PLASTIC STANDPIPE FOR SAMPLING STREAMBED ENVIRONMENT OF SALMON SPAWN

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PLASTIC STANDPIPE FOR SAMPLING STREAMBED ENVIRONMENT OF SALMON SPAWN

by

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ABSTRACT

Knowledge of prevailing conditions of streams for spawning salmon can lead to improved management of those streams and improved production of salmon. All-important to the salmon is the condition of the streambed, based both on the characteristics of seepage rate and on the availability of oxygen at spawn depth. At Mill Creek, California, the most feasible method for procuring this information is by using the standpipe system. This paper describes the design of the Mill Creek standpipe and its method of operation, discusses the mechanics of seepage, and compares the data obtained with data on the survival of king salmon spawn.

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INTRODUCTION

The existence of adverse conditions of the streambed as a limitation to the production of salmon has received less attention than have other phases of salmon biology. The streambed, as a habitat for the eggs of salmonoids, is subject to constant change. The problem is to obtain continuous information about the changes that affect the survival of eggs, which the fishery manager has previously gone to great effort to protect. Guaranteeing escapement of adult spawners by measures of enforcement or construction of costly fishways, for example, can be wasted effort if the streambed has become an unsuitable habitat for incubation of eggs. Conditions that sometimes render a drainage area unfit for fish include road construction, mining and logging operations, and certain land cultivation practices.

The prerequisite for the survival of spawn is an adequate flow of oxygen-bearing water through the gravel containing the eggs. Thus, in the management of a stream, it is desirable to know (1) the concentration of oxygen present in the water of the spawning bed and (2) the rate of seepage of this oxygen-bearing water through the gravel. Obtaining a water sample from the streambed for determining the dissolved oxygen present at the spawn level is relatively simple, but the determination of the rate of seepage is somewhat involved.

In the past, several methods have been used for measuring seepage rate in the gravel. Generally, these methods involve pouring a saline solution or fluorescein dye into a pipe that has been driven into the streambed. The rate of flow then is determined at a measured distance downstream by inserting electrodes into the streambed to detect the arrival of the salt solution or by observing the arrival of the dye. One weakness of this method stems from the complexity of the pattern of flow in the streambed. The dye, for example, may appear at the test spot within 30 minutes and continue to flow for the next 20 minutes. The same pattern of flow is observed if a salt solution is used instead of dye. Thus, these methods still leave unsolved the question how fast the water is moving past a particular point where incubating eggs may be located.

A new procedure being used in the freshwater-survival studies of king salmon in California has proved superior to other methods. It involves the standpipe principle that was pioneered in fishery work of the Biological Station at Nanaimo, B. C., and reported by Wicket (1954), Pollard (1955), and Terhune (1957).

Essentially, the standpipe is a short length of pipe that is lodged in the streambed and extends upward above the surface of the stream. In this position, it serves as an access tube through which the quantity of oxygen in the groundwater and the rate of flow of water in the gravel may be tested.

The standpipe may be used in either one of two ways: (1) It may be inserted in the streambed and removed after one use, or (2) it may be kept imbedded for a systematic and progressive recording of conditions in the gravel.

In the first example, the standpipe is driven into the streambed by means of a sledge. This system has the advantage in that the same standpipe can be used over and over again to cover a number of streams. In the second, the standpipe remains in the gravel and becomes a component of the streambed. It therefore may be inserted by digging a hole, placing the pipe in it, and then refilling the hole with gravel. The placed standpipe has several advantages over the temporary installation:

1. Data obtained are continuous; thus, observed fluctuations in the amount of dissolved oxygen or the rate of seepage of water through the gravel then are known to have occurred since the previous examination and not to be a result of local variability.

2. The data are obtained more readily than are data from a temporary standpipe, which usually requires a period of waiting

while the stream adjusts to the imposed conditions.

3. The influence of artificially created compaction caused by driving a temporary standpipe into the streambed is eliminated.

This paper gives an account of the adaptations in design of the placed standpipe developed at the Mill Creek Fisheries Station in California and at the laboratory of the U. S. Bureau of Commercial Fisheries in Seattle. Specifically the presentation describes:

1. Innovations in the design of the standpipe.

2. How to derive rates of flow of water through the gravel in feet per hour from the calibration of the standpipe in the laboratory.

3. Methods developed for sampling the streambed by use of the standpipe.

4. Some comparisons of rates of flow of water and of amounts of dissolved oxygen in the streambed with the survival of king salmon eggs.

ACKNOWLEDGMENTS

The authors wish to acknowledge the assistance received by Robert D. Broad who participated in the development of the Mill Creek Standpipe, R. G. Hennes, Professor of Civil Engineering, University of Washington, who served as consultant, and Glenn Pedersen who reviewed the presentation.

The illustrations were prepared by Virginia Coleman.

INNOVATIONS IN THE DESIGN OF THE MILL CREEK STANDPIPE

To keep a standpipe operational for prolonged periods of time in an open stream requires use of special materials and design. Some of the hazards that must be overcome are corrosion, plugging of the standpipe with silt, and washouts. A plastic material, polyvinyl chloride, which is very durable and resistant to water and chemicals, solves the problem of corrosion. Eliminating corrosion has advantages besides preventing the deterioration of the device itself: providing samples of water free of both oxidizing impurities and suspended silt; both precautions are recommended in the determination of dissolved oxygen by the Winkler method. These and other advantages that will be discussed later in the article are made possible by use in the standpipe of a free-moving, noncorroding sleeve, which functions as a valve.

The parts and assembly of the polyvinyl chloride plastic standpipe used at Mill Creek are illustrated in figure 1. The plastic comes in all forms--including pipe, pipe fittings, sheets, and cylindrical bars--and is easily shaped on a lathe. The sleeve is made from 1 1/4-inch pipe stock, which fits into the 1 1/2-inch milled shaft. The inside diameter of the lower 5 inches of the shaft is increased to a generous 1 5/8 inches, and the outside of the sleeve is turned down to a skimpy 1 5/8 inches. A silicone paste applied to these parts creates a seal and supplies lubrication for free movement. The foot-like attachment at the base anchors the pipe securely in the streambed to forestall washout.

The valve generally is trouble free; however, a grain of gravel may lodge in two of the alined holes and subsequently prevent free movement of the valve. This difficulty has occurred on occasion but has not proved to be serious; nevertheless, duplicate installations are desirable as a safeguard. Duplication also provides more reliable data.

The standpipe separates into two parts: the main shaft and the extension tube. After the measurements have been taken, the extension tube is removed and the shaft is capped and left imbedded in the gravel. Since the shaft of the standpipe protrudes only slightly above the gravel, it is moderately safe from drifting objects and from the force of water occasionally moving at high velocities.

The lower 4-inch section of the shaft is grooved to lessen the chance of stopping a hole in the lower perforated section by a stone that may be pressed flat against the standpipe over the hole.

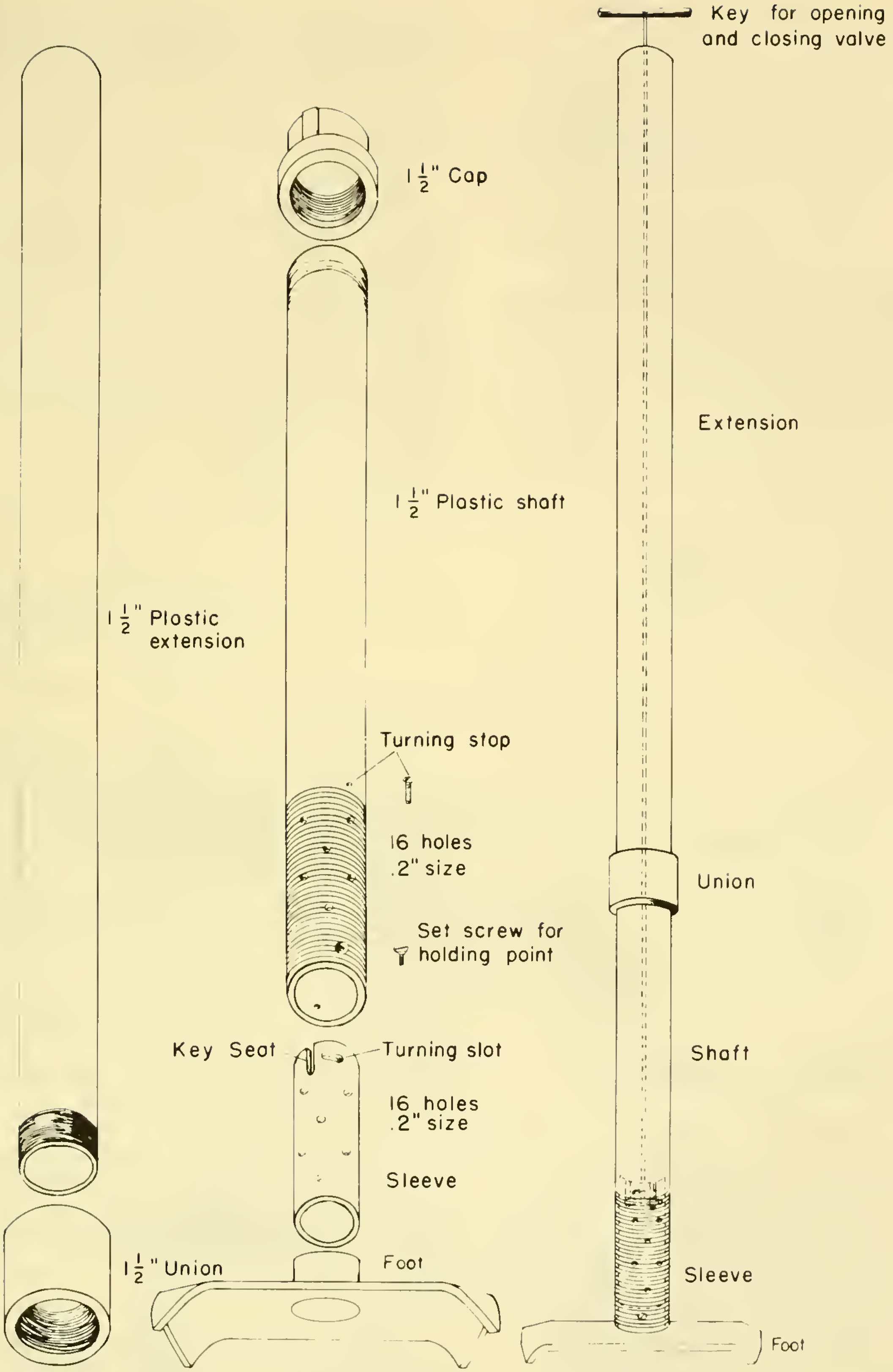

Figure 1.--A plastic standpipe for sampling water seeping through stream gravel.

THEORETICAL DISCUSSION AND LABORATORY CALIBRATION OF THE STANDPIPE

As we have seen, the water seeping through the gravel of the streambed must contain dissolved oxygen if the spawn is to survive. If the level of oxygen is to be adequate, a fresh supply of oxygen-bearing water must displace depleted water.

During the extended period of incubation of the eggs, the amount of seepage usually declines from the original cleansed condition of the redd because the migration of fine particles closes pores in the gravel of the streambed. On the other hand, turbulence of the water over the redd tends to remove these fine particles and to improve seepage, thus resulting in a fluctuating pattern of seepage, as has been pointed out by McDonald and Shepard (1955).

The best method found for observing these changes in seepage at Mill Creek is the standpipe method presented in this paper. With this method, seepage rate is associated with the rate of displacement of water in the chamber of the standpipe buried in the streambed.

To measure the exchange of water in the standpipe chamber, Wickett (1954), Pollard (1955), and Terhune (1957) insert a dye and compare changes in its coloration with standard dilutions of the dye. In the Mill Creek work, a weak solution of salt and a portable conductivity bridge is used to detect this exchange. Here, the structure of the Mill Creek standpipe facilitates measurements by its ability to open and close, making possible both (1) precise timing of the dilution interval and (2) stirring of the salt solution without unnatural washing. With the use of the sensitive conductivity bridge, the slowest movement of groundwater is measurable.

Theoretical Discussion

The problem of correlating laboratory tests with field tests has been pointed out by Burmister (1954): "In principle, determination of the permeability of soil is quite simple. However, due to natural variations of material in place, it is often difficult to relate tests on small to large masses. In sampling soil it is hard to prevent disturbing the density and structure of the material. Changes in chemical and organic content of the permeating fluid can cause differences. Migration of particles may occur both in the field and laboratory. While some variables can be arbitrarily controlled or eliminated in the laboratory, it is often necessary to consider them in the field application."

The laboratory test is based on the formulations of Hazen (1893) and Poiseville (1846), who found that the velocity of flow in capillary tubes is proportional to the slope of the hydraulic gradient. Darcy (1856), Fancher and Lewis (1932), Fishel (1935), and Burmister (1954) confirmed the application of this principle to rates of flow in uniform sands. The formula, referred to as Darcy's Law, expresses this flow in the following:

$$V = \frac{HK}{L}$$

Where:

V = velocity

K = permeability

H = height of drop (fig. 3)

L = length of drop section (fig. 3)

H/L = hydraulic gradient

In addition to the factors given in the above formulation, other factors must be considered. Fair (1934) states in this regard: "Starting from the well-known formula for flow of water through pipes, a rational expression of the flow of water through sand was obtained by regarding the pore space of sand as a series of tubular passages through which water flows in much the same way as it does through interconnected pipes. The factors that enter into the formula are the frictional resistance of sand, the velocity and temperature of water passing through it, the void space through which the water flows, and the size, shape, and packing of the sand . . ."

The formula for flow of water through pipes has been discussed. The expressions "turbulent" and "laminar" in reference to flow involving frictional resistance are commonly used and are explained in table 1, which is taken from the work of Burmister (1954).

Observations indicate that the flow of water in the gravel at Mill Creek may be either turbulent or laminar, but since this study concerns critical minimum seepage rates, only the laminar flow is dealt with in the laboratory calibration tests described here.

Among the factors mentioned by Fair as governing the flow of water through sand are those of velocity and temperature. Girard (1891), Slichter (1905), Christiansen (1944), and Burmister (1954) also cite the importance of temperature or viscous forces in laminar flow. The viscosity factor is used to transform the velocity at the temperature of the test to the corresponding velocity at a standard temperature. In the tests reported in this paper, 50° was taken as standard and the following formula was used:

$$\text{Velocity at } 50^{\circ}\text{F.} = \text{Velocity at } T^{\circ} \; \frac{\text{Kinematic viscosity at } T^{\circ}\text{F.}}{\text{Kinematic viscosity at } 50^{\circ}\text{F.}}$$

Values of kinematic viscosity are given in table 2.

Another factor considered by Fair is the void space, which is governed by the size, shape, and packing of material through which the water flows. Jones (1954) compares the influence of gravel sizes; Burmister (1954) compares gradation, shape, and compaction of materials; and Mavis and Wilsey (1937) and Bodman and Harrodine (1938) note clogging of sand in permeability tests.

Application of Factors Peculiar to the Mill Creek Standpipe

Other factors requiring correction in laboratory tests stem from the use of a salt solution and the conductivity bridge. One of these corrections is the temperature influence on resistance readings. The formula for the correction is as follows:

$$R_s = R_t\ (1 - 0.01389\,\Delta_t)$$

R_s = Specific or measured resistance at the standard temperature

R_t = Specific or measured resistance at higher or lower temperature

Table 1.--Description and Classification of Turbulent and Laminar Flows

Gravel			Sand			Silt	
Coarse	Medium	Fine	Coarse	Medium	Fine	Coarse	Fine
Practically always turbulent.			Darcy Laminar flow only for H/L less than about 0.2 to 0.3 for loose state and 0.3 to 0.5 for dense state.			Always laminar flow for the H/L found in nature.	

Table 2.--Kinematic viscosity values for appropriate temperatures, from King and Brater (1954).

Temperature	Kinematic viscosity
0°F.	Sq. ft. per second
32	0.00001931
39.2	0.00001687
50.0	0.00001410
60.0	0.00001217
70.0	0.00001059
80.0	0.00000930

Δ_t = Difference in degrees Fahrenheit between the standard temperature and the temperature of test measurement, taken as positive in value when the test temperature exceeds the standard, and as negative in value when the test temperature is below the standard

In the present work, 50° F was used on the standard temperature. By use of the above formula, the values given in table 3 were calculated.

Another correction necessitated by the use of the salt solution is that of "diffusion" or "bleeding" caused by the loss of salt in still water exclusive of diffusion from the outside influence of seepage action. The influence of bleeding as recorded by resistance increase is obtained by running the test in conditions of zero velocity in the flume in the laboratory.

Table 3.--Resistance coefficients for correction to 50°F

Temperature Degrees F	Conversion Factor	Temperature Degrees F	Conversion Factor
34	0.778	52	1.038
35	0.792	53	1.042
36	0.806	54	1.056
37	0.819	55	1.069
38	0.833	56	1.083
39	0.847	57	1.097
40	0.861	58	1.111
41	0.875	59	1.125
42	0.889	60	1.139
43	0.903	61	1.153
44	0.917	62	1.167
45	0.931	63	1.181
46	0.944	64	1.194
47	0.958	65	1.208
48	0.972	66	1.222
49	0.986	67	1.236
50	1.00	68	1.250
51	1.014	69	1.264
		70	1.278

Outline of Steps Taken in Calibrating Mill Creek Standpipe

With the information provided by the references cited, a series of calibration tests were run in a laboratory flume to correlate dilution rate in the standpipe with measured velocities of flow past the standpipe (fig. 2). This is done as follows:

1. In the laboratory, set up a test flume of known dimensions, fill it with a known mixture of sand and gravel, place a standpipe in the gravel, and pass water through the flume at a known rate of flow in cubic inches per second.

2. Knowing the width of the flume and the rate of flow, after measuring the height of water at the standpipe, compute the average velocity of flow at the standpipe in feet per hour.

3. Obtain a corrected velocity of flow by (a) noting the temperature of the water and (b) calculating what the velocity would be at the "standard" temperature.

4. Determine the volume of water in the standpipe, and calculate the ratio of this volume to a "standard" volume.

5. Introduce a few drops of salt solution into the chamber of the standpipe and note the rate at which the resistance changes as the rate of seepage of water through the gravel is varied.

6. Correct the resistance readings to corresponding resistance at the "standard" temperature.

7. Correct the "end" resistance reading for the effect of "bleeding".

8. Calculate the "displacement number" by use of a chart of displacement curves. The displacement number is a one to one progression of dilution which is associated with appropriate resistance readings as indicated beforehand by a conductivity bridge

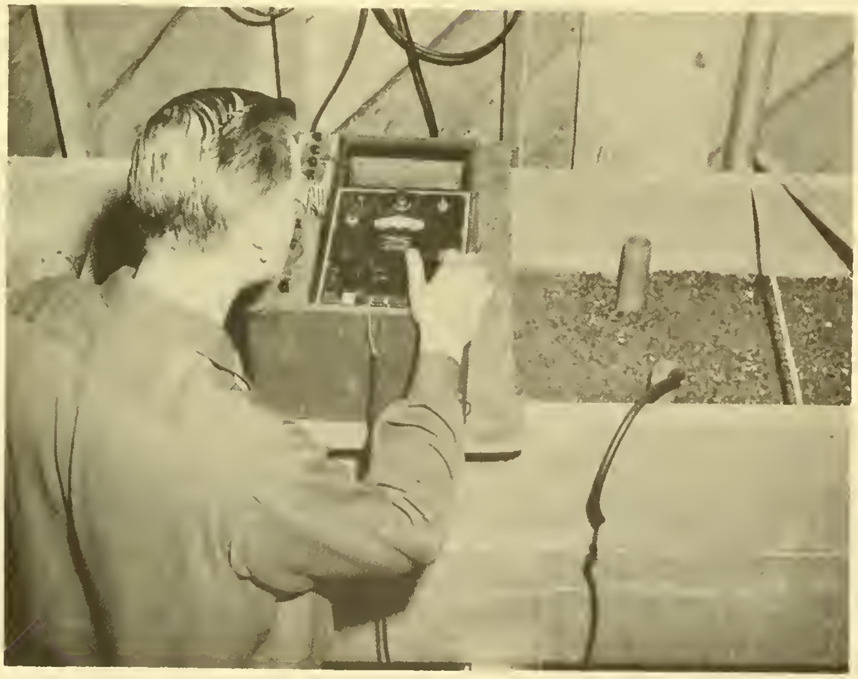

Figure 2.--Calibrating the standpipe in the laboratory.

in the laboratory.

9. By use of the ratio determined in step 4, correct the displacement number found in step 8 to a displacement number relative to the standard volume.

10. Correlate the displacement number obtained in step 9 with the average velocity obtained in step 3.

Explanation of Steps Taken in Calibrating Mill Creek Standpipe

To obtain a good correlation between salt dilution in the standpipe and seepage rate in the test flume it is important to measure features of the test precisely and in the manner suggested. An illustration of the flume used in the laboratory is shown in figure 3. The materials through which the water flows are held in place by fine screening. Head and tail pools provide normal flow through the gravel. An overflow drain pipe discharges water from the tail pool. A closed system adapted for recirculation of water provides water similar to that found in the upper Sacramento River. As has been pointed out by Professor Hennes 1/ the difference in level between the head pool and tail pool does not necessarily represent the hydraulic gradient in the flume and may give rise to an erroneous measure. The drop in elevation is measured by comparing the upstream pool level and the level of water in a well located in the aquifer material adjacent to the downstream pool.

In tests conducted in the laboratory, various combinations of small gravel and coarse sand are used as aquifers. Jones (1954) has found that if less than 20 percent gravel is mixed with sand, the mixture is less permeable to water than is sand alone. If more than 20 percent gravel is mixed with the sand, however, the permeability increases, and the rate of increase is especially rapid above a content of

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1/ Personal communication from R. G. Hennes, Professor of Civil Engineering, University of Washington. Professor Hennes points out that there is usually a steep gradient at the lower end of the flume, as indicated in figure 3.

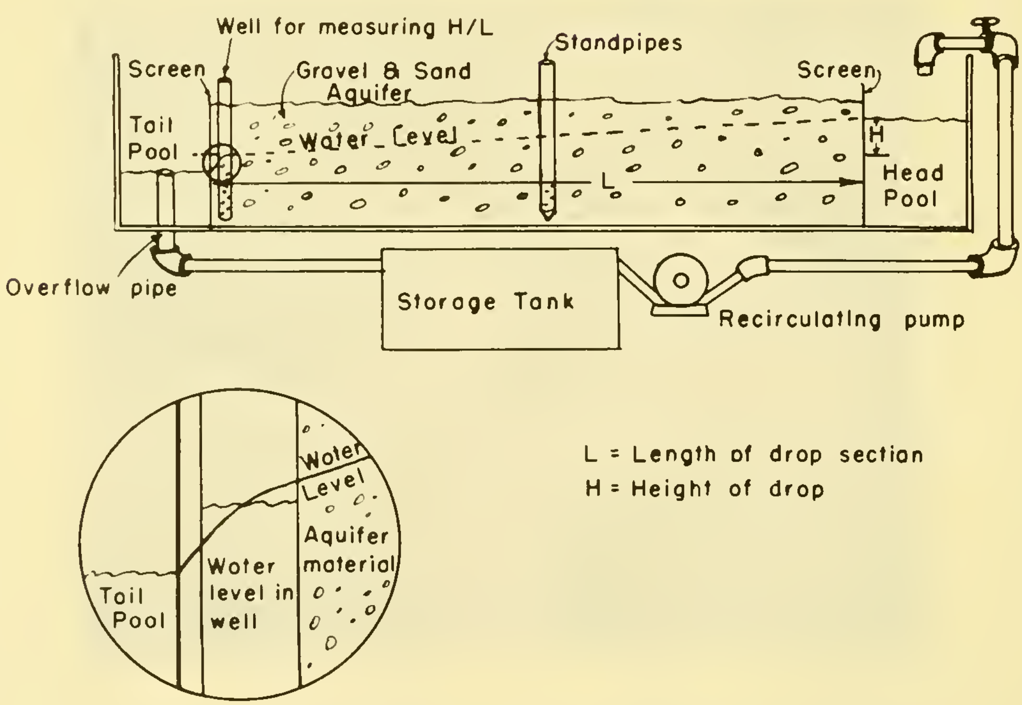

Figure 3.--Diagram of test flume in laboratory.

65 percent gravel. In our tests, the combinations of sand and gravel used covered the greater part of the range of water permeabilities.

Seepage in the flume is measured by dividing the rate of inflow or outflow (they must be equal) by the cross sectional area occupied by water in the flume. In laboratory tests it was found that a minimum of 4 hours is needed for complete adjustment to occur after changing flow rate in the flume and before running another test. In the determination of the cross-sectioned area, the height dimension is taken from the height of water in the standpipe. The following equation is used for determination of seepage in terms of feet per hour.

$$\frac{D}{A} = V$$

Where: D = total volume of water displaced in the flume in cubic feet per hour.

A = cross-sectional area in square feet at the standpipe as determined by multiplying the height of water measured in the standpipe by the width of the flume.

V = rate of flow, seepage, at the standpipe in feet per hour.

A clarification of the terms "seepage" rate or "velocity" in the gravel is appropriate. "Apparent" velocity is derived from the formula shown above; "true" or "absolute" velocity can be detected only at one specific point because of the complex pattern of seepage. True or absolute velocity is best interpreted by the use of the standpipe system described and must be expressed in terms of "apparent" velocity. The relation between "apparent" velocity and "true" or "absolute" velocity is illustrated in figure 4. The "true" or "absolute" velocity of flow in the gravel may be several times faster than "apparent" rate of flow, since the path actually followed by the water between points A and B may be several times longer than the linear distance between these points.

In the laboratory the attempt is made to relate "true" or "absolute" velocity as interpreted by the standpipe with "apparent" velocity as measured in the flume by the formula, $\frac{D}{A} = V$. Actually, units of displacement are counted by changes in resistance of a salt solution that has been introduced into the chamber of the standpipe. The end objective sought in the calibration process in the laboratory then is to correlate changes in resistance with measured apparent velocity.

To accomplish this, two all-important factors must be considered: (1) the volume of water to be displaced, and (2) the conversion of the dilution of a salt solution into units of displacement as recorded by resistance readings on a conductivity bridge.

Determination of the volume of water to be displaced in the standpipe is governed by the height of the column of water in the standpipe which is in turn governed by the stream depth at the location of the test. By measuring the depth of water in the standpipe, of known diameter, the volume of

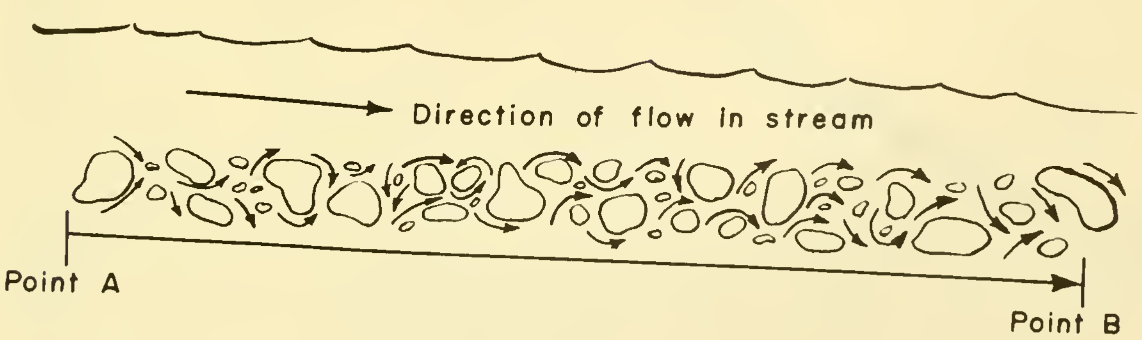

Figure 4.--Showing the complex nature of "true" or "absolute" velocity and its relation with "apparent" velocity of water between points A and B.

water in the standpipe may be ascertained. With the volume known, a ratio is available between existing volume and standard test volume, upon which laboratory measured velocities are based.

A weak solution of salt is introduced into the chamber of the standpipe to obtain rate of displacement from dilution of the salt solution. The difference in weight between the original solution and the inflowing seepage creates vertical currents within the chamber and results in mixing, which is desirable. A 0.06 percent solution of salt with a resistance reading of 1,000 ohms per centimeter cube allows an adequate range for measuring dilution in the Sacramento region, where resistance readings as low as 7,000 ohms per centimeter cube have been recorded. The rate of dilution is then measured in units of 100 percent displacement. One part salt solution diluted by 1 part water, for example, is 100 percent displacement. One part salt solution diluted by 3 parts water is 200 percent displacement, and so on. This displacement may be calculated by means of the following formula showing the general relation between Y, the parts of diluent, and P, the percentage of displacement:

$$Y = (2^n - 1), \text{ where } n = P/100$$

In the accurate measurement of dilution by a conductivity bridge, the conductivity of the diluent itself must be considered. A series of 3 curves representing the range of conductivities expected in the upper Sacramento River area were prepared in relation to their respective multiples of displacement and are represented in figure 5.

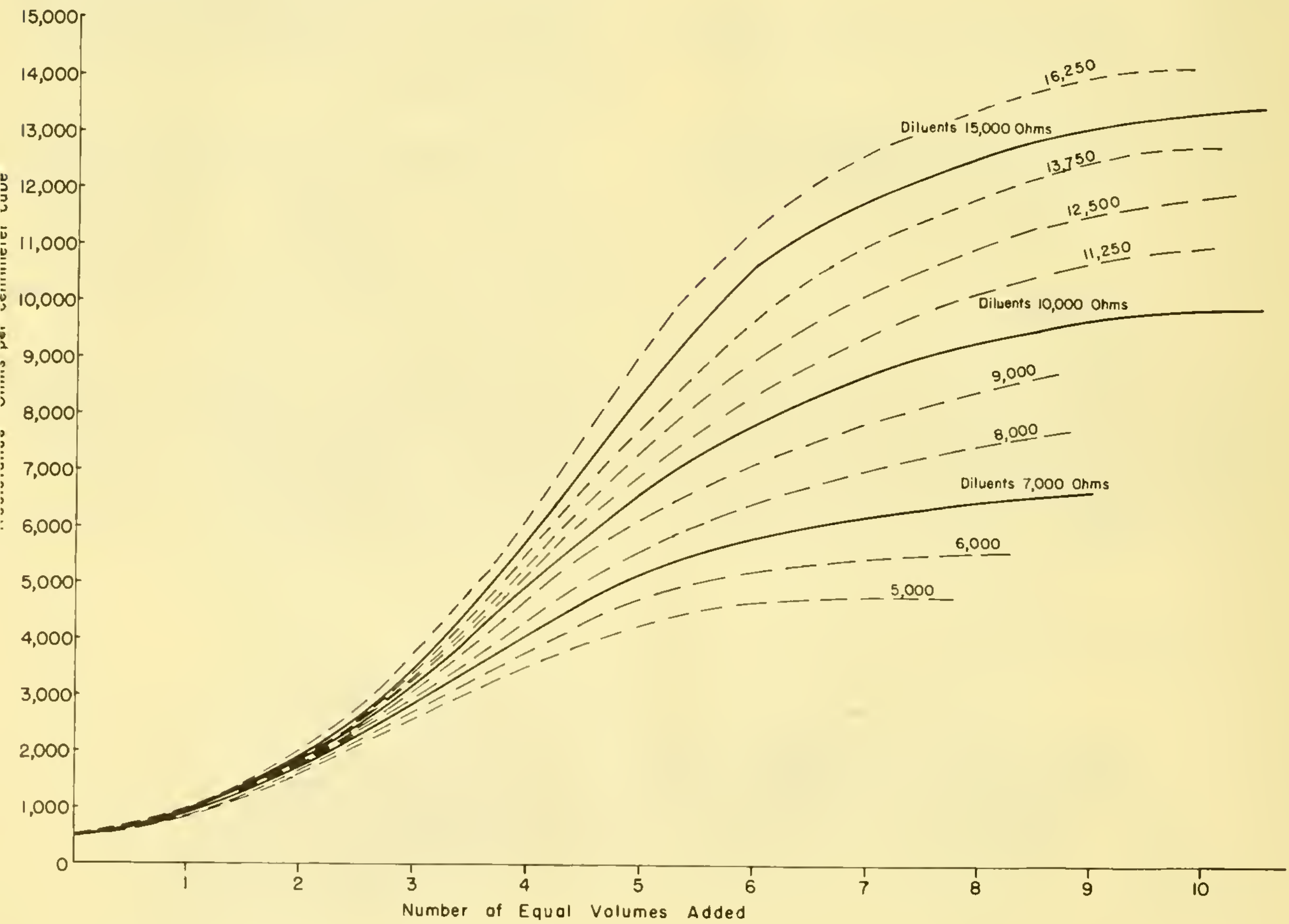

Figure 5.--Three curves plotted with electrical resistance readings corresponding to displacement units of salt solution using typical diluents expected in the Sacramento River area.

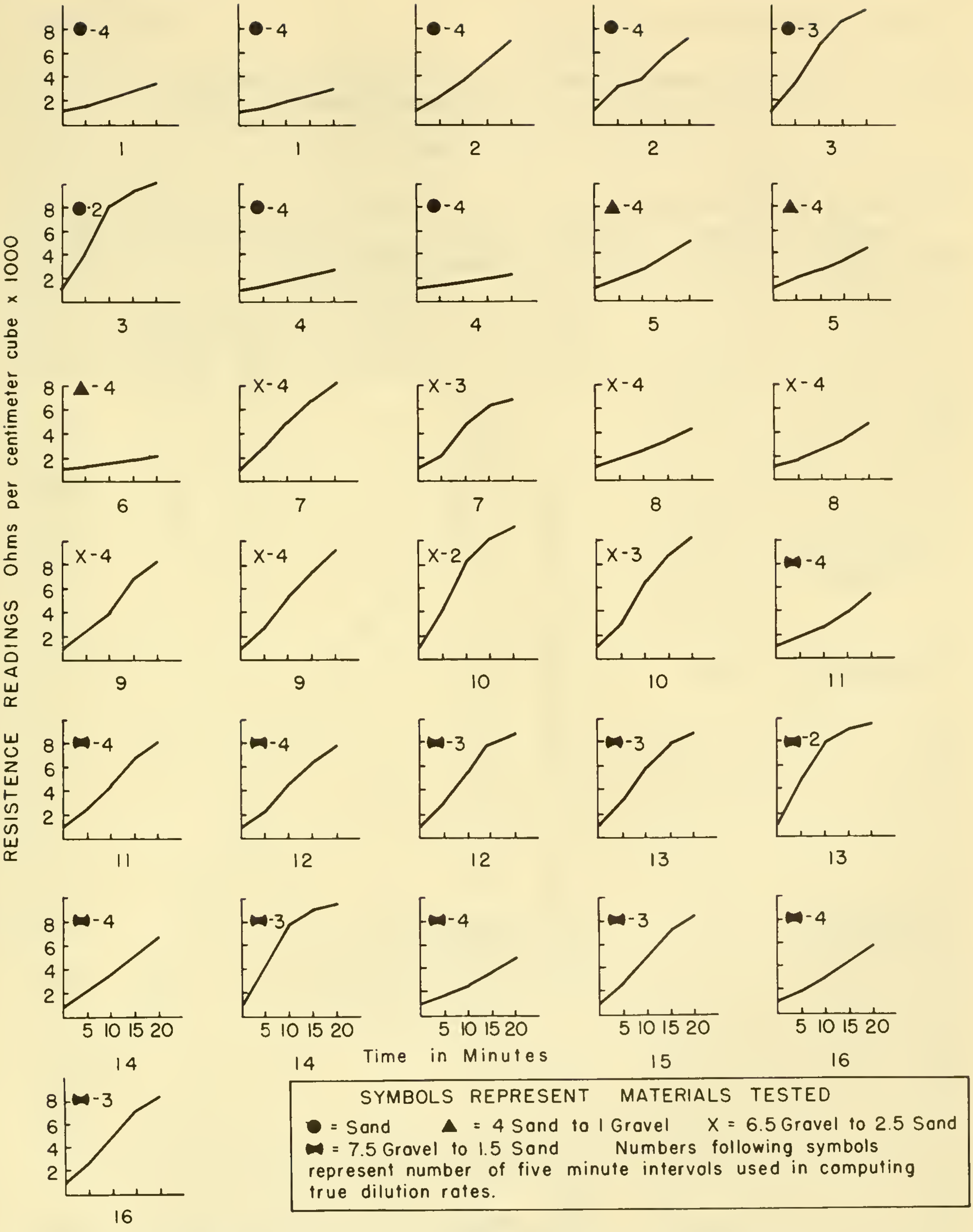

Figure 6.--Dilution plots represented by resistance readings at four 5-minute intervals for individual standpipes in calibration tests.

Table 4.—Dilution rates and measured velocities corrected for resistance coefficients and viscosity to 50° F. Permeability values determined by Darcy Formula V = K H/L.

Test	Material used	Temp. °F.	Viscosity factor	H/L 50°F.	Calculated K ft/hr.	Porosity (Percent)	Velocity ft/hr. 50°F.	Dilution rate 50°F	Average dilution rate
1	Sand	66	.80	.052	6.9	36	.36	1.64	1.54
				.052	6.9		.36	1.44	
2	"	64	.82	.093	7.0	36	.65	4.15	4.21
				.093	7.0		.65	4.28	
3	"	66	.80	.174	8.2	36	1.42	7.87	8.62
				.174	8.2		1.42	9.38	
4	"	64	.82	.060	3.7	36	.22	1.24	1.07
				.060	3.7		.22	.90	
5	4 sand to 1 gravel	65	.81	.069	6.1	26	.42	2.57	2.36
				.069	6.1		.42	2.16	
6	"	66	.80	.037	6.2	26	.23	.85	.85
7	6½ gravel to 2½ sand	66	.80	.056	12.8	33	.72	5.06	4.51
				.056	13.2		.74	3.97	
8	"	64	.82	.044	10.0	33	.44	2.02	2.12
				.044	10.2		.45	2.23	
9	"	66	.80	.085	10.1	33	.86	4.45	4.69
				.085	10.1		.86	4.93	
10	"	62	.84	.135	10.7	33	1.44	10.16	8.67
				.135	10.7		1.44	7.19	
11	7½ gravel to 1½ sand	64	.82	.006	115.9	33	.73	3.25	3.98
				.006	115.9		.74	4.72	
12	"	65	.81	.011	97.2	33	1.06	4.61	5.23
				.011	97.2		1.06	5.84	
13	"	68	.77	.016	94.9	33	1.49	6.59	7.87
				.016	99.4		1.56	9.15	
14	"	64	.82	.013	76.4	33	.97	4.76	6.23
				.013	77.2		.98	7.71	
15	"	65	.81	.011	65.4	33	.70	3.00	4.22
				.011	66.4		.71	5.44	
16	"	65	.81	.011	65.4	33	.70	3.42	4.36
				.011	66.4		.71	5.31	

Calibration Results

From a series of calibration tests performed in the laboratory in the manner described, a series of plots of resistance readings were prepared in figure 6 (see page 11). These were made for four 5-minute intervals at varying rates of velocity. The plots reveal that rate of dilution is linear. If dilution is such that the resistance value in the standpipe approaches that of the diluent, however, the plot then obviously will level off. Preparation of such a graph is recommended for determining the number of 5-minute tests that will accurately represent dilution rate and velocity before the resistance of the solution in the standpipe approaches the resistance of the diluent.

Table 4 and figure 7 present the comparisons of apparent velocity and displacement made in the laboratory using the procedure outlined in steps 1 to 10. It will be noticed that the points were established with several mixtures of materials yielding a variety of permeabilities and porosities. The value of permeability, K, was solved for as the unknown factor in Darcy's formula $K = \frac{LV}{H}$. The three other components of his formula were measured directly from the test flume. The porosity factor was determined by the displacement method; i.e., a given volume of material displaces a measurable volume of water. The standard volume of water in the standpipes in these tests (step 4) was taken to be 5 cubic inches. Using the method of least squares, we obtained the straight line Y = 0.0600 + 0.1634X (figure 7), where Y is the apparent velocity in ft./hr. and X is the dilution units.

OPERATION OF THE MILL CREEK STANDPIPE IN THE FIELD

As mentioned before, the method for using the Mill Creek standpipe is to dig a hole in the streambed, place the pipe in it, and refill the hole with gravel. For obvious reasons, this method precludes immediate sampling of conditions in the streambed. However, the plan calls for prolonged occupancy in the gravel of the streambed as during the entire incubation period of the salmon eggs. For this reason the standpipe is in two pieces. When the standpipe is not in use, the main shaft protrudes only slightly above the gravel, the cap is screwed on and the sleeve is turned to the closed position. It is then moderately safe from drifting objects, from the occasional force of water moving at high velocities, and does not become filled with silt. In operation, the cap is removed and the

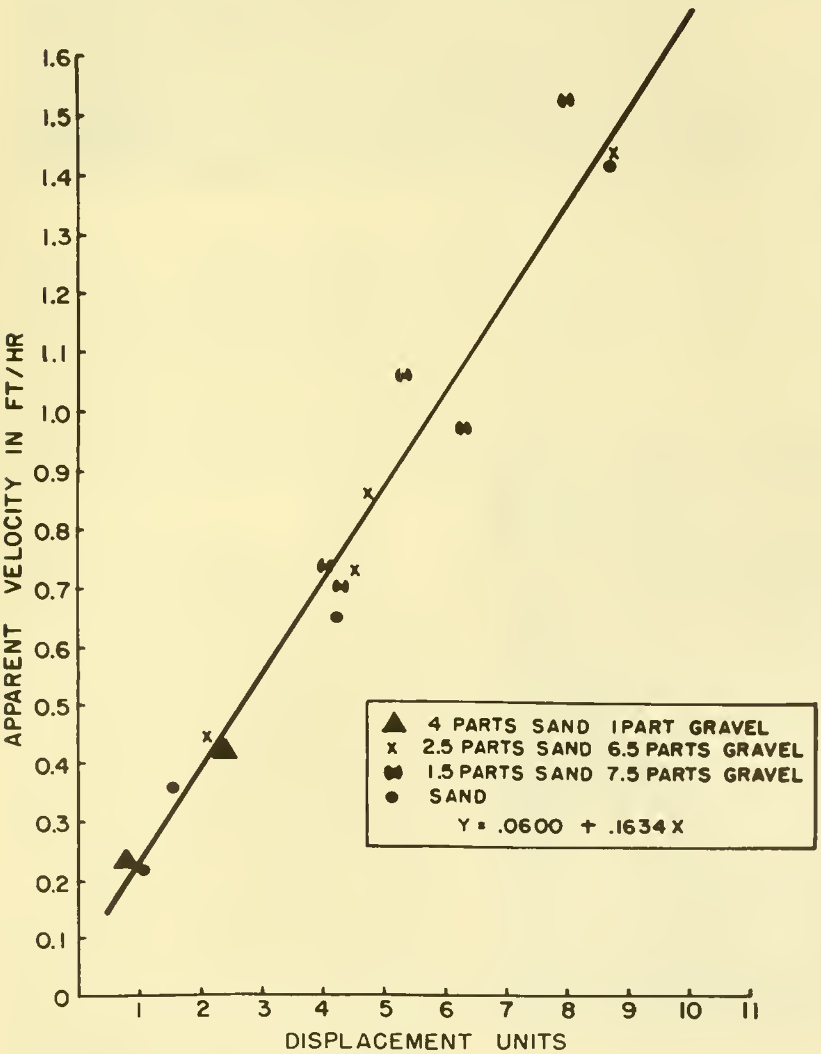

Figure 7.--Relation established in the laboratory between displacement on the X axis and apparent velocity of the Y axis derived as explained in the text.

second piece, with union attached, is threaded onto the shaft (figure 8). As the extension brings the height of the standpipe above the surface of the stream, water then is easily removed from the chamber of the pipe with a small bilge pump.

Obtaining a Dissolved Oxygen Sample

After the water has been evacuated from the standpipe, the key inserted, and the sleeve turned to the open position, ground water seeps into the chamber of the standpipe and fills it. The temperature of the water in the standpipe is recorded, the valve is closed, and a sample of water for oxygen determination is drawn off with a suction bottle as is shown in figure 9. The sample then is allowed to siphon back into tinted flasks for "setting" in the manner commonly employed in the Winkler method (American Public Health Association, 1947). This process is repeated if a larger sample of water is needed. When water is being drawn, the valve always is closed to keep sediment out of the standpipe and to prevent vacuuming the particles surrounding the base of the standpipe. Another essential precaution is to avoid jarring the standpipe. These precautions are deemed necessary to avoid disturbing the natural structure of the streambed and causing surface contamination of the groundwater sample.

Percolation Tests

On the basis of the behavior of a salt solution in a standpipe that has been calibrated for apparent velocity in the laboratory, velocities are ascertained by comparable behavior of a salt solution in a standpipe in the field.

Figure 10 illustrates the use of the conductivity bridge and cord. At Mill Creek, a plastic cell was used instead of the regular glass cell to avoid breakage from rough treatment, which is unavoidable under conditions in the field. The conductivity bridge is operated most conveniently from the bank of the stream. This operation from a remote location requires a much longer cord than normally is supplied with the instruments. With the longer cord, however, it is advisable to use a cell with a constant of one-tenth of that normally used, to reduce the percentage error of increased resistance resulting from the use of the longer cord.

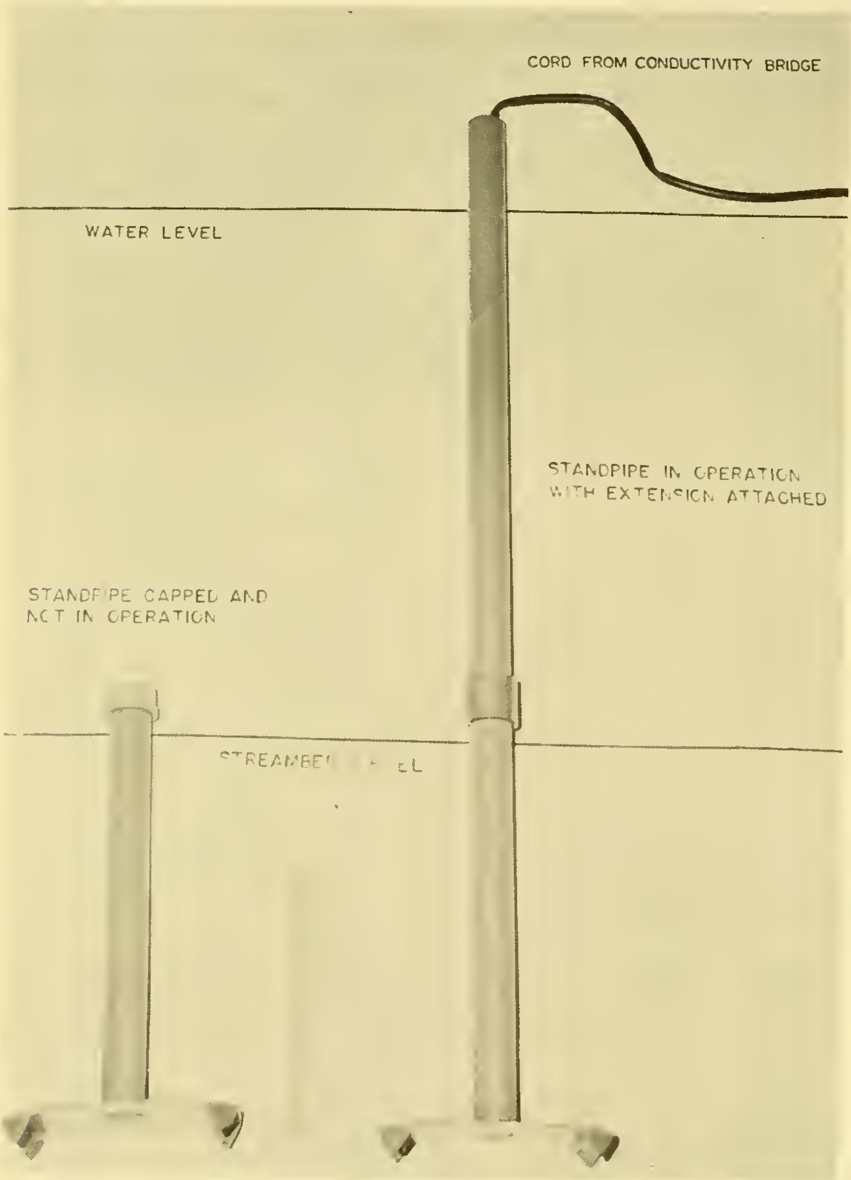

Figure 8.--On the left, the standpipe is in nonoperation position. On the right, the standpipe is in operationaposition, with the conductivity cell in the standpipe and with cord leading from the cell.

Figure 9.--Drawing a sample of water from a standpipe in order to determine the amount of dissolved oxygen in water seeping through gravel of the Sacramento River.

Figure 10.--Using the conductivity bridge for determining apparent velocity in the controlled-flow channel at Mill Creek. Operator in background is dropping conductivity cell into the chamber of a standpipe.

FIELD PERCOLATION TESTS

INCUBATION STAGE:

Initial ________
1. ________
2. ________
3. ✓
4. ________
5. ________

ENVIRONMENT:

Gravel-filled trough ________
Flow Control Channel ✓
Mill Creek ________
Sacramento River ________

Stream surface temperature: 41° F.

Air temperature: 42° F.

Resistance Reading Diluent: 11,000

Date: Jan. 22, 1958

Location	Volume depth	Initial reading	Time start	5-Min. reading	Time start	10-Minute reading	Time start	15-Min. reading	Time start	20-Min. reading	Surface velocity factor L.	M.	R.	Surface Velocity F.P.S. L.	M.	R.
I 1L	10.875	1000	8:59	2600	9:05	4600	9:11	6800	9:17	8050	26	14	30	1.46	0.80	1.67
1R	10.875	750	9:00	2550	9:06	5000	9:12	7000	9:18	8200						
2L	11.375	800	9:01	1550	9:07	2450	9:13	3550	9:19	4750	12	18	34	0.70	1.01	1.89
2R	10.875	750	9:02	1400	9:08	2500	9:14	4400	9:20	6200						
3L	10.125	800	9:03	1950	9:09	3800	9:15	5600	9:21	7100	5	7	14	0.30	0.40	0.80
3R	10.125	800	9:34	1800	9:40	3950	9:46	6700	9:52	8600						
4L	10.125	700	9:35	1400	9:41	2800	9:47	4650	9:53	6400	11	8	11	0.60	0.50	0.60
4R	10.875	750	9:36	1700	9:42	3150	9:48	4650	9:54	6100						
5L	10.625	600	9:37	1450	9:43	3000	9:49	4600	9:55	6400	11	7	13	0.60	0.40	0.70
5R	9.875	650	9:38	1300	9:44	2400	9:50	4000	9:56	5500						

Figure 11.--Field data sheet illustrating number and timing of 5-minute periods used in percolation tests.

A transistor-equipped version of the conductivity bridge would facilitate its operation in the field because the standard portable bridge is bulky and awkward to pack. A transistor-equipped model is in planning stages of development at the Fisheries Instrumentation Laboratory in Seattle.

Percolation Test Procedure

Using 5-minute dilution intervals in the field, we found that five standpipes can be worked together both efficiently and effectively. With the extension of the standpipe in position as previously described, proceed as follows to determine the rate of seepage in the streambed:

1. Measure depth of water in the standpipe, and from the known diameter, compute the volume of water to be displaced. The ratio between existing volume and standard test volume is used to obtain displacement rate in terms of measured velocities in the laboratory.

2. Evacuate the water from the standpipe, open the valve to allow fresh water to seep in, close the valve, and record the conductivity of the fresh seepage as reference for selecting the proper diluent curve. (figure 5).

3. Introduce into the standpipe a salt solution in an amount sufficient to bring the meter reading to approximately 1,000 ohms per centimeter cube, stir thoroughly, and record the exact reading.

4. Open the standpipe valve, and exactly 5 minutes later, close the valve again, stir the water and take another reading. Repeat procedure for four 5-minute periods as illustrated in figure 11.

5. Record the beginning and ending conductivity readings, and correct them for influence of temperature by the formula and resistance coefficients (table 3) to correct to 50° F.

6. Subtract the "bleeding" value found in the laboratory in still water from ending conductivity reading.

7. Apply the corrected beginning and ending conductivity values to the graph in figure 5. Using the proper diluent curve, obtain the displacement number, and multiply by the ratio found in step 1.

8. Compare the resulting rate of displacement with correlated apparent velocity in the laboratory.

DISSOLVED OXYGEN AND VELOCITIES IN GRAVEL COMPARED WITH SPAWN SURVIVAL

The objective of the work at Mill Creek, California, is to assess sources of egg mortality under natural conditions, and to determine what constitutes optimum natural spawning and incubation environment. The standpipe contributes to this program by showing what seepage and oxygen requirements are needed to sustain salmon spawn in natural stream gravel. To fill in the necessary points for plotting the unknown limits of these requirements will call for numerous survival, seepage, and oxygen comparisons. The reliability of the ensuing plot will undoubtedly be improved with increased numbers of such tests.

At the present stage of progress the picture is complicated by three interrelated sources of mortality in the gravel resulting from deficiencies in oxygen and seepage: deficiencies in the level of dissolved oxygen, the delivery of oxygen, and the cleansing of waste products. Two of these, well-defined by Wicket (1954), involve delivery of oxygen to the eggs; in his words, "gross supply is QDO". In this formula (Q) equals the volume of water (per unit of time) delivering oxygen to the eggs and (DO) is the oxygen (per unit of volume) dissolved in the water. Mortality, then, may result from either critical oxygen levels or inadequate seepage to introduce oxygen to the eggs.

A third source of mortality, described by Wolf (1957a, b) in his hatchery research on blue-sac disease, may result from one of these factors alone. The eggs may become enveloped by a film of their own metabolic waste which is not washed away by seepage or free water movement. Wolf states as follows: "The kidney may be pumping its products against increased osmotic pressure. If it is severe enough, death results; intermediate severity results in damage--blue-sac disease." It follows from this that the very same things may occur in the natural gravel environment, i.e., loss of eggs from their own metabolic products.

To test the survival of spawn and conditions affecting it during the incubation season, eggs are planted in the gravel as described by Gangmark and Broad (1955). The planted eggs are then grouped around standpipes into areas resembling salmon redds. The eggs are removed in part during the season and percentages of survival determined from original counts.

Table 5 gives the environment and survival data recorded during the 1956-57 incubation season. In agreement with Wolf, there is evidence that early critical flow levels may not take their toll until the young salmon reach hatching or post-hatching stage. In face of some irregularities revealed concerning critical limitations of flow presented in table 5, larger numbers of such tests are in progress to establish confidence in specifying these limitations. This is especially true of critical levels of dissolved oxygen.

DISCUSSION AND CONCLUSIONS

Some innovations have been utilized in the construction and use of the standpipe at Mill Creek, California. The pipe was designed specifically to make available a systematic history of the influence of environment on the spawn of the king salmon in natural stream gravel through the period of incubation. After the experience in which the methods described in the text have been developed, the authors feel that the extended sampling and recording approach has advantages for stream-management work.

To make this method effective, we have made several special adaptations. One of these is the use of noncorroding materials for prolonged submergence of the standpipe in water. Another is the use of a 2-part instrument, the permanent part protruding only slightly above the gravel and being capped between readings. A third is the

TABLE 5 SEEPAGE AND DISSOLVED OXYGEN VALUES COMPARED WITH SURVIVAL OF KING SALMON SPAWN AT MILL CREEK DURING THE 1956-1957 INCUBATION SEASON

Location	Stand-pipes	Nov. 19, 1956	Dec. 13, 1956				Jan. 7, 1957				Jan. 31, 1957 (Newly Hatched Alevin)				Mar. 7, 1957 (Emerging Fry)			
		% Survival	Vel. ft/hr.	D.O. ppm	°F	% Survival	Vel. ft/hr.	D.O. ppm	°F	% Survival	Vel. ft/hr	D.O. ppm	°F	% Survival	Vel. ft/hr.	D.O. ppm	°F	% Survival
Mill Creek	1	85.5	2.94	5.5	44.0	89.5	2.56	11.1	44.0	71.5	.21	6.1	36.5	31.0	-	-	-	0.5
	2	94.5	1.13	8.0	44.0	85.0	3.47	10.9	43.0	84.0	.87	6.5	36.5	22.5	-	-	-	22.0
	3	87.0	2.56	6.7	44.0	81.5	3.52	11.3	43.0	79.5	2.40	9.3	36.5	68.0	-	-	-	-
Sacramento Rv.	1	84.5	2.52	4.7	50.0	70.0	1.68	9.4	47.0	92.0[1]	2.80	3.2	42.0	89.7	-	-	-	-
	2	81.0	3.30	4.9	50.0	71.5	2.16	10.7	47.0	95.5[1]	3.32	3.6	42.0	60.2	-	-	-	-
	3	90.5	2.96	4.5	50.0	80.5	-	10.5	47.0	89.5[1]	1.41	5.3	42.0	83.8	-	-	-	-
N. F. Mill Cr. Riffle I	1	93.5	3.62	5.5	44.0	84.0	3.91	10.5	39.0	85.5	2.73	11.0	34.0	66.0	0	4.0	50.0	0
	2		1.46	6.9	44.0		1.47	10.7	39.0		1.25	6.9	34.0		0	4.6	50.0	
	3	95.0	0.30	8.6	43.0	77.0	2.32	10.5	39.0	71.0	2.41	10.9	34.0	26.5	0	3.8	50.0	0
	4		0.27	8.4	44.0		0.23	9.4	39.0		0.15	8.1	34.0		0	5.8	50.0	
	5	95.5	2.70	6.3	44.0	87.0	1.35	8.0	39.0	75.0	3.95	11.3	34.0	60.0	0	5.8	50.0	0
Riffle II	1	94.5	0	6.5	43.0	95.5	0	9.8	39.0	79.5	0	11.5	34.0	16.5	.51	7.8	50.0	0
	2		1.10	8.0	43.0		1.26	10.7	39.0		1.76	11.7	34.0		.82	5.4	50.0	
	3	97.0	.53	7.1	43.0	97.0	1.19	10.9	39.0	92.5	1.07	11.7	34.0	92.0	.91	7.0	50.0	0
	4		1.39	7.5	43.0		2.15	10.5	39.0		.98	6.7	34.0		.86	7.0	50.0	
	5	96.0	1.68	7.8	43.0	94.5	.75	10.0	39.0	96.5	1.38	5.9	34.0	91.5	0	7.0	50.0	0
Riffle III	1	96.0	2.82	6.3	43.0	83.0	2.07	10.5	39.0	85.0	1.59	8.1	34.0	70.5	1.16	4.0	50.0	7.5
	2		2.44	8.2	43.0		2.45	9.2	39.0		2.95	9.7	34.0		1.10	2.6	50.0	
	3	94.5	3.54	7.5	43.0	94.0	2.01	10.9	39.0	85.5	1.55	11.9	34.0	72.0	.95	3.6	50.0	24.5
	4		4.56	8.0	43.0		3.63	10.0	39.0		3.72	11.9	34.0		3.07	10.0	50.0	
	5	94.0	2.36	8.2	43.0	86.0	2.20	7.8	39.0	92.5	1.43	11.1	34.0	19.0	2.10	6.2	50.0	3.0
Gravel-filled Troughs Trough I	1	94.0	2.21	9.4	43.0	96.0	1.71	10.0	39.0	95.5	2.11	5.0	36.0	88.0	1.15	8.0	50.0	46.5
	2	95.0	2.16	8.0	43.0	94.0	2.02	10.2	39.0	91.5	2.43	4.8	36.0	79.0	1.43	8.0	50.0	47.0
Trough II	1	96.5	1.97	7.8	43.0	96.0	1.63	11.5	39.0	95.5	1.80	13.3	36.0	98.5	1.47	7.6	50.0	59.0
	2	95.5	1.37	9.2	43.0	94.5	2.28	11.3	39.0	98.5	1.38	9.5	36.0	82.5	1.58	7.4	50.0	75.0
Trough III	1	97.0	1.96	9.2	43.0	97.0	1.82	7.0	39.0	96.0	1.70	12.9	36.0	95.5	1.93	7.0	50.0	74.0
	2	99.0	2.63	8.0	43.0	93.0	2.16	7.2	39.0	95.5	1.64	12.7	36.0	98.5	2.38	8.1	50.0	84.0
Trough IV	1	96.0	2.86	7.5	43.0	97.0	2.88	7.0	39.0	83.0	3.35	11.5	36.0	93.0	1.90	7.8	50.0	34.0
	2.	96.0	2.75	7.6	43.0	95.5	2.54	7.8	39.0	94.0	2.48	12.3	36.0	87.0	1.32	7.2	50.0	30.5

1/ Replanted with eggs of same lot when low water killed original plant.

March 7, 1957 data for Mill Creek and Sacramento River unobtainable because of high water.

valve system, which prevents the lower end of the standpipe from becoming filled with silt.

Another adaptation developed at Mill Creek allows the use of the conductivity bridge for measuring dilution and apparent velocity in the gravel. The bridge combined with the opening and closing feature of the standpipe makes possible precisely timed and accurate determination of displacement of water in the standpipe by resistance measurements of a dilution of salt solution. Laboratory comparisons between displacement and measured velocity appear consistent and reliable.

Migration of particles of silt is known to cause blockage of pores in the gravel and thus cause inadequate seepage. The result is a low level of dissolved oxygen, poor delivery of oyxgen, and inadequate cleansing of wastes all of which lead to mortality of spawn.

Assessment of the above limitations will be better defined by a greater number of tests.

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