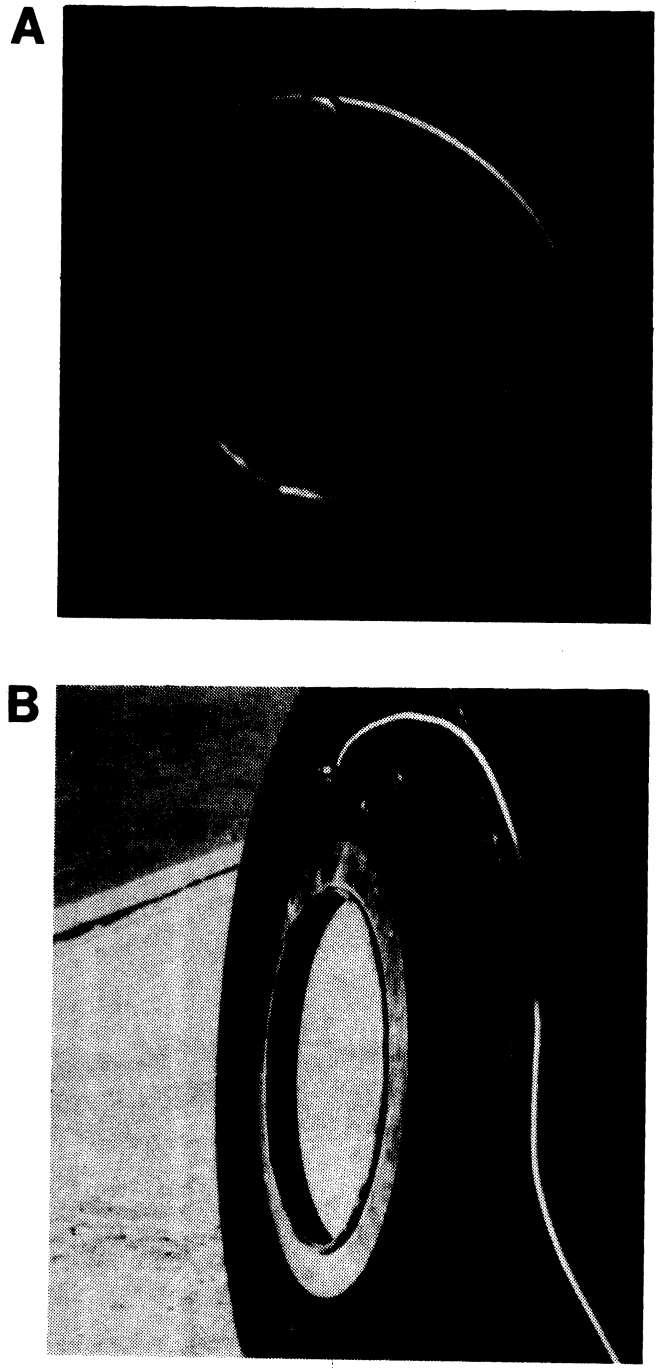


Figure 5.--A = view of existing circular flange insert forming entrance to submerged orifice. B = circular flange load cell was constructed to replace the circular flange insert.

Methods

The study was conducted in an oval flume where water was pumped through a bank of jets to obtain the desired velocity (Figure 6). A panel containing a 12-inch diameter orifice was inserted in the path of the flow to simulate conditions as they exist at orifices in gatewells. Hydraulic head and submergence, however, were limited to 1.5 and 4.0 feet, respectively.

For the sensitivity tests, we employed a 1/4-inch diameter dowel of sufficient length to span the 12-inch diameter orifice. We judged that a single stick of this size probably would not present a hazard to the fingerling salmon transiting the orifice, but could be considered the minimum debris that could present a problem because a single stick of smaller diameter most likely would be broken and carried through the orifice by the velocity of the flowing water.

Results and Discussion

Paired Aneroid Sensors

Sensitivity tests employing the 1/4-inch diameter dowel were conducted at a hydraulic head of approximately 1 foot. Although the rings of surgical tubing suffered from a lack of stability, particularly at higher water velocities, the addition of the 1/4-inch diameter dowel produced a significant change in the mean differential pressure at all velocities.

The inherent instability of this method at the relatively low velocities available in the flume suggested that, under the higher velocities which could occur in the field, fluctuations in pressure might be severe enough to mask the presence of small debris.

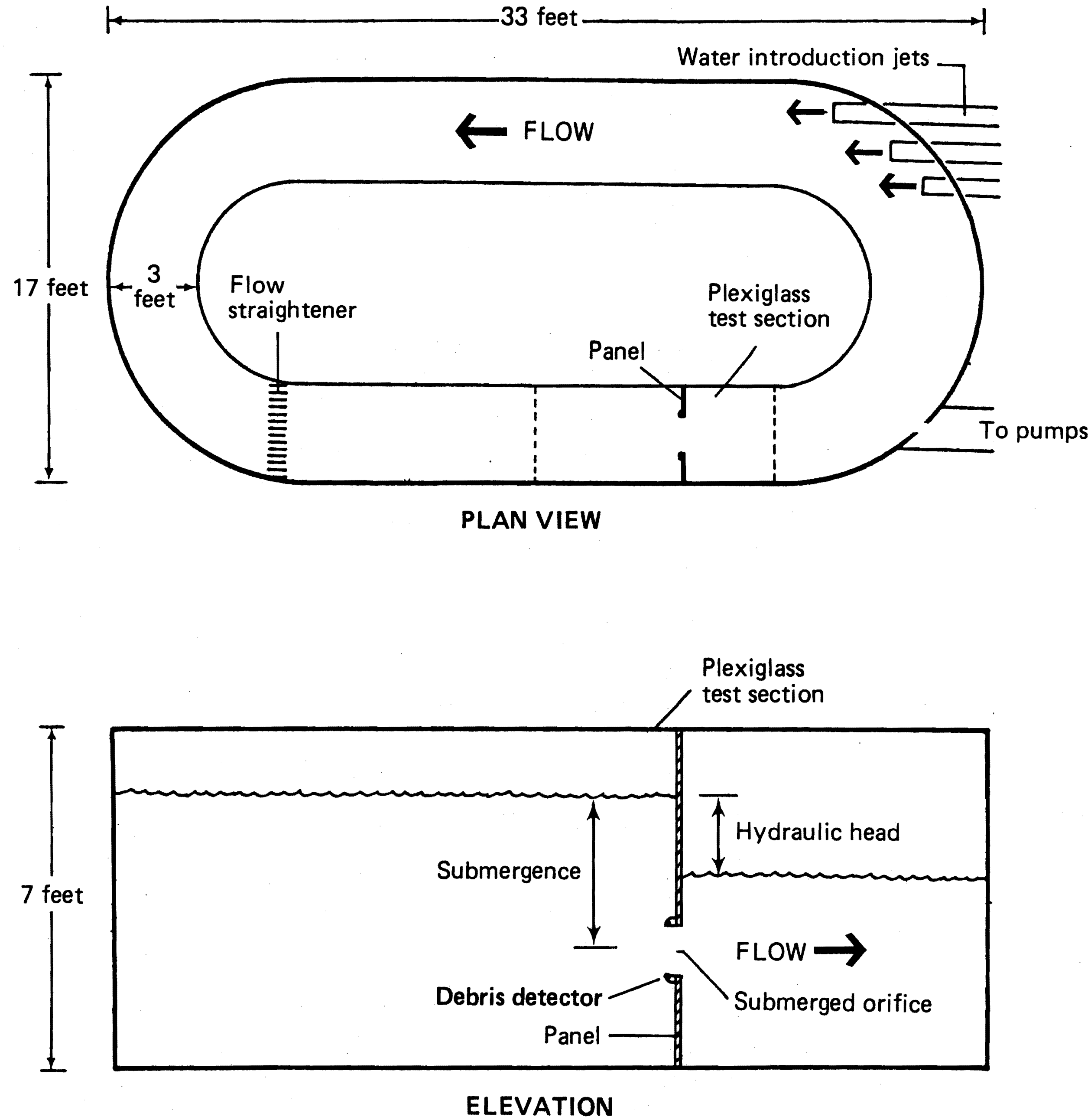


Figure 6.--Oval flume in which laboratory study was conducted.

We also found that the resiliency of the surgical tubing changed with the duration of submergence, which in turn resulted in a difference in the response to pressure pulses. Apparently, the surgical tubing was slowly absorbing water.

These problems no doubt can be solved; however, continued pursuit of this technique was considered to be beyond the scope of the present contract.

Circular Flange Load Cell

The circular flange load cell was tested at hydraulic heads of 1 to 3 feet. Under all velocities, the signal produced by the load cell was reproducible, and the addition of the 1/4-inch diameter dowel produced a clear-cut signal. The results clearly showed that this method warranted further study. We therefore decided to test the circular flange load cell under actual conditions.

FIELD TRIAL

A single trial of the circular flange load cell was made in Gatewell 3B in the first powerhouse at Bonneville Dam. The objective was to determine if the load cell would be adversely affected by field conditions and to verify that it would work as it did in laboratory tests.

Methods

The circular flange load cell assembly was mounted at the orifice intake by means of an adapter that replaced the existing orifice plate (Figure 5). This provided a mount that was essentially flush with the face of the gatewell's inner wall, thereby eliminating any projections that could interfere with normal maintenance operations. Submergence of the orifice was approximately 8 feet, and the hydraulic head was approximately 2 feet.

The signal from the load cell was fed through signal conditioning circuitry to a Motorola-based GIMIX Model 09 micro-computer[1/] with a Televideo Model 925 terminal. The computer was programmed in Forth language to allow various combinations of running and exponential averages to be used in signal conditioning. The computer was interfaced to the load sensing ring through a Tri-Coastal signal-conditioning amplifier and a triple integrating analog-to-digital converter. The output was converted back to an analog signal for input to a strip chart recorder. This system permitted adjustments to be made quickly and easily so that suitable output signals could be obtained.

Results and Discussion

The tests indicated that the load-cell debris detector provided a means for detecting debris which impinged upon gatewell orifices. Figure 7 is a sample of the output of the conditioned signal. Analysis of the test data showed that the most serious concern with the load-cell detector was the necessity to re-establish the true base line each time debris was removed.

We found that the baseline signal (without the presence of debris) for the submergence and hydraulic head tested varied significantly over time,

[1/]Reference to trade name does not imply endorsement by the National Marine Fisheries Service, NOAA.

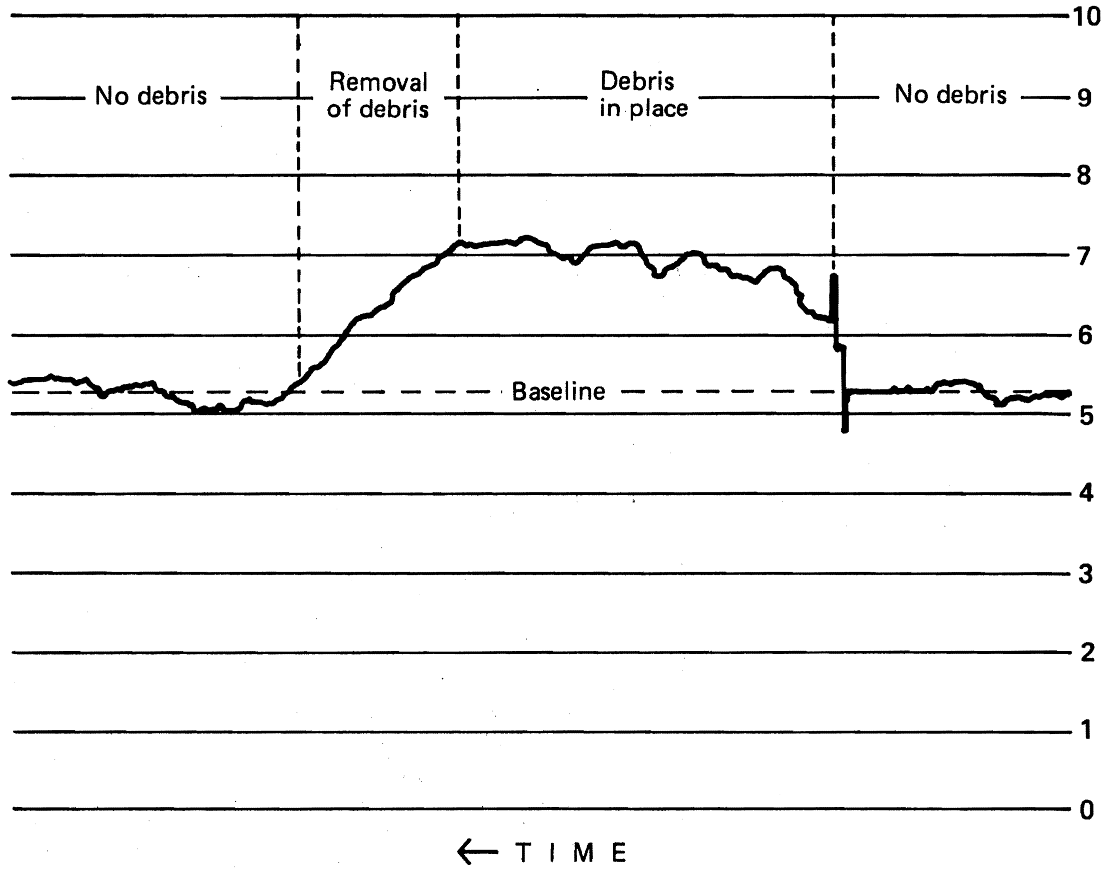


Figure 7.--Trace of signal output from circular flange load cell with and without 1/4-inch diameter dowel in place.

thus producing a wide range of output signals. It may be possible for example, that after the removal of debris, subsequent baseline signals in the high part of the normal range might actually be due to a combination of a true baseline signal in the low part of the range plus a small amount of debris that failed to be removed. Under certain conditions of flow and submergence, it may be possible to incorrectly assume that complete debris removal was achieved.

The possibility of utilizing a paired-sensor system as a means to avoid the potential baseline problems was considered and appears to be practical. Sufficient information was collected during testing to establish the parameters for construction of a suitable paired-sensor system. In essence, a detector assembly would contain two separate rings (matched sensor arrays)--an outer ring and an inner ring. The inner ring would not be contacted by debris but would be affected by changes in flow, temperature, etc. and provide baseline compensation. The signal from each array would be fed to an amplifier/filter which would permit initial adjustment of zero and gain. The conditioned signal from each of the arrays would be fed to a comparator, and any signal difference would be used as output to an alarm or signal/control system. Since both arrays would be subjected to the same influences except for the debris itself, any changes in baseline conditions would be compensated for automatically, and the reference point would remain fixed. The electronics required for signal conditioning would be simpler, less subject to outside influences, and would require less intervention and monitoring by operating personnel.

CONCLUSIONS AND RECOMMENDATIONS

The testing indicated the capability of the load-cell to detect debris under operational conditions. We feel that the sensitivity and durability of the sensor system are adequate for the application. By using a paired sensor system, the potential problem of base-line instability can be circumvented and operation of the system can be simplified. Such a system will lend itself readily to automated control of debris removal.

Based upon the information obtained thus far, we recommend the construction and installation of three or four paired-sensor array load cells in the orifices of operating turbine intake gatewells. These units would be operated as a prototype system for testing and evaluation. Various alarm/control systems could be tested at the same time to establish the level of automation desired.

Anticipated capital costs for the proposed test system would be approximately $4,000 each for the double-ring load cells and approximately $700 each for the associated electronics. These costs would be reduced in production quantities.

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