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"STREAM RECLAMATION PROCEDURES"

by

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INTRODUCTION

The control of undesirable fish in streams is often an essential and necessary procedure for attainment of quality fishing. The use of toxicants offers this potential but their use in a flowing water system is much more complicated than older techniques used on lakes. The eradication or severe reduction of undesirable populations of fish from streams with the use of rotenone is a relatively new procedure, consequently, the methodology is of interest and it is the subject of this paper.

Problems encountered in stream reclamation proposals are accurate determination of the amount of toxicant needed, determination of the strengthening station locations, time of exposure necessary to kill fish, the amount of toxicant to be added, and the distance downstream the toxicant would kill fish. Techniques used to meet these problems follow.

Lennon (1959) pointed out that a solution of common salt (Na Cl) will mix somewhat the same as an emulsion of rotenone in water. The salt concentration provides a convenient measure of stretchout, dilution, and movement. Therefore, concentrations of rotenone can be calculated accordingly, since salt concentration can be readily determined because of its electrolytic properties, simply by measuring degree of conductivity.

Factors limiting the use of this salt technique are highly turbid waters and hard water with resistivities below 6000 ohms. Turbidity and hard water tend to increase conductivity and mask the effects of the salt. Proportionately the salt accounts for a smaller segment of conductivity and therefore makes it difficult to drop low resistances significantly with reasonably handled quantities of salt. A prerequisite for a successful project of this type is a dam or other effective fish barrier at the lower limit of the treated area, in order to prevent rapid reinfestation of undesirable fish.

Measurements of resistivity were taken with a Model RC-7P, portable, battery-powered unit manufactured by Industrial Instruments, Inc. It is equipped with a "tuning eye" null indicator and a variable frequency pitch modulator which permits readings to be made quickly and easily. It measures resistivities of a liquid in ohms per centimeter cube.

Water temperatures are a contributing factor in resistivity measurements. Therefore, water temperatures are taken and recorded each time a measurement of resistivity is made. The relationship between temperature and resistivity is considered linear and amounts to a two per cent decrease in resistivity with each centigrade degree rise in temperature.

In order to standardize methods for comparing resistivities, it is common practice to correct all measurements to 77° F. (25°C.) (Table 1).

RELATIONSHIP OF RESISTIVITY TO DISSOLVED SOLIDS

The principal solids in non-turbid fresh waters are Ca, Mg, Na, K, Cl, SO_4 , HCO_3 , and SiO_2 . The measure of total electrolytes can be obtained by determining the electrical resistance of a sample of water (Lennon, 1959).

Field measurements of resistivities can be converted to estimates of total dissolved solids or electrolytes present in water. Other things being equal, the richer the water in electrolytes, the greater the biological productivity (Welch, 1948). These results can also serve as a tentative index of biological productivity and form a basis for waters classification. Resistivities or dissolved solids may serve as an index in regard to duration of toxicity in a treated body of water.

Previous work with salt and dye in streams has indicated that the stretchout, dilution, dissipation, and velocity of a known amount of salt can be measured over a mile or several miles of stream and correlated with toxicant requirements. (Lennon, 1959). Data accumulated from salt measurements can be applied, and used to compute rotenone requirements for stream reclamation projects.

PROJECT PROCEDURES

In conducting a stream reclamation project, it was found that following an outline of standardized procedures was very desirable. The following outline was developed to provide guidance for the procedure used in a project of this nature.

1. Conduct a biological survey to determine the need for the project.
2. Promote a public relations program to sell the proposed project.
3. Obtain written approval from the following:
 - a. Riparian landowners, local sportmen clubs and civic groups.
 - b. Public Service Commission approval if required by Statutes.
4. Set a tentative date for the project.

5. Make an outline map of the project area and include all roads, trails, the stream, backwaters, and isolated pools; indicate all stations and sections.
6. Establish stations for salt introduction approximately one mile apart.
7. Take metered flow measurements at each station to calculate the water volume.
8. Establish a bench mark at every fifth station when flow measurements are taken.
9. Conduct salt and resistivity tests at each station above and below the point of salt introduction.
10. Calculate the toxicant requirements for each station (Table 2).
11. Calculate the volume of impoundment and toxicant requirements.
12. Set up a detoxification station if necessary.
13. Set up stations for test cages of fish.
14. Set up manpower and equipment requirements.
15. Set up post-treatment survey procedures.

METHODOLOGY

1. Salt Calculations

Cattle salt blocks are the most common type of salt used in reclamation projects. These blocks are placed at 3 to 5 feet intervals across the stream, 100 to 200 feet above the station. This is important because uneven distribution of salt concentrations will cause variations in the resistivity readings and result in unstable calculations. The salt blocks are weighed before introduction into the stream and again after they are removed. Another method used is to dissolve salt in water and drip the salt solution into the stream at known concentrations in parts per million.

The minimum of 50 p.p.m. of salt should be introduced into the stream but an even higher (50 to 100 p.p.m.) concentration is desirable. A salt concentration below 20 or 30 p.p.m. will not produce a straight line relationship between salt concentrations and resistance readings in waters of moderate to high resistivities (10,000 to 80,000 ohms).

- A. At station number one, the upper-most station:
- 1) Record water temperature
 - 2) Record resistance and correct to 77°. (Table 1)
 - 3) Introduce salt for fifteen minutes.
 - 4) Record resistance during salt passage at 2 to 3 minute intervals and correct to 77° F.
 - 5) Calculate the amount of salt introduced in parts per million.
 - 6) Compute the percentage of drop in resistance at peak salt concentration.
- B. At station number two, one mile downstream:
- 1) Record temperature.
 - 2) Record resistance and correct to 77° F.
 - 3) Record resistance at 2 minute intervals during salt passage and correct to 77° F.
 - 4) Compute the following:
 - a) The time it takes salt to travel from station number one to station number two at peak salt concentration.
 - b) The duration of peak salt concentration.
 - c) The maximum salt concentration in parts per million.
 - d) The percentage of drop in resistance at the peak salt concentration.
 - e) The length of time required for the salt to pass through station number two.
 - f) The percentage of drop of salt in parts per million between stations number one and two.

Definitions and Example

1 gram of salt per 35 c.f. water = 1 (part per million)
 1 gallon of pro-noxfish per 3 acre feet = 1 p.p.m.
 c.f.s. x seconds x minutes = c.f.h. (cubic feet per hour)
 c.f.h. + 43,560 = acre feet of water per hour (A.F.)
 R = resistivity
 Conversion of rotenone calculations based on volume of flow (Table 2).

<u>Hypothetical Stream</u>	<u>Flow</u>	<u>Natural Resistivity</u>
Station #1 - Headwaters	10 c.f.s.	10,000 ohms @ 77°F.
Station #2 - Mid-station	12 c.f.s.	9,000 ohms @ 77°F.
Station #3 - End of area to be treated	15 c.f.s.	8,000 ohms @ 77°F.

50,000 grams of salt were dissolved at Station #1 in 15 minutes in 10 c.f.s. of water.

10 c.f.s. x 60 seconds x 15 minutes = 9,000 c.f. of water passed through station in 15 minutes.

Since 1 gram of salt per 35 cubic feet of H₂O = 1 p.p.m. concentration, then 9,000 c.f. of H₂O + 35 = 257 grams of salt required for 1 p.p.m.

50,000 : 257 = 194 p.p.m. salt added.

R. at Station #1 is 10,000 ohms at 77° F. Addition of the original 50,000 grams of salt at Station #1 drops R. from 10,000 ohms to 5,000 ohms.

R. at Station #2 is 9,000 ohms at 77° F. First trace of salt recorded in 30 minutes. R. drops to 8,400 ohms at 77° F. Peak drop in 45 minutes is to 7,000 ohms R. at 77° F. To calculate amount of salt remaining:

$$\frac{194.0 \text{ p.p.m. of salt}}{5,000 \text{ ohms (loss of R)}} = \frac{x \text{ p.p.m. of salt}}{2,000 \text{ ohms (loss of R)}}$$

$$5,000 \text{ ohms } x = 388,000 \text{ (p.p.m. - ohms)}$$

$$x = 77.6 \text{ p.p.m. salt remaining}$$

$$77.6 \text{ p.p.m. salt} = 60\% \text{ loss between stations}$$

Station #3. R. = 8,000 ohms. Salt influence drops R. to 7,000, a loss of 1,000 ohms. To calculate amount of salt remaining:

$$\frac{77.6 \text{ p.p.m. of salt}}{2,000 \text{ ohms (loss of R)}} = \frac{x \text{ p.p.m. of salt}}{1,000 \text{ ohms (loss of R)}}$$

$$2,000 x = 77,600$$

$$x = 38.8 \text{ p.p.m. salt remaining or } 50\% \text{ loss between Stations 2 and 3.}$$

2. Stream Toxicant Calculations

We have found that the addition of rotenone at 5 p.p.m. for the first hour of operations followed by a concentration to 1 p.p.m. for an additional 4 or 5 hours will produce excellent fish kills. The addition of the 1 p.p.m. for the second phase insures that toxicant will be present in the stream for an additional 6 to 10 hours at each station. This is necessary to remove hard-to-kill species such as bullheads, carp, and lamprey larvae.

Convert cubic feet per second (c.f.s.) to acre feet (A.F.):

$$\text{Station \#1} - 10 \text{ c.f.s. } \times 60 \text{ seconds } \times 60 \text{ minutes} = 36,000$$

$$\text{c.f.h. } 36,000 \div 43,560 = .82 \text{ A.F. per hour}$$

$$\text{Station \#2} - 12 \text{ c.f.s. } \times 60 \text{ seconds } \times 60 \text{ minutes} = 43,200$$

$$\text{c.f.h. } 43,200 \div 43,560 = .99 \text{ A.F. per hour}$$

$$\text{Station \#3} - 15 \text{ c.f.s. } \times 60 \text{ seconds } \times 60 \text{ minutes} = 54,000$$

$$\text{c.f.h. } 54,000 \div 43,560 = 1.23 \text{ A.F. per hour}$$

To compute rotenone requirements, always use flow calculations from the next station where the rotenone is to be introduced.

Toxicant requirements to achieve 1 p.p.m. per hour:

Since 1 gallon of rotenone per 3 A.F. of water gives a concentration of 1 p.p.m. rotenone, therefore, at Station #1:

$$\begin{array}{r} \frac{1 \text{ gallon rotenone}}{x \text{ gallon rotenone}} = \frac{3 \text{ A.F. water}}{.99 \text{ A.F. water}} \\ 3x = .99 \\ x = .33 \text{ gallons} \end{array}$$

At Station #2:

$$\begin{array}{r} \frac{1 \text{ gallon rotenone}}{x \text{ gallon rotenone}} = \frac{3 \text{ A.F. water}}{1.23 \text{ A.F. water}} \end{array}$$

At Station #1, .33 gallons produces a 1 p.p.m. concentration, therefore, 1.65 gallons = 5 p.p.m. over an application period of one hour. To compensate for 60 percent dissipation, as indicated by salt calculations, an additional amount must be added at Station #1. Computations to find the required amount of toxicant are as follows:

$$\begin{array}{l} 40\% \text{ of total amount added (1.65 gallons) remain} \\ .40x = 1.65 \text{ gallons rotenone} \\ x = 4.12 \text{ gallons rotenone needed at Station \#1 to} \\ \text{maintain 5 p.p.m. at Station \#2.} \end{array}$$

At Station #2, the toxicant concentration is 5 p.p.m. when it reaches this station. Station #3 has a 3 c.f.s. increase in flow volume. Therefore, an additional .41 gallons of toxicant must be added to 1.65 gallons of toxicant present at Station #2. Salt calculations indicate a 50 percent loss of toxicant from Station #2 to next station. Computations to find the additional amount of toxicant needed to insure a 5 p.p.m. concentration at Station #3 are as follows:

$$\begin{array}{l} 50\% \text{ of total amount added remain} \\ .50x = 2.06 \text{ gallons rotenone} \\ x = 4.12 \text{ gallons needed to insure a 5 p.p.m.} \\ \text{concentration needed at Station \#3.} \end{array}$$

There already is 1.65 gallons rotenone present from Station #1, therefore, 4.12 minus 1.65 = 2.47 gallons rotenone to be added at Station #2.

3. Impoundment Calculations

The impoundment must be drawn down to minimum pool level and calculations made to determine number of acre feet of water present. The time required to fill reservoir and number of acre feet of water present when the reservoir is full must be calculated to determine maximum concentration of toxicant in the reservoir at spillway level.

DETOXIFICATION PROCEDURES

In many stream reclamation projects the objective is to treat only a segment of stream or a tributary branch of a major system. In this case it is necessary to detoxify the water before it leaves the treated area to prevent a fish kill in the stream system below. In soft water, a concentration of either potassium permanganate (KMnO_4) or chlorinated lime (Cl_2) is necessary to detoxify an equal concentration of rotenone. In effect 2 p.p.m. of KMnO_4 or Cl_2 will detoxify 2 p.p.m. pro-noxfish (Jackson, 1957). In alkaline water, more of the detoxicant must be used as the inorganic material present will use up a considerable amount of the detoxicant.

One gram of potassium permanganate (KMnO_4) or chlorinated lime (Cl_2) per 35 cubic feet of water equals 1 p.p.m. One gram per $(35 \times 7.5 = 262.5)$ 262.5 gallons of water = 1 p.p.m.

Example:

Seep at a dam is flowing at 100 g.p.m. with a toxicant concentration of 5 p.p.m. The detoxification period is 24 hours.

$100 \text{ g.p.m.} \times 60 \text{ min.} \times 24 \text{ hrs.} = 144,000$ gallons of water flow in 24 hours.

Since 1 gram of KMnO_4 per 262.5 gallons $\text{H}_2\text{O} = 1$ p.p.m. concentration KMnO_4 , therefore,

$$\begin{aligned} 1:262.5 &= x:144,000 \\ 262.5x &= 144,000 \\ x &= 548.5 \text{ grams or } 1.20 \text{ pounds} \end{aligned}$$

548.5 grams or 1.2 pounds of potassium permanganate (KMnO_4) or chlorinated lime (Cl_2) produce 1 p.p.m. in 144,000 gallons of water.

1 p.p.m. needed to detoxify 1 p.p.m. rotenone and since the rotenone concentration is 5 p.p.m., therefore, $548.5 \times 5 = 2,742.5$ grams needed to detoxify 5 p.p.m. rotenone in 144,000 gallons of water.

$1.20 \times 5 = 6.00$ pounds needed to detoxify 5 p.p.m. rotenone in 144,000 gallons of water.

About 11 p.p.m. of activated carbon will adsorb 1 p.p.m. of pro-noxfish or other rotenone-bearing substance (Cohen, 1961). In order to detoxify a body of water with a residual amount of rotenone (1 p.p.m.), 11 p.p.m. of activated carbon must be added.

8.34 pounds of carbon per million gallons = 1 p.p.m.

Example:

Seep at a dam is flowing at 100 g.p.m. with a toxicant concentration of 5 p.p.m. The detoxification period is 24 hours.

100 g.p.m. x 60 min. x 24 hrs. = 144,000 gallons water flow in 24 hours.

$$\begin{aligned} 8.34:1,000,000 &= x:144,000 \text{ gallons} \\ 1,000,000x &= 1,200,960 \\ x &= 1.2 \text{ pounds} \end{aligned}$$

1.2 pounds carbon produces 1 p.p.m. in 144,000 gallons of water.

11 p.p.m. needed to detoxify 1 p.p.m. rotenone in 144,000 gallons.

13.2 pounds carbon needed to detoxify 1 p.p.m. rotenone in 144,000 gallons of water.

13.2 x 5 p.p.m. = 66 pounds of carbon to detoxify 5 p.p.m. rotenone in 144,000 gallons of water.

A total of 66 pounds of carbon plus 10 percent for error = grand total of 72 pounds of carbon will detoxify 5 p.p.m. of toxicants in 144,000 gallons of water.

SUMMARY

Procedures concerning stream reclamation are described within this paper. Introduction of salt and measurement of the concentration by a resistivity meter provides a convenient index of the concentration of rotenone. Percent loss of salt (Na Cl) is the basis for determination of the amount of rotenone required to sustain the necessary lethal concentration equally throughout the treated area. Examples are provided to illustrate techniques.

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TABLE 1. Temperature Factors, f_t , For Use In Correcting Resistance To The Standard Temperature Of 77°F. Using The Equation: $R_{77} = R_t / f_t^*$

°F.	f_t	°F.	f_t
38	1.711	62	1.205
39	1.683	63	1.190
40	1.657	64	1.174
41	1.631	65	1.160
42	1.606	66	1.145
43	1.580	67	1.131
44	1.555	68	1.118
45	1.532	69	1.104
46	1.509	70	1.090
47	1.486	71	1.075
48	1.464	72	1.062
49	1.443	73	1.048
50	1.421	74	1.034
51	1.400	75	1.023
52	1.380	76	1.012
53	1.361	77	1.000
54	1.342	78	0.989
55	1.323	79	0.977
56	1.305	80	0.966
57	1.288	81	0.956
58	1.271	82	0.945
59	1.254	83	0.935
60	1.237	84	0.925
61	1.221	85	0.916

* R_{77} = Specific Resistance at 77°F. R_t = Specific Resistance at known temperature; f_t = correction factor.

**Revised and Adapted from L. R. Richards, "The Diagnosis and Improvement of Saline and Alkali Solids." U. S. Department of Agriculture Regional Salinity Laboratory, 1947.

TABLE 2. Calculations - Potenone

Flow c.f.s.	No. gal. @5p.p.m. 1st hr.	No. gal./ @1p.p.m.
1.0	.138	.028
2.5	.343	.068
5.0	.687	.137
10.0	1.375	.275
20.0	2.750	.550
40.0	5.500	1.100
80.0	11.000	2.200
160.0	22.000	4.400

Flow c.f.s.	No. ml. @5p.p.m. 1st hr.	No. ml./hr. @1 p.p.m.
.1	51	10.2
.25	128	26
.50	255	51
1.0	510	102
2.0	1,020	204
3.0	1,530	306
4.0	2,040	408
5.0	2,550	510

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