CALIFORNIA SEA GRANT

REPORT OF THE THIRD CALIFORNIA SALMON AND STEELHEAD RESTORATION CONFERENCE

FEBRUARY 23-24, 1985
UKIAH, CALIFORNIA

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Cover Photo: Silver salmon fry from the Salinas pond rearing facility of the Monterey Bay Salmon & Trout Project (1977).

Photograph by Dave Streig, Watsonville, California

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Edited By:

Christopher Toole - Univ. of California Cooperative Extension/Sea Grant Program
Bruce Wyatt - Univ. of California Cooperative Extension/Sea Grant Program
Steve Taylor - California Department of Fish and Game

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INTRODUCTION

Since 1983 the University of California Cooperative Extension/Sea Grant Program and the California Department of Fish and Game have co-sponsored conferences for groups and organizations actively involved in salmonid restoration and enhancement activities. The purpose of these conferences has been to promote communication between the different groups, agencies, and University researchers; to share ideas; and to promote the use of the best available technology by all projects. In addition, a strong theme has been to encourage planning, monitoring, and evaluation of projects.

The 1985 conference was planned by an organizing committee made up of Chris Toole (UCCE/SG), Bruce Wyatt (UCCE/SG), Steve Taylor (CDF&G), Ken Hashagen (CDF&G), Mike Bird (CDF&G), Dave Ickes (CDF&G), Sari Sommarstrom (Mendocino Fish and Game Adv. Comm.), Ron Kusina (Center for Education and Manpower Development), Nancy Reichard (Redwood Community Action Agency), Scott Downie (Eel River Restoration Project), Meca Wawona (New Growth Forestry), and Jud Ellinwood (Humboldt Fish Action Council). The committee decided that the focus of the conference should be a "nuts and bolts" approach to specific technical problems encountered by many of the groups. It was felt that relatively small concurrent work sessions which would encourage an exchange of information between all participants were the best means of accomplishing this. As a result, six work sessions were developed and notes and handouts from these sessions are included in the second half of this Report. Displays of traps, winches, and other pieces of equipment also added to this portion of the program and field trips to nearby projects were also very valuable.

To tie the more specific topics together, several overviews were presented the first morning of the conference. Ron Kusina reviewed the past and present development of enhancement projects in California, Supervisor Norman DeVall and Congressman Doug Bosco gave a legislative perspective, Wendy Jones presented an overview of salmon and steelhead biology and habitat requirements, Gordon Reeves gave a talk on the necessity and benefits of proper planning and evaluation of projects, and George Allen gave a perspective on the appropriate conditions for large and small-scale artificial propagation programs. Papers from three of these talks are included in the first half of this Report.

The second morning of the conference was a mixed bag of topics of interest to most of the enhancement and restoration programs. Speakers addressed topics such as working with landowners, recruiting volunteers for projects, and fundraising activities. The need for public education was stressed and James Boland of the Canadian Salmonid Enhancement Program showed how public education has been successfully incorporated into their overall program. Many educational materials were displayed and a list of educational resource materials obtained from the O.S.U. Sea Grant Program is included in the first section of this Report. Finally, Ken Hashagen described the status of the Dept. of Fish and Game's grant program and reviewed application and review procedures.

Over 150 people participated in the 1985 conference and it was the input of everyone involved that made it a successful gathering. This Report is intended to serve as at least a partial record of the conference and as a resource for those involved in or planning restoration and enhancement work.

Chris Toole
Bruce Wyatt
Steve Taylor
July, 1985

SALMON ENHANCEMENT:

A LOOK TO THE FUTURE

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1052 W. Standley
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Good morning everyone.

As a Ukiahan, I would like to begin by extending a personal welcome to each of you this morning. It is my wish that your stay here will be a pleasant one, and that this conference proves to be a success for you.

There are a few individuals that I would like to recognize and thank for their efforts on behalf of our salmon and steelhead trout resources. They include Congressman Doug Bosco, and Senator Barry Keene and Assemblyman Dan Hauser. I trust that we here on the North Coast are well aware of the leadership and representation these gentlemen have provided us with respect to the issues effecting the fishery resources of this state. We rely on their continued commitment. To Mendocino County Supervisor Normal DeVall, thanks for your kind words of welcome this morning. Your interest and participation is most appreciated. To those who helped organize and develop this conference, a very special thank you for the time and creative talents you have so generously given. The conference program and topics are well chosen, and provide us all with unique opportunities for learning. There is someone noticeably missing from our midst today, a friend who has not only been deeply involved in the issues that affect our salmon and steelhead trout resources, but was a principal in organizing and starting these conferences some three years ago. Her name is Sari Sommarstrom. Sari has recently given birth to a son, and is unable to attend our proceedings. I want her to know that our thoughts are with her, and that she is missed. Finally, my thanks to all of you for being here, and for choosing to make the salmon and steelhead trout resources of this state a matter of personal importance in your lives.

As Chairman of the California Advisory Committee on Salmon and Steelhead Trout, I am honored to have this opportunity to speak to you today. My subject is "Salmon Enhancement: A Look to the Future." But before we begin to envision what tomorrow may bring, let us spend just a few moments reflecting on yesterday. As I was reviewing some materials sent me a few days ago, I discovered an old quotation that I would like to share with you. It tends to capture a very crucial issue in just a few words..."Whiskey is to drink. Water is to fight over". The originator of that comment was Samuel Clemens, who most of us may remember as Mark Twain.

It has been nearly fifteen years since the first California Advisory Committee on Salmon and Steelhead Trout was formed and their first annual report was presented to the Legislature. It contained information on the status of the salmon and steelhead trout resource. During the period 1940-1969, the North Coast experienced 80% declines in steelhead, 65% declines in coho slamon, and 64% declines in chinook salmon. Further, between 1953-1969, there was a decline of 46% in the fall-run salmon resource of the Sacramento-San Joaquin River system. These are most startling figures, as suggested by the title of the committee's report, "An Environmental Tragedy". Over the period 1970-1975, the committee continued to examine and identify many problems affecting the resource. Their hours of dedicated service laid the foundation upon which we are building today. Acting with the conviction that the resource could be improved, numerous recommendations were developed. It appears that only one-third of these recommendations have been implemented.

In the late 1970's, restoring habitat for salmon and steelhead trout received new impetus, and this activity began expanding throughout the North Coast. Many of you have become directly involved in that effort and related enhancement work. Each of you can see some measure of success in this work, some small gain that recharges your personal batteries and renews your commitment. Yet it appears that the over-all picture has not brightened. Where do we go from here? The future rests within your mind and your will. Reflect for a moment on those words of Mark Twain, written nearly one hundred years ago. We have not fared well in the fight. We must seek new means of working with competing interests, find new methods of cooperation.

The California Advisory Committee on Salmon and Steelhead Trout has been re-established for the purpose of developing a comprehensive management plan for California's Salmon and Steelhead trout resources, and our approach to that task will be twofold. One aspect will entail the preparation of a report containing information that has statewide application: a general status report on such topics as habitat, genetics, laws and enforcement, and so on.

The other aspect is a basin-by-basin approach to management planning which will contain specific information and plans for individual drainages. This part is highly dependent on local involvement. It is your river, your stream, your resource that we are talking about. It is a matter of public trust. Thus, when we look to the future, what we see belongs to you. As resource managers and members of the professional community, as contractors and service providers, as concerned Californians that care...it is your continued participation, your inspired creativity, your unyielding dedication that will determine the course we are charting.

As I close my talk this morning, I would like to introduce those of my fellow committee members who were able to attend today, and ask them to stand for a moment: Earl Carpenter, Mike Maahs, Scott Downey, and our staff, Ken Hashagen. Each of us welcome your thoughts and ideas. I would like to leave you with this thought, a simple three-word phrase: and although it may seem a rather discouraging statement, the intent is really quite the opposite. I hope it might serve to remind each of us of the responsibility we carry, and the commitment and resolve we must maintain with respect to the salmon and steelhead trout resources of California. Think of it as a means of encouragement, as we look to the future! And so, my friends and colleagures, ladies and gentlemen, from the cover of the 1985 Annual Report of the California Advisory Committee on Salmon and Steelhead Trout...The Tragedy Contunues.

Thank you, and good day.

EVALUATION OF STREAMS FOR SALMONID ENHANCEMENT PROJECTS

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Successful salmonid enhancement projects require evaluating both the physical and biological components of a system in order to determine the characteristics and condition of the system. This helps determine a starting point and the appropriate techniques for the program. Enhancement programs should be placed in the perspective of an entire watershed, and if possible, an entire basin. Because streams are interconnected, activities in one part of a system will influence what happens in another. Therefore, a program's chance of success will be greatly increased with a basin-wide approach.

Evaluation of physical conditions should include both present and past conditions in the basin. Ground surveys should be made to assess present conditions, both in the stream and on the surrounding hillsides. Recent aerial photos can also be used for this purpose. The historical record can be used to reconstruct the probable condition of the system in its natural state and thus provide an idea of the habitat conditions the program should be working towards. Journals of explorers and early settlers and government surveys and records are good sources of historical information.

Identification of the life-history patterns and habitat requirements of the species of interest is essential to the success of any enhancement program. It is necessary to know such things as the time of entry to freshwater by returning adults, amount of time juveniles reside in freshwater, etc. This information can be obtained directly by the interested group or from local management agencies. As with the evaluation of physical conditions, the biology of the system should be considered in historical terms.

The identification of a limiting factor or factors is the key to the success of any enhancement program. Limiting factors, however, are very difficult to determine in most instances. Most of the time we must make educated guesses as to what factors are limiting the production of fish. The more information one has on the system, both in terms of past and present physical and biological conditions, the better are the chances for identifying limiting factors.

Evaluation of an enhancement project is difficult and can take many years. We are unable to evaluate a project simply by looking at the numbers of fish in a given area before and after a project. Projects can cause a redistribution of fish and not an actual increase of numbers or survival. Ideally the success of an enhancement project should be measured in terms of changes in the number of returning adults. However, there are many problems, such as variability in ocean conditions, fishing pressure, etc. which make the use of returning adults impractical. The best method, therefore, is to measure the number of smolts leaving the system before and after completion of the project. This requires a trap to monitor smolt movement. This should be done over a long time period, at least one complete life-cycle of the species of interest.

Evaluation should be an on-going process throughout the life of the project. By monitoring the impact of a project over the course of the project, we can insure the project is accomplishing its goals. If it is having no apparent impact or a negative impact, appropriate adjustments can be made.

There is no need to monitor or evaluate every enhancement project, but we do need to select certain projects for evaluation. There is currently strong financial support for enhancement projects but in almost all instances there is no support or requirement for evaluation. As a result, we seldom know whether a particular project or program was successful or not. In the future when the political support for enhancement projects begins to wane and funding becomes more difficult to obtain, someone is going to ask whether anadromous fish have benefitted from all the money spent in the name of enhancement. Without valid evaluation programs there will be no way to answer this question.

ARTIFICIAL PROPAGATION IN NORTH COASTAL CALIFORNIA CITIZEN-OPERATED SALMON AND STEELHEAD RESTORATION AND MITIGATION PROGRAMS

George H. Allen

Professor Emeritus Fisheries, Humboldt State University

Director of Aquaculture and Fisheries, City of Arcata

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PROLOGUE

During a recent visit to a famous watering hole at Hopland, California, I noticed on the wall at my elbow an international service club motto which read:

> The FOUR WAY test of things
> we think, or say, or do

1. Is it the truth?

2. Is it fair to all concerned?

3. Will it build goodwill and better friendships?

4. Will it be beneficial to all concerned?

It appeared to me that such a set of operational principles could be adopted by the participants in the California salmon restoration and enhancement programs to increase chances of measurable success in common efforts to maintain and restore steelhead and salmon populations (Figure 1). Since California funding for non-state operated programs appears restricted to action projects, collective decisions on how to innovate, to demur , to delete, or to not act in certain ways, also suggests a great utility for the motto. In the long run, the inevitable accountability will be well served by adherence to such a philosophy by program participants.

Hopefully I have applied these principles in offering here my comments on the role of artificial propagation in north coastal California anadromous salmonid restoration and enhancement programs.

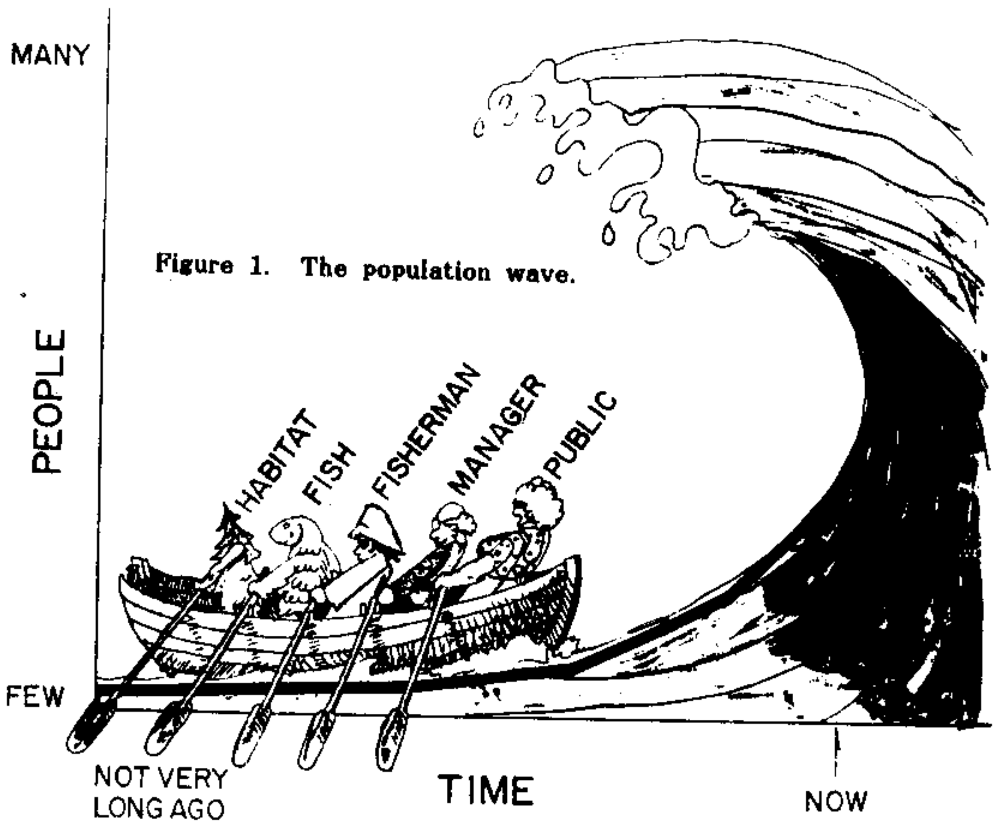

Figure 1. The population wave.

INTRODUCTION

The direct involvement of citizens in artificial propagation of salmon and trout mandates managerial and educational organizations to furnish the most useful and appropriate techniques to these new practioners. A most timely example of such an activity is that of the Fish Culture and Fisheries Management Section of the American Fisheries Society (AFS) in holding a "Symposium on the role of fish culture in fishery management" in March 1985. A brochure announcing the symposium stated:

> The relationship of fish culture to fishery management has changed dramatically through the years. In the late 1800s and the early part of this century, fish culture was fishery management. Indiscriminate stocking occurred throughout the United States without proper regard to species selection, habitat requirements, or the actual need for additional fish. Fishing quality continued to decline. State fishery biologists were employed throughout the country beginning largely in the 1930s. Modern fishery managers, combining professional objective fish population and habitat analyses, imaginative ideas, and social needs, are finding more and more uses for quality cultured fish. Culturists continue to improve their techniques and provide a better product. But are today's fishermen really reaping the benefits? Will tomorrow's? Will we have the imaginative managers and culturists and the modern hatcheries to keep pace with the increased fishing demands? Can we coordinate and communicate sufficiently to achieve needed advancements to improve fishing quality?

The brochure then outlines specific objectives of the AFS' symposium to address the concerns as:

1. Synthesize and publish key information on the cooperative role of fish culture in fishery management.

2. Define common principles for the use of cultured fish in fishery management.

3. Identify needs and opportunities for improvement of fish culture in meeting fishery management goals.

The AFS symposium agenda listed at least 20 papers dealing with trout and salmon, many specifically addressing anadromous salmonid management-fish culture topics. Three papers are from California authors. What few remarks I can make here should be greatly supplemented by the published information which will result from the AFS symposium. Lay groups designing, choosing, and pursuing fish culture activities that are appropriate to individual enhancement programs should find the symposium proceedings most useful.

Restoration and enhancement programs conducted by citizen-based cadre generally are locally-oriented, and thus are usually associated with drainages that are most subject to environmental degradation from urbanization, improper land uses and other activities that influence aquatic habitats (Figure 2). Consequently small local projects may have a great potential for beneficial long-term effects on anadromous salmonid populations because of this site specific focus (Rank 1983). Larkin (1981) also suggested a local approach to salmon population genetics and management: "The simplest, safest, and most lasting ways of assisting salmon populations are highly localized. They require an intimate knowledge of a stream, close scrutiny to its ecology, and attention to many geographic details. They are, perforce, labor intensive." Unequivocal beneficial results, however, will only occur if fish culture and management errors of the past are avoided. This paper hopefully will aid new citizen efforts in planning artificial programs to increase the probability of success and reduce the chances of doing damage unknowingly.

My approach to this task has been organized as follows. After introductory chapters on definitions, life history and life cycles, a short over-view of the historical role of "hatcheries" is used to survey the status of existing hatcheries located north coastal drainages of California. This is followed by a brief survey of possible salmonid culture techniques, and some of the major sources of literature on the subject. Next is a major section in which I present views on what appears to me as factors necessary, but not sufficient, for eventual "successful" results from artificial propagation-based enhancement and restoration projects. There are two major themes presented in this section I feel most relevant to new practioners:

1. realism in planning artificial propagation ventures, especially in expectations of results, and

2. allowing sufficient time in any venture for:

   a. construction, preliminary operations, and modifications of physical facilities as dictated by the life history needs of the species cultured;

   b. development of stock(s) adapted to the facility and the watershed that consistently return at some minimal level to the facility (escapement) or at least contribute to the fisheries (catch);

   c. an evaluation at some meaningful level of both the positive and possible negative impacts of the operation.

To illustrate some of these suggestions on realistic planning and expectations, I use data from the culture operations in an integrated program of aquaculture, fisheries management, and urban stream restoration currently underway at the City of Arcata, plus a preliminary evaluation of the system. Finally, I review some general biological principles that can be illustrated by results of salmonid culture at the City of Arcata, and suggest some salmon and steelhead trout culture potentials for north coastal California programs.

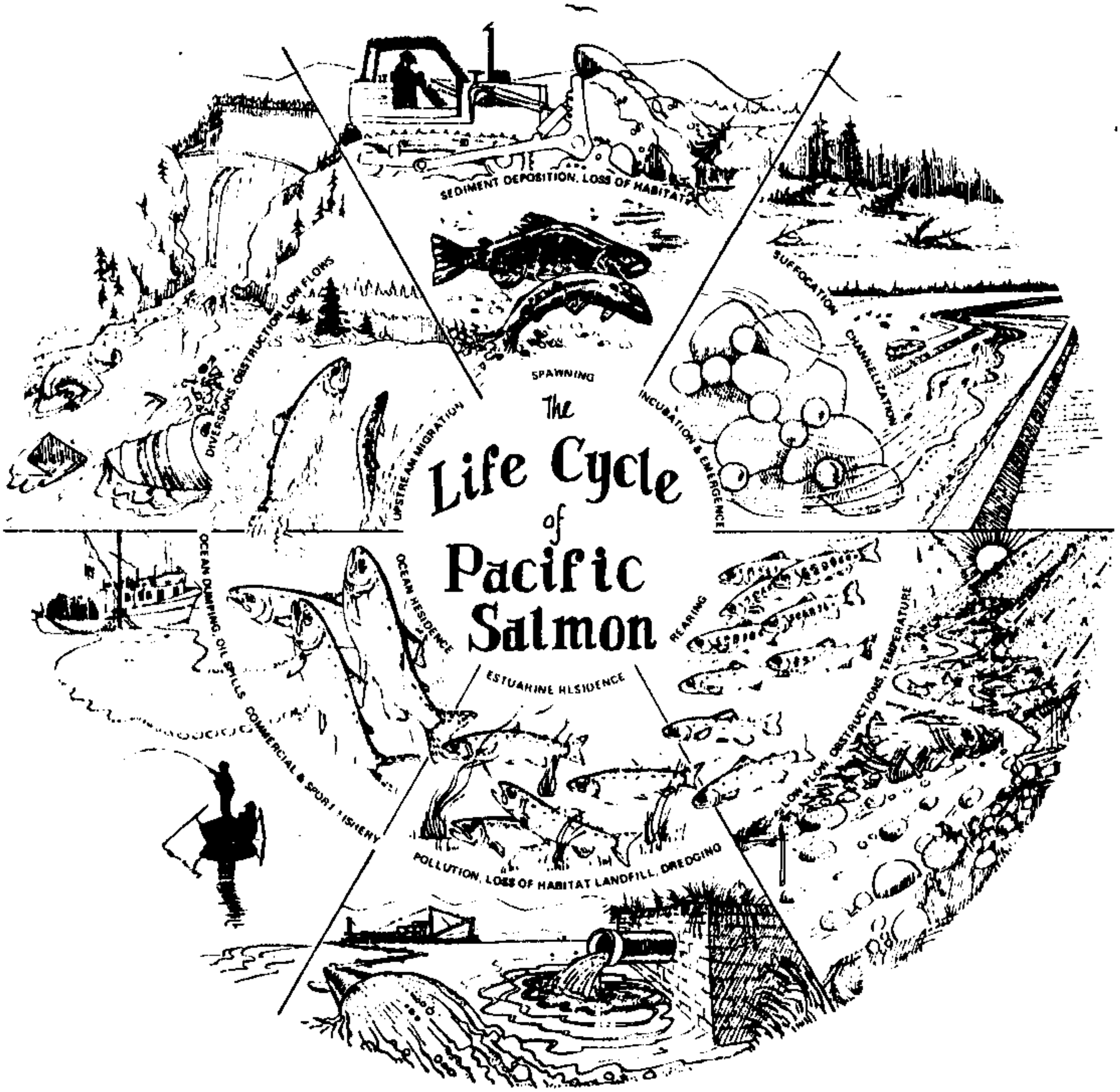

Figure 2. Human activities that impact on the normal life cycle of Pacific salmon (from: Get Hooked on Salmonids. Government of Canada, Fisheries and Oceans) (Original not seen).

DEFINITIONS

Larkin (1979, 1981) notes that an apparent obvious way to compensate for the shortcomings in salmon fishery management, and in offsetting environmental degradation, is by a variety of techniques termed "salmonid enhancement" (other terms being "restoration", "rehabilitation", "augmentation" etc.).

Webster's Third International Dictionary defines "enhance" as:

> 1. raise, lift; 2. advance, augment, elevate, heighten, increase; 3a. to increase the worth or value of (an estate enhanced by careful management); and 3b. ornament, beautify;

and then defines enhancement as "the act of enhancing or state of being enhanced; augmentation; intensification". Thus it is not surprising that many terms appear in publications by various state and local describing programs and activities to increase salmon resources. California uses the term restoration for its public involvement program. Mendocino County (Sommarstrom 1980) uses the term "enhancement" defined as "Management activities designed to augment the fish population beyond its historic or existing level." In Oregon enhancement refers to programs fostering public involvement in salmon and steelhead management (Salmon and Trout Enhancement Program, STEP) (Anon 1985a). In British Columbia enhancement has been used to identify a massive program in which fishery management goals have been linked to goals of the Canadian federal government (Schouwenburg 1984). Activites found within the Canadian definition range over the entire gamut of management activities (e.g. from raising salmon and steelhead juveniles in private and public hatcheries to the restoration of local anadromous salmon populations for purely esthetic or cultural objectives). A separately identified Public Involvement Program now lists over 6,000 citizens in some phase of salmonid culture (Rank 1983). Most citizens probably view artificial propagation of salmon and steelhead as a "hatchery" program. However, a recent formal definition has given the term a much wider connotation:

> "Artificial propagation. Any fish culture activity involving modification of the natural spawning, incubating, or rearing habitat. The amount of habitat modification may range from small (e.g. spawning channels) to large (e.g. net pen culture)." (Lannan and Kapuscinski 1984).

For purposes of this paper, I restrict the concept to those activities in which adult salmon or steelhead are physically handled to obtain eggs (artificially spawned).

LIFE CYCLE AND LIFE HISTORY

Of the five species of anadromous Pacific salmon confined to the north American coast (Table 1), north coastal watersheds historically have harbored natural populations in substantial numbers of only two species (coho and chinook). California chinook salmon stocks have always been relatively important to the coastwide commercial catch (Figure 3). In contrast, coho have been of lesser and variable importance (Figure 3), and mostly taken north of Cape Mendocino when northern stocks have migrated into northern California areas. In 1984, a major distribution of coho occurred south of Cape Mendocino. Steelhead trout populations have always been relatively abundant. Coastal cutthroat trout are now only found in reduced numbers in coastal areas of Humboldt and Del Norte counties.

Table 1. Common and scientific names of anadromous salmon and trout.

Common name	Scientific name
Coho (silver) salmon	Oncorhynchus kisutch
Chinook (king) salmon	Oncorhynchus tshawytscha
Sockeye (red) salmon	Oncorhynchus nerka
Pink (humpback) salmon	Oncorhynchus gorbuscha
Chum (dog) salmon	Oncorhynchus keta
Steelhead rainbow trout	Salmo gairdneri
Cutthroat trout	Salmo clarki

Anadromous salmonid populations of north coastal California exhibit complicated life cycles with associated life history stages (Figure 2). It is not possible to discuss the details of between and within species similarities and difference in life history and cycles. There is one environmental factor, however, which I believe is most responsible for producing "adaptiveness" of local spawning populations. This factor is the hydrologic cycle of a drainage and its associated water temperatures. Adult migratory behavior and freshwater residence in any spawning population appears correlated with the time of appearance of an optimum water temperature for spawning. This included the disappearance of both lower and upper limiting temperatures (Chambers et al. 1955). Critical water temperatures are also associated with "smoltification" and seaward

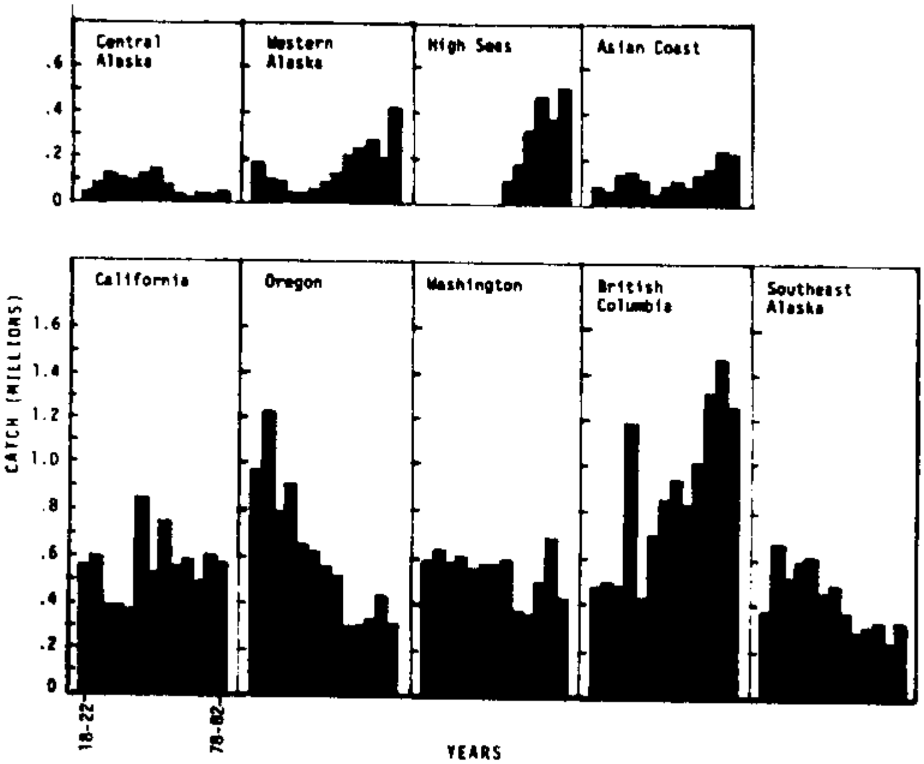

Figure 1. Mean annual commercial catches of chinook salmon by five-year periods beginning 1918-1922 and ending 1978-1982.

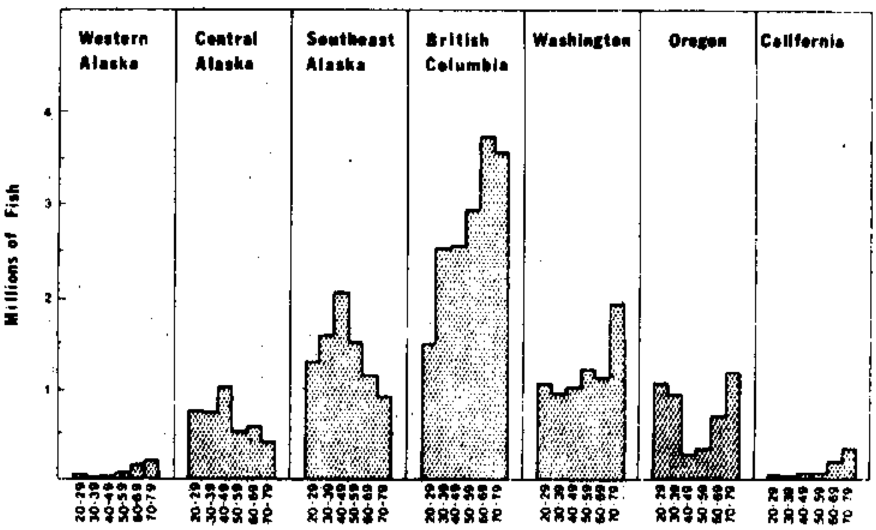

Figure 2. Numbers of coho salmon landed in the OPI area, 1890-1984. Landing records prior to 1923 are incomplete because fish dealers were not required to report landings.

Figure 3. Relative distribution and abundance of chinook and coho salmon along the west coast of the North American continent as indicated by catch statistics. (Figure 1, above, from Salo and Rogers 1983; Figure 2, below, from Anon 1985a).

migration in juveniles, especially the inhibitory effects from higher water temperatures (Johnston and Saunders 1981).

Ricker (1972) reviewed the literature on the degree that differences in various parameters characterizing Pacific salmon stock were controlled by genetic or environmental influences. Knowledge of such variability associated with discreet (strongly reproductively isolated) stocks (whether natural or hatchery-dominated) is essential for successful artificial propagation. Some of the life history characteristics associated with a specific life cycle important in selecting stocks for artificial culture ventures, include but are not limited to, those listed in Table 2.

Table 2. Life history characteristics involved in selecting salmonid stocks restoration or enhancement projects involving artificial propagation.

Rates of growth	Size and age at maturity
Thermal tolerance	Time of upstream migration
Resistance to disease	Precision of homing
Age at seaward migration	Distance spawning ground from sea
Behavior of seaward migrants	Spawning season
Length of estuarine residence	Colonizing and straying behavior

Chinook salmon characteristically are species associated with large river systems and spawn in mainstem and lower reaches of major tributaries. There are, of course, scattered instances throughout their range, (Sacramento-San Joaquin drainage in California to river systems along the eastern coast of Siberia) of stocks spawning in small creeks and drainages. Although presently northern coastal California chinook occur most abundantly in larger drainages (Smith, Klamath, Mad, Eel), in historic times, there were many chinook stocks adapted to smaller coastal drainages as suggested by the early commercial gill net fisheries for chinook salmon in Humboldt Bay (Wainwright 1965). After emergence from stream gravels, chinook remain in fresh water for varying lengths of time depending upon water temperature. In the southern portion of the range (i.e. California), migration to the sea begins in fall chinook in May and June after about three months of freshwater feeding. In the northerly portion of the range, chinook spend at least a year in fresh water before seaward migration. Since altitude can substitute for latitude in producing water conditions, there are in California "spring" runs of chinooks, the juveniles of which also remain at least one year in fresh water. The complexities in migrational behavior of out-migrating juvenile chinook salmon have only been detailed in the last decade. Reimers (1973) showed that juvenile "fall" chinook that begin migration to the ocean in the spring after three months of fresh water feeding, have the best relative survival in the ocean only if the juveniles remain in brackish water until early fall before completing movement into the ocean. Behavior in estuaries of out-migrating chinook of yearling and older aged juveniles are major topics of chinook estuarine ecology today. Once in the ocean, chinook migrate vast distances along the north American coast, and tend to remain relatively close to the continental shoreline (e.g. 100 miles). Off California, due to a narrow continental shelf and a restricted zone of cold upwelled water, the chinook hug the coastline, often producing feeding concentrations virtually in the surf zone, along bay jetties, and into estuaries and the lower reaches of major river systems. The age at maturity of chinook salmon varies with stock. Generally, much older age at maturity characterizes northern stocks due to the longer residence in freshwater and additional years at sea. Relatively younger age at maturity are found for southern stocks, such as those in California, with fish of three, four and five-years total age most abundant in existing runs. The seasonal return to freshwater by mature adults has lead to vernacular descriptions of stocks by time of appearance (summer, fall, winter, spring). Along north coastal California most chinook runs are fall type, but remnant spring runs still exist in some drainages such as the Klamath River. Additional life cycle details can be found in Feinberg and Morgan (no date). Increasingly more detail is accumulating in the planning and environmental review documents associated with recent efforts with salmon management problems of the Klamath-Trinity drainages (CH2M Hill 1985).

Coho salmon, in contrast to chinook, are notorious for their association with small drainage-small stream habitats (Ricker 1972). Coho are distributed widely from California around the Pacific rim to Siberia. After emerging from stream gravels, coho juveniles spend at least one year in freshwater before a rapid migration to the ocean. Only a short estuarine residence is required by coho before ocean feeding. Coho invariably spend only two summers feeding in the ocean maturing as three years of age. In freshwater habitats with cold water temperatures, minimum size required for seaward migration (about 11 cm) may take more than one summer of growth. Thus in northerly drainages, total age at maturity may be four or five years, but time spent at sea is still overwhelmingly two years. California coho have the more typical life cycle of one summer growth in freshwater and two summers in the ocean. Coho tend to remain closer to the continental shelf than chinook (i.e. 25 miles) and to be relatively distributed in the surface waters in comparison to chinook which tend to feed at deeper depths. Since coho tend to spend relatively fewer years in the ocean, they grow to lesser average size at maturity. The total ranges in migrational distances exhibited by coho are not as great as for chinook, but they do make extensive migrations. Time of return to freshwater by mature adults is highly variable, undoubtedly a function of water flow and temperature, especially for stocks associated with small drainages and estuaries blocked by sand bars. Where larger drainages provide year-round stream flows (Russian, Eel, Mattole, Klamath, Smith) coho can start appearing in late summer, but generally the first heavy rains of late October or November mark the initial time of appearance of maturing adults. Since coho have the ability to "wait out" drought conditions, adult migrations have been recorded in late winter and even spring months. A recent example of this phenomenon occurred in Humboldt Bay streams in 1985. An interested citizen delivered to me a frozen carcass of a male spawned-out coho which was part of a small run of spawning fish in Washington Gulch creek which enters Humboldt Bay immediately south of Jacoby Creek. The fish were in the creek spawning in late March. Then on April 9, 1985, a sizeable run of coho were found in Jacoby Creek during a survey of the creek for juveniles. The adult coho were actively spawning (Van Kirk 1985).

The life cycle of anadromous trout in north coastal California streams are equally complex, if not more so, than salmon. Since steelhead trout stocks are classified as game fish, there is less direct user conflicts, and less evidence of overall depletion for the dominant winter runs. Summer and spring runs, however, have experienced substantial historic declines. Steelhead must reach much larger minimal sizes before smolting (14-17 cm range) and thus remain in freshwater at least one year. Age of maturity in the ocean is highly variable. Some steelhead survive spawning, return to the ocean, and may spawn more than one time These variables in life history may produce up to 25 different age categories in steelhead populations in large drainages. Small drainages and hatchery operations generally involve fewer categories (i.e. smolting in 1-2 years and adults maturing after 1-4 years in the ocean).

Anadromous cutthroat trout life cycles have not been reported for California stocks but probably will resemble that reported for Oregon (Giger 1972). Life history studies are now underway, especially as the recreational importance of species is being recognized (Mitchell 1985, Personal communication).

ARTIFICIAL PROPAGATION

Historical Role of Hatcheries

Expansion of European settlers over the north American continent was heavily dependent on the availability of food furnished by existing populations of birds, mammals, and fish prior to establishing traditional agricultural production. Colonization of the northwestern portion of the continent followed access routes carved out by the larger river drainages (Sacramento-San Joaquin, Klamath, Columbia). Here large populations of indigenous peoples were being supported by the high quality, abundant, and seemingly inexhaustible supply of anadromous salmonids (Smith 1979). Both native and immigrant people used the resource in common, with the resource soon coming under excessive harvesting with the development of a canning industry that sent a cheap, high quality protein, to industrial nationals throughout the world, but principally Europe (Smith 1979). Successful utilization of techniques developed initially in the eastern United States for culturing brook trout (Salvelinus fontinalis) were adapted to anadromous salmonids. Early artificial culture operations accompanied and often were stimulated by serious economic impacts from resource depletion caused by the combined impacts of subsistence and commercial canning activities (Hume 1983).

A definitive history of west coast salmon and steelhead propagation probably will never be written due to the magnitude and complexity of these efforts (Wahle and Smith 1979; Wahle et al. 1981). In preparing for this paper, however, I encountered some new publications, both recent and old, that report on anadromous salmonid management issues which would be of some utility to emerging anadromous salmonid culture programs. A fascinating history of the rise and decline of the Columbia River salmon canning industry and associated fisheries has been written by an anthropologist (Smith 1979) under a grant from the National Marine Fisheries Service Sea Grant Program. The book will be invaluable to anyone in salmon and steelhead work who needs to understand the social, economic, and political forces involved in anadromous salmon management, and the involvement of arrtificial propagation as an enhancement tool. The second document is a small pamphlet written by a pioneer in the fish canning business and one of the first west-coast salmon hatcherymen (Hume 1893). The original 1893 document was reprinted in 1975 by the Curry County Oregon Historical Society. Hume, after setting up the first cannery on the Sacramento River, developed a salmon hatchery at the mouth of the Rogue River in order to increase runs for a second canning venture he had started there. Selected paragraphs from Humes' work are reprinted in the Appendices.

A third publication of interest is a most recent example of a now fashionable genre of books exploring the mystical and aesthetic values of salmon and steelhead stocks untainted by human hands (Brown 1982). Fishers, managers, culturists, politicians, administrators, and educators all stand at the dock in this book for past transgressions awaiting some ray of hope at books end -- in vain. Both popular writers (Brown 1982) and scientific writers often quote the work of Royal (1972). I have always found Royal as one of the more instructive writers on the proper role of hatcheries in fisheries management. Royal was the research director of the International Pacific Salmon Commission formed by the U.S. and Canadian governments to jointly manage sockeye salmon of the Fraser River, B.C. Excerpts from this classic paper, long out of print and not generally available in libraries, outline ways to increase the survival of hatchery steelhead while minimizing the possible adverse impacts on existing salmonid populations from improper hatchery practices. Some of the Royal's concepts may not be entirely valid for California conditions, and some of the problems listed have, more or less, been addressed by research results published in the past 13 years. Nevertheless, I feel the pertinent practices and principles suggested for the Washington steelhead hatchery operations are also applicable to any salmonid enhancement effort that involves the use of culture techniques. Extensive pertinent quotes are given in the Appendices. Finally, I wish to note that Humboldt State University has hosted several conferences and symposia on subjects directly related to the proper role of hatcheries in fisheries management (Barnhart and Roelofs 1977; Hassler 1981; Hassler and Van Kirk 1977).

Juvenile salmonids reared in hatcheries when released to supplement existing native stocks have often lead to contributions to sport and recreational fisheries and to runs of returning adults. Currently 75 percent of the ocean caught coho salmon off Oregon are hatchery fish (Anon 1985a). Thus it is not surprising that the general public and the concerned lay worker has historically viewed culture as an obvious and unquestioned beneficial practice (Larkin 1974). Professional fisheries biologists and managers, charged with administering public policies outlined by federal and state agencies, also find fish culture as a useful tool in enhancing anadromous species (Blackett 1981). The proper use of cultured fish, however, has always been strongly argued (Larkin 1979). Problems are now being identified from the very success of culture operation associated with both mitigation and compensation efforts, as well from artificial propagation for direct supplementing of native stocks to increase ocean harvests. In preparing this paper, I uncovered in my files an unsigned and undated mimeographed pamphlet titled "Are you 'Sold' on Artificial Propagation?" I suspect it was a handout at one of the many early meetings between the California Department of Fish and Game and local user groups which took place at Humboldt State College back in the late 50's. The pamphlet reads in part:

> Are you <u>sure</u> that we could not get more fish for our money by spending it on stream improvement, fish rescue, research, etc.?
>
> Fishery workers the country over pretty well agree that there is a definite need for hatcheries for the following functions.
>
> 1. To stock waters without fish present.
>
> 2. To restock fish in streams depleted of fish life (it is worth the <u>high cost</u> to get the population back on its feet...<u>not</u> worth the money to <u>maintain</u> the population in this manner over a period of years).
>
> 3. To provide at least some fishing in heavily fished areas, restricted in size, where all or nearly all fish are caught each

year and where the water level drops so low as to kill fish remaining during the summer. (Example: some of the small streams in Southern California near large cities).

4. To provide fishing in areas where natural spawning is not possible (such as in lakes that have no inlets or outlets, or in creeks that have no gravel beds suitable for spawning, or where dams have cut off runs into the suitable spawning areas such as is partly the case in the Sacramento River in connection with Shasta Dam).

5. To provide fish for experimental disease treatment, research into requirements and reactions of fish...all this in order to provide a factual basis for fish management.

Implicit in these five comments is a policy to maintain anadromous fisheries by habitat management, still a basic tenet of anadromous salmonid management in California. Habitat protection has been a difficult task in California where massive growth and urbanization and associated water development projects have produced considerable alterations in freshwater aquatic systems. In addition to intense modifications directly caused by human activities, much of the north coastal anadromous salmonid habitats are associated with a unique geological province (Wallace 1984). These two factors probably account for the intense sedimentation rates found in northern California drainages that are among the highest in North America for basins of comparable size (Hofstra 1983). Perturbations in aquatic systems important to salmon and steelhead in California may produce more exaggerated consequences than in more northerly areas since California is at the southern edge of the range for salmon and steelhead, especially coho salmon (Figure 3).

Historically perceived and actual demonstrated need for, artificial propagation has resulted in the production of juveniles of the anadromous trout and Pacific salmon along the rim of the north Pacific Ocean of staggering proportions. Some efforts involve national policies of encouragement (Japan, Russia, Canada, and by some agencies and states in the United States) (McNeil 1976; Thorpe 1980). Biologists, however, still continue to point out that there are short-comings and pitfalls from a too heavy reliance on standard hatchery approaches to maintaining anadromous salmonid populations. Recently Helle (1981) outlined how Alaska should manage hatchery operations to maximize the chances for increasing salmon numbers without causing both short-term or long-term consequences that can result in decreasing salmon numbers. Helle categorized the release of artificially propagated salmonids as being categorized biologically in three ways (all of which as been mentioned previously in this paper in slightly different form):

1. Range extension - transplant of a species to an area where that species is not present,

2. Reintroduction - transplants of a species to a barren system in an area where the species exists in nearby systems,

3. Supplementation - transplant of a species to a system where that species is already present.

Reintroduction and supplementation transplants were the main "enhancement" strategies of hatchery operations in north coastal drainages prior to the initiation of the California Steelhead and Salmon Restoration Program. These early activities were undertaken to "mitigate" losses of production when spawning grounds and rearing habitats were isolated behind dams and irrigation diversions (Meacham 1973). Recently private culturing of anadromous salmonids has been reinstituted. It was inevitable that the information on culturing Pacific salmon developed by public agencies would be employed eventually by private investors to develop culture systems as part of the salmon food industry. Private hatcheries are proving successful with pink and chum salmon, but are still in the developmental stage for coho and chinook despite large capitalization of initial efforts (Clay 1974; Johnson 1982a, b, c). California currently has but a single private salmon producer operating under experimental permit from the legislature. Those California citizens now entering artificial salmon and steelhead propagation restoration and enhancement programs join a long-standing heritage of culturing Pacific salmon and steelhead trout by both private and public agencies (Larkin 1974).

North Coast Hatcheries

Some knowledge of the existing north coast hatchery operations should be of interest to those considering a future role for artificial propagation in a salmonid restoration or enhancement program. I surveyed seven hatcheries operating on north coastal streams by use of a short questionnaire sent to hatchery superintendents (Figure 4). Survey results showed substantial diversity of hatchery operations (Tables 3-5).

The California Department of Fish and Game has the responsibility for operating Iron Gate, Trinity River, and Mad River hatcheries. Humboldt County now manages Prairie Creek, formerly a CFG facility which reared fish rescued from intermittent streams and initially was involved in cutthroat culture. The Humboldt State University hatchery is part of the California State University educational system. The Arcata aquaculture system is municipally-owned. The last three operations were all probably unique in the United States at the time of their inception (county operation; municipal operation; total recirculation system).

Two of the hatcheries were constructed in order to mitigate for destruction of salmon numbers due to spawning ground and habitat losses caused by construction of dams (Iron Gate and Trinity Hatchery) (Table 3). Three hatcheries were built with the express purpose of increasing the numbers of anadromous fish to user groups (Mad River, Rowdy Creek, and Prairie Creek). One hatchery was built primarily for education and research (Humboldt State University), and one system has evolved from an innovative attempt to develop a salmonid aquaculture system based mainly on the reuse of treated domestic wastewaters (Arcata).

Source and amounts of revenue for the hatchery operations also show an interesting diversity (Table 4). At least eight governmental funding sources were identifiable. Public donations and fund raising activities contributed to financing two operations (Prairie Creek and Rowdy Creek). "Pass-through" funds were involved in supporting one station (Mad River) but specific source of monies were not provided for this preliminary compilation.

Capitalization also varied greatly between facilities. The three facilities operated by DFG have the largest capital outlays (Table 5). Facilities and budget levels for the other four facilities were much less and bore some relationship to the financial power of the supporting organizations: (service club, county, state university, small municipality) (Tables 4 and 5).

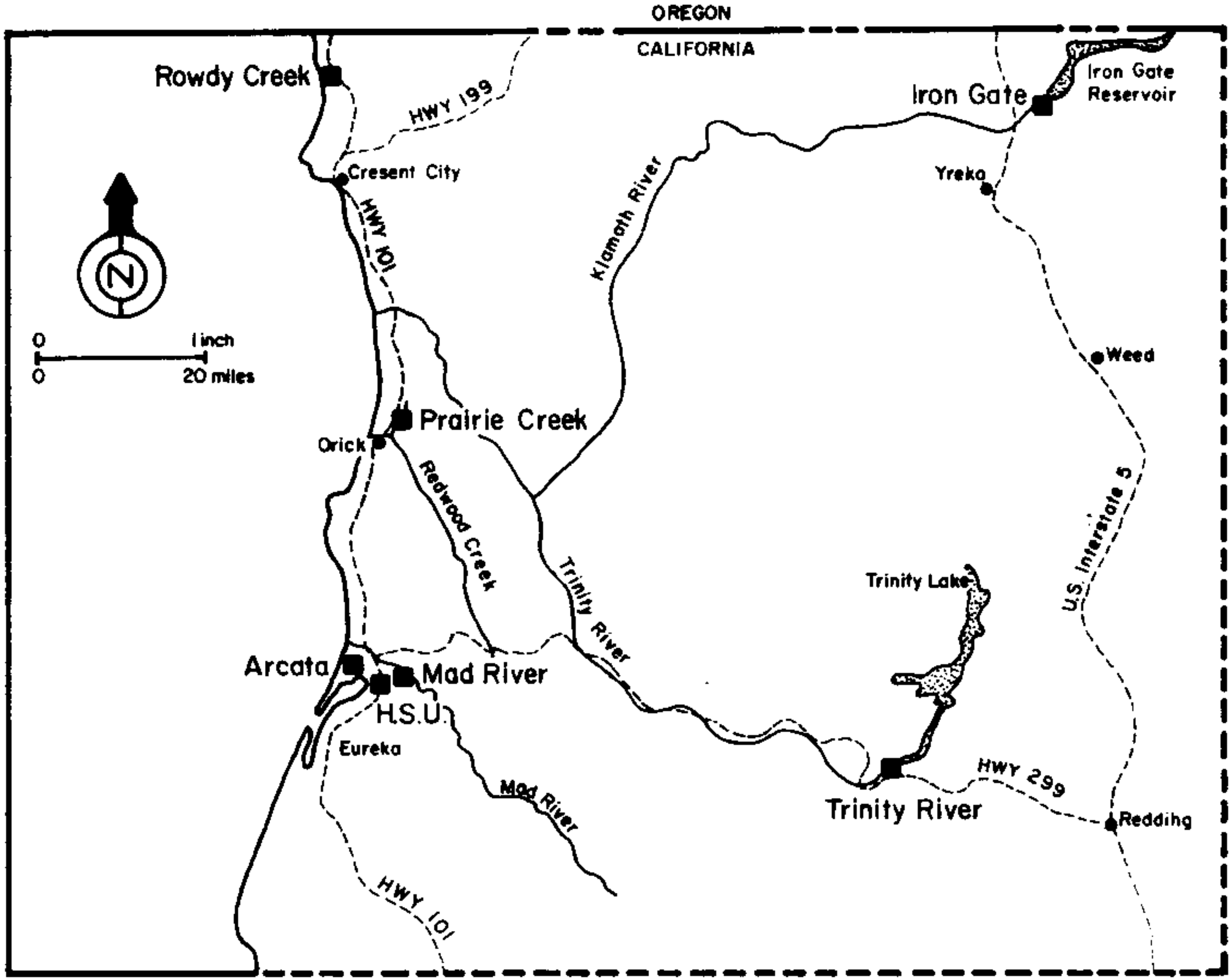

Figure 4. Location of seven north coastal California anadromous salmonid hatcheries.

Table 3. Current functions reported for seven north coastal California fish hatcheries (alphabetical order).

Official name	Function
Arcata Aqaculture and Fisheries Program	URBAN FISHERIES (development, rehabilitation and enhancement). Other functions: wastewater salmon aquaculture system; education; research.
Humboldt State University Fish Hatchery	EDUCATION (Mandated). Other functions: research (student projects); fish production (surplus to local waters for recreational fishing).
Iron Gate Salmon and Steelhead Hatchery	MITIGATION (Mandated). Chinook (6 million); steelhead (0.2 million). coho (0.075 million). Other functions: enhancement (with CDFG, chinook - 1.0 million).
Mad River Hatchery	MAINTENANCE AND ENHANCEMENT. Salmon and steelhead runs in Mad River and other north coast streams.
Prairie Creek Fish Hatchery	ENHANCEMENT. Chinook, coho, steelhead for ocean and river fisheries. Other functions: Trout for recreational fishing, lagoons and ponds; educational programs and work experience site.
Rowdy Creek Fish Hatchery, Inc.	ENHANCEMENT. Ocean and river fishing to improve Del Norte county economy.
Trinity River Salmon	MITIGATION (Mandated). Chinook, coho, steelhead. Other functions: Some enhancement (supported by state funds).

Table 4. Source and amount of funding in 1984 for seven north coastal California fish hatcheries (listed in descending order of operating budget).

Hatchery	Budget (dollars)	Funding Sources: Source	Funding Sources: Percent budget
Trinity River	600,000	U.S. Bureau of Reclamation	100
Iron Gate	474,000	Pacific Power and Light Co.	80
		Calif. Dept. Fish and Game	20
Mad River	300,000	Calif. Dept. Fish and Game Preservation Fund	100
Rowdy Creek	152,000	Calif. Dept. Fish and Game	79
		Private Contributions	13
		Fund Raising Projects	8
Prairie Creek	120,000	Humboldt Area Foundation	22
		Calif. Dept. Fish and Game	45
		State Dept. Transportation	28
		Public Donations	5
Humboldt	42,500	California State University System	100
Arcata	24,000	City of Arcata Public Works	100

Table 5. Capital costs (not adjusted for inflation) of seven north coastal California fish hatcheries (listed in descending order of capitalization).

Hatchery	Cost of facilities (millions of dollars)	Remarks
Trinity River	2.80	Original cost, 2.3 with additional 0.5 for settling pond.
Mad River	2.76	No major additions since construction.
Iron Gate	1.08	Original cost 1.0 with 0.08 for recent auxiliary ladder and trap.
Rowdy Creek	0.50	Facility under phased development.
Humboldt	0.16	Does not include water supply reservoir. Major repairs to recirculation system now required.
Arcata	0.05	Major capital outlay 0.032 from CDFG Wild. Cons. Bd. for pilot project ponds. Facility under phased development, using city materials and equipment as available.
Prairie Creek	-	Cost to county 1 dollar for operational rights from State of California. Cost of major facilities additions not available for this report.

Capitalization and operating costs for large-scale high-technology salmonid production systems continue to increase. Oregon recently estimated that a two million smolt system now would cost around $5 million for facilities and $0.25 million minimal operating costs (Anon 1985a).

Techniques

Although I briefly discuss fish-rearing techniques and present a few useful references on the subject, such information is readily available elsewhere, especially through the technical assistance offered by Sea Grant extension agents, county agricultural agents, and technical personnel of the California Departrment of Fish and Game assigned to the restoration and enhancement programs in California.

For comparative purposes, I have listed anadromous salmonid enhancement techniques using artificial propagation as a continuum from modern hatchery operations representing a high degree of culture and manipulation, to techniques which emphasize habitat restoration and protection (Table 6). Activities 1-3 require catching adult fish for artificial spawning. Activities 4-6 are those in which the fish reproduce without the direct hand of man or woman. For groups employing activities 1 and 2, there is usually some rearing of fish prior to release. Some hatch boxes allow emerging fry to migrate directly to a receiving water while others collect fry for rearing prior to release. There is an infinite variety of containers used for rearing juvenile salmonids. Again a detailed discussion of these techniques is not within the purview of this paper, however, a scheme of classification of fry, fingerling, and yearling rearing units (Table 7) may have some utility for new practitioners. Use of renovated facilities, or temporary structures constructed with volunteer or service oriented help programs, are practical ways of keeping capital and operating costs low. Artisanal culturists world-wide have developed an amazing array of containers for rearing fin-fish (Pillay and Dill 1979; See chapter VI), and I believe the general public are being equally as creative.

Enhancement programs operated by private citizens that involve artificial propagation must use alternative techniques to that employed by large-scale production systems. Today high-quality water supplies recommended for culturing are severely limited and often are the major cost in a system involving pumping of water. Two north coast hatcheries rely on water from discharges below dams (Iron Gate, Trinity); one uses water from a small tributary creek (Rowdy Creek), while the remaining four rely on supplies not taken directly from a stream drainage (Mad River - multiple tube well field; Prairie Creek - tube well; HSU re-circulating water; and Arcata domestic water and treated wastewater). Ingenuity can be applied in identifying and utilizing non-traditional sources of water in north coastal California areas. One such potential source is the effluents from sewage treatment facilities, where most wastewater reuses are for beneficial food and fiber production in systems other than aquaculture (Ling 1980).

Table 6. Artificial propagation strategies compared with those based on improving or establishing natural habitats.

Strategy	
Artificial propagation	Natural Habitats
1. "Fish Hatcheries" (see Tables 2-4)	4. Spawning channel
2. Hatch boxes	5. In-stream manipulations
3. Planting eggs	6. Watershed Protection

Table 7. Partial list of containment systems potentially or actually available for development of artificial propagation enhancement strategies requiring rearing of fry and juveniles of anadromous salmonids.

Type of container		
Permanent facilities		
New	Renovated	Temporary facilities
Concrete configurations	Log storage ponds	Wash-out ponds
Dirt ponds	Stock watering dams	In-stream ponds
Wood tanks	Highway borrow pits	Off-stream ponds
Plastic containers	Abandoned quarries	Movable pens
Metal vessels	Abandoned sewage treatment facilities	Other
Other	Drainage channels	
	Low areas (land use changes)	
	Waterproofing	

CONSTRAINTS AND CHALLENGES

Choice of an artificial propagation technique to enhance anadromous populations in a particular drainage varies from high technology-high cost facilities and operations to low cost and less sophisticated approaches involving only a minimum of culture practices (Tables 3-7). Should careful analysis suggest a culturing operation on appropriate technique to be used, and should adequate funding be assured for the operation, there are many "uncertainty factors" that may place limits on the increase in anadromous salmonid populations to be expected. Limiting factors should be understood by citizen practitioners so that reasonable expectations may accompany new culture programs (Rank 1983; Wahle and Pearson 1984; Larkin 1974).

Technical Factors

Fish Culture Ability

There are several highly recommended publications that can provide a basic knowledge of successful fish cultural practices that have evolved from considerable trial and error, and from research and experimentation. A manual developed for California Fish and Game hatcheries by Leitritz and Lewis (1980) is used worldwide. A similar manual developed for federal hatcheries is now available (Piper et al. 1982) as well as books on salmonid culture that can provide a unique European prospective (Sedgewich 1982). Private salmon growers have also developed manuals that are most useful for developing proper culture techniques (McNeil and Bailey 1975), as have water development agencies (Senn et al. 1984). Recent bibliographies on salmon aquaculture can also be helpful as a source of information for improving an organization's culture ability (Anon 1982; Brown 1976). Government services such as INFO Fisheries designed for internal, informal, and received rapid exchange of information between data producers and users should be received by citizen organizations to obtain up-to-date information without being awed by the mysteries of ordinary library research. A major challenge exists in the successful extrapolation from existing manuals and books on fish culture techniques to maximize the advantages and to overcome the limitations offered by specific sites. Unfortunately, there is no guarantee that after the most thorough analysis by experts and the use of the most tested technologies, that a system will consistently produce quality juveniles for release. The probability of success, however, will be increased if the approach is taken that the culture system and its operation must be designed to fit the needs of the fish rather than that of the culturist (Thorpe 1980, p. 403; Reimers 1979).

Carrying Capacity

Each body of water at a given time has a finite ability to produce and maintain fish flesh. This is a very fundamental and well documented concept used in management of salmonid fisheries resources (1981). The carrying capacity concept in fisheries management has recently been summarized by McDowall (1984, p. 205) for New Zealand freshwater habitats. The limits to which fish culture was able to improve populations of exotic trout in North Island between 1900 and 1940's were described as follows:

> By the 1930s the early spectacular success of brown and rainbow trout was beginning to fade away. Lakes, particularly in the central North Island, were becoming overpopulated with poor conditioned fish, and revised management practices were adopted to increase harvest rates and improve

food resources that had become seriously depleted. These practices included capture of large numbers of trout for public sale. Following this, the populations largely settled down, and equilibrium developed among environment, food resources, salmonid populations, and exploitation. All that was required to sustain good fisheries was periodic adjustment of the rates of exploitation. Some environmental deterioration was beginning to be noticed. Acclimitization societies persisted in their policies of massive releases of young trout, but scientific evidence now available indicated that this was largely an unproductive activity.

In other words, the naturally reproducing salmond populations of North Island had reached equilibrium with the carrying capacity of the lake and stream aquatic systems. Such a dynamic balance probably exists in the anadromous populations of South Island, and the application of modern culture techniques appears not to have broken through some "limiting barrier" at this time:

> The mid-1970's saw a developing interest in the ocean ranching of chinook salmon (Waugh 1981). This activity has not yet had any major impact on the distribution or abundance of the species although the expansion of the range of the species in New Zealand is possible as already two ocean-ranching ventures, operating outside the "natural range" of chinook salmon in New Zealand, seek to generate runs in new river systems. Success to date has not been notable.

Principles developed by Royal (1972) (Appendices) should be adhered to avoid over-reaching the carrying capacity in a freshwater drainage. Royal warned against deleterious effects of planting of fry and pre-smolts. Oregon is now actively studying the problem, and a preliminary study strongly suggested that releases of hatchery pre-smolts may actually reduce coho production, not increase it. (Anon 1985a, p. 8). Fry and pre-smolt planting have been sharply curtailed in Oregon in recent years.

Two classic studies dealing with steelhead trout and silver salmon can still be recommended for basic biological data applicable to north coastal California river systems, particularly the smaller drainage entering directly into saltwater (Salo and Bayliff 1958; Shapovalov and Taft 1954). For northern California streams, Burns (1971) still appears as the best source of values for salmonid stream carrying capacity. Hamilton (1983) is a good example of an extensive and well documented evaluation of steelhead enhancement program using in-stream habitat structures and the carrying capacity concept. Yearly variations in the carrying capacity of a small pool in an intermittent stream has been reported for resident cutthroat trout (Tsao 1979). Stream carrying capacity is vital to rational planning of restoration and enhancement programs using artificial propagation techniques.

Ocean carrying capacity may be limited under certain conditions such as lack of upwelling (Scarnecchia 1981). Early workers had to assume that ocean capacity a constant or at least probably not of great concern in determining smolt survival during initial studies on the results of hatchery production (Royal 1972). With the large increases in production of hatchery smolts, the possibility of wasting smolts in an ocean with a finite capacity is under heated debate especially for coastal coho stocks (Johnson 1982b). In contrast, Larkin suggests there may be "holes" in the ocean pasture for increased smolt production since current salmon abundance is not as large as those present at the turn of the century. Recent studies in Oregon have correlated increasing smolt production with a declining ocean catch. Clark and McCarl (1982) using currently available data suggested that the carrying capacity value for hatchery smolts of Oregon origin released into the "Oregon Production Index Area" probably lies between 30 and 180 million smolts. Current production is near the middle of this range. Proponents of a limited carrying capacity argue the capacity is near 40 million, with hatcheries only needing to add around 30 million. Clark and McCarl concluded that there are not sufficient data to recommend limiting hatchery production at this time. Thorpe (1981) recently suggested that "Concern about oceanic carrying capacity should focus first on production dynamics of coastal waters at the time of entry of salmon to the sea". Estuarine-carrying capacity studies are now underway on north coast drainages (Redwood Creek by National Park Service; Eel River by California Cooperative Fisheries Unit, Humboldt State University). Considerable recent work has been conducted on Redwood Creek in conjunction with mitigation efforts from channelizing the stream for flood control objectives (Hofstra 1983). No formal study has been conducted on Humboldt Bay, although Waldvogel (1977) captured both unmarked and fin-marked juvenile coho, and unmarked chinook salmon juveniles, during studies on herring using lampara bait seines. Very recent studies in Oregon showed much greater survival resulted by barging smolts through estuaries and releasing them at sea (Mc Allister 1985). However, homing may be impaired in such fish. Estuarine carrying capacity as a constraint to artificial propagation was noted by Brannon (1984):

> "Numerous small production sites spread out over our coasts will maximize the productivity of potential salmon rearing areas without crowding the estuary and concentrating the predators."

In summary, expectations of smolt-to-adult survival rates for artificially cultured stocks must be tempered by the uncertainty in the magnitude of surplus carrying capacity available in freshwater and estuarine rearing habitats through which the smolts must pass.

Smolt Quality

Smolt quality is now appearing as a major constraint in achieving and maintaining "successful" anadromous salmonid culture operations (Wedemyer et al. 1979). Smolt quality research is the growth industry in anadromous salmonid research (Folmar and Dickhoff 1980). Stress brought on by poor diet, crowding, poor water quality, parasites, and diseases, can all act to produce smolts that may appear reasonably healthy and fit prior to release, but which fail to return as adults. Poor returns also can result from use of improper stock (genetic factor) as discussed later. Contribution of adult salmon to sport and commercial fisheries and in returns escapement to freshwater are the only practical index on smolt quality available to the lay culturist.

Public Waters

The utility of improving upon nature by husbandry as evidenced in agricultural production schemes must not obscure the fact that culturing anadromous salmonids has peculiar problems. The analogy of open-range ranching of cows to anadromous salmon and trout culture is somewhat imperfect. Early immigrants on crossing the Mississippi River converted buffalo herds to hides and substituted Texas longhorns as open-range cattle (Johnson 1982). They ranched the longhorn until a series of very severe blizzards in the late 1900s killed the cows and ended the practice. Carefully husbanded, selectively bred strains of cattle now graze inside fenced landscape where the animals receive supplemental feed and shelter in winter as necessary. The anadromous salmonid aquaculturist husbands young fish under artificial conditions then turns them out to an ocean pasture to fend for themselves, thus avoiding heavy feed costs. Here the analogy ends. The fish have to adapt not only to natural conditions when growing to maturity both in freshwater and saltwater, but to crowded, stressful, unnatural conditions as juveniles living in artificial containers. Buffalo were killed on a first-come-first-serve basis. Cows had to be rounded up and individually branded for allocation. In contrast, salmon in the ocean belong to anyone that has been authorized a permit to catch them, which parallels the buffalo-stage of "ranching". Frontier cow ranches went broke from adverse weather conditions, decreasing carrying capacities of range, poor stock, improper management, not to mention fluctuating prices from world-wide factors not under their direct control. So too with anadromous salmonid culture operations. Unsuccessful private operations go belly up (McFarland 1984). Unsuccessful public ventures tend to survive through public funding. Since it is not physically possible to enclose the waters of the continental shelf and the Pacific Ocean, and politically impossible anyway, the analogy of anadromous salmonid culturing to open-range cow ranching is weak. Since enclosing the commons in California appears highly unlikely for physical reasons alone, releasing anadromous juvenile salmonids appears the most likely culturing system in California in the foreseeable future. Under this system, after smolts enter the ocean, survival rates will vary with two conditions: ocean environment (uncontrollable) and exploitation by fishers (partly controllable). Migration and distribution routes in the ocean of salmonids produced by any method (culturing or habitat improvement) once can be major factors in determining the rate of return to the habitat or to the site involved in the salmonid enhancement program (Allen 1966). Thus, uncertainty in results can be expected as the rule. Understanding the probable degree of uncertainty with any operation requires a program of marking or tagging that allows for ocean recoveries (Sommarstron 1980). Uncertainty in ocean factors causing variable survival rates is faced by all enhancement efforts - habitat oriented or fish culture oriented, public, non-profit, or private.

<u>Planning Parameters</u>

Performance expectations in both public and private culture operations are often not met once operations are underway (Wahle and Pearson 1984). This often results from calculations of potential increase in numbers of adults from juveniles to be released from incorrect parameter values extracted from the literature. Good survival rates are much more likely to have been reported in the published literature than failures. Successful operations reported in the literature are more likely to be reporting results of work conducted within the optimal range of the species. Successes are likely to occur at facilities with optimal "site specific" conditions. Thus it would be highly unlikely that California conditions could produce adult returns back to the hatchery from coho smolts released at a rate of 15 percent currently reported for some new installations along the inland coast of British Columbia (Schouwenburg 1984). Many of the coastal hatcheries along the Oregon coast report returns of 1-7 percent (Johnson 1982), with public hatcheries now assuming 2.5-5% smolt survival (Anon 1982; Hankin 1981). A private anadromous salmon culture operation releasing smolts at Yaquina Bay, Oregon, is returning coho at a rate of around 0.75 percent rate, although planning for the operation used two percent expected return needed to a completely economic self-sustaining operation. The value now has dropped to 1.5 percent if coho and chinook are both cultured (Johnson 1982). The most recent smolt survival rates for artificially propagated coho in private hatcheries as determined by CWT-recoveries in 1984 are: 0.95 percent (0-aged accelerated fish) (Ore-Aqua [Yaquina Bay] hatchery) and 0.65 percent (yearling fish) Anadromous ([Coos Bay] hatchery) (Pacific Fishery Management Council 1985b, p. III-1). Hull and Allen (1983) computed escapement rates based on available data from northern California hatcheries experiments releasing groups of juveniles identified by fin clipping (Table 8). Actual mean percent return of coho and chinook salmon and steelhead trout to northern California hatcheries has been less than one percent for all species at all stations. Thus expecting a fish culture operation to perform at levels from values reported in the literature from work done to the north might lead to uncalled for disappointments. This

Table 8. Adult return rates of three species of salmonids to north coastal California hatcheries as measured by known returns from lots of fin-marked juveniles (Hull and Allen 1983). (Hatcheries arranged in increasing distance from Pacific Ocean).

Species	Hatchery	Percent of marked adult fish recovered at or near release site			Standard deviation	No. of studies
		Min	Mean	Max		
Coho	Arcata	0.0	0.08	0.57	0.18	9
	Mad River	0.0	0.02	0.08	0.03	3
	Prairie Cr.	0.002	0.07	0.10	0.06	7
	Trinity	0.0	0.79	3.94	1.57	5
	Iron Gate	0.006	0.02	0.04	0.01	4
Chinook	Arcata	0.0	0.01	0.02	0.009	3
	Mad River	0.004	0.006	0.007	0.001	2
	Prairie Cr.	0.006	0.01	0.02	0.002	7
	Trinity	0.43	0.80	1.31	0.28	6
	Iron Gate	0.0	0.08	0.24	0.07	10
Steelhead	Arcata	0.0	0.20	1.01	0.04	5
	Mad River					
	Winter run	0.0	0.64	1.88	0.64	10
	Summer run	0.0	0.10	0.23	0.10	4
	Prairie Cr.	0.02	0.33	1.10	0.44	4
	Trinity	0.0	0.08	0.99	0.17	43
	Iron Gate	0.0	0.48	3.90	0.95	17

appears particularly true for coho, less so for chinook and steelhead. Artificial culture should not plan for results that are inherently unattainable because this will produce a "failure" when measured against unrealistic planning documents.

Hatcheries involved in the analysis shown in Table 8 might be actually performing at a higher level than indicated by escapement only. Data to estimate ocean catches were limited since most of the experiments used single-fin marks which were not recorded in sampling of the ocean catch. Marking of juveniles from these hatcheries by CWT-techniques has been underway in recent years and analysis of real rather than apparent success of hatchery releases by using catch plus escapement data should be soon forthcoming.

Genetic Considerations

Conservation of native gene pools of plants and animals has become a concern throughout the world. The issue as related to salmon and steelhead populations in California has been reviewed by Berger (1982). "Genetic pollution" and "genetic integrity" are words that seem to have taken on political dimensions in west coast salmon and steelhead conservation and management discussions. Legislation and administrative policies recently promulgated in Oregon and California now restrict private salmon enhancement operations to locations directly on the ocean or lower estuarine regions (Silver King (coho) in California; Burnt Hill (chinook) near Brookings, Oregon). These locations presumably protect "genetic purity" and avoid wild/hatchery competition. The issues being raised are substantive (Larkin 1981), but concern must also be applied to public and non-profit aquaculture operations to avoid a double standard within what should be a unified approach to anadromous salmonid enhancement (Allen 1979). Habitat management that integrates fish culture techniques will also involve population genetics. There are, however, strong management and moral reasons for using artificial propagation in maintaining populations of rare or endangered trout restricted to isolated drainages (Hassler 1982; Behnke 1982).

The selection of stocks to be used in north coastal artificial propagation efforts, will have to assess possible negative impacts on wild gene pools. Evaluation may be confounded by the degree to which past transplants of exotic stocks of coho and chinook throughout the region may have already inbred wild stocks. Strict application of the gene pool concept to remaining wild stocks of summer-run steelhead and spring chinook, however, appears unambiguous. Even for coastal coho and fall run chinook, however, there are data strongly indicating a continued existence of native stocks with genetic integrity (egg size-body size relations among chinook from the Elk, Chetco, Smith, and Mad-Klamath-Eel rivers) (Hankin 1985; and Dave G. Hankin 1985. Humboldt State University, Personal communication). Continued within system differences in timing of chinook salmon migrations and spawning in the Klamath River drainage would not be expected if gene pools were being swamped with highly selected hatchery fish now massively being released into the system. Since hatchery fish have been reported migrating earlier onto the spawning grounds than wild stocks in the same system (Leider et al. 1984), interbreeding may be minimal. If a transplanted stock is sufficiently similar in life history to a local stock, little damage may result even if interbreeding takes place. If the transplanted stock is not adapted to a local environment, it will not survive to reproduce and no impact results. Since prudence in the stewardship of naturally producing populations of whatever genetic background may be the better part of valor, I suggest consideration of the guidelines recently promulgated for enhancement and other types of salmonid management programs on the Columbia River (Lannan and Kapuscinski 1984), or for fish culture activities in Alaska (Hynes et al. 1981) (See Appendices).

Thorpe (1981) notes that good imprinting is a way of safeguarding "against genetic pollution of wild by ranched populations". The same of, course, is true for public hatcheries or any stock that may be subject to any degree of artificial propagation where wild/hatchery stock interactaions have been determined deleterious to wild stocks. Straying is most probably related to imperfect imprinting of smolts, as well as to suboptimal smolt quality. Massive studies on these problems are currently underway on the Columbia River to improve artificial cultural practices (Slatick et al. 1984), in Canada in planning enhancement strategies (Lister et al. 1981) as well as at all hatcheries in northern California operated by the Department of Fish and Game.

Utilizing stocks of salmonids not suited to the particular environment conditions in the watershed in question is a management decision having a genetic base. A recent example of genetic attributes that resulted in ineffectual planting of steelhead was reported by Smith (1985 and Personal Communication). Mad River steelhead released into streams in the Monterey Bay area were found to migrate during late spring months as is characteristic of the stock in northern California. Rivers in the release area, however, are intermittent or dry except during exceptionally heavy winter storms. Thus, no flows existed in the lower reaches of the planted watersheds when the Mad River smolts migrated to sea and all the fish presumably perished. Native surviving steelhead stocks in California coastal areas south of San Francisco are maintaining themselves by migrational behavior by both adults and down-stream migrants adjusted to in erratic, altered, and manipulated stream flow regimes of the region. Gene pools for steelhead enhancement in watersheds under stress and devoid of native stocks would better come from southern stocks rather than northern stocks which are adapted to conditions associated with more normal environments.

There also may be behavioral aspects under genetic control associated with ocean distribution and migration of salmonids (Allen 1966). Ocean migrational behavior in only now being slowly unravelled through analyses of the recoveries from millions of coded-wire tagged fish released during the past several decades. Perhaps greater emphasis should be placed on analysis and publishing results of all presently existing data as reported in the PMFC mark list. Such information would allow all culturists to have a common data bank on stock behavior in the ocean upon which to make operational decisions.

A careful reading of the reports on experimental work on potential problems with the "genetic pollution" of wild stock with hatchery stock indicates the need for changes in hatchery practices where hatchery-wild stock interactions have been shown deleterious (Reisenbichler and McIntyre 1976). Smith's (1979) outline of the historial events that have lead to the decline of up-river Columbia River stocks should be compared to the opinions of Bakke (1983) who suggests a deliberate management policy for rearing lower river fall chinook stocks was to blame. However, Wahle et al. (1981) suggest that the genetic variability of spring chinook stocks remaining in the system can be the basis for improved hatchery operations and have suggested the same for coho (Wahle and Pearson 1984). The conflict with wild and hatchery stocks in the highly modified Columbia River basin may be unresolvable, but perhaps in the highly discrete north coastal drainages, delineation of ocean distribution and migration patterns of local stocks could be a basis for management action. Thorpe (1980) noted that time and release strategies perhaps could have fish remain in an area most favorable to the culturist. Heredity or environment (Larkin 1981)?

Non-Technical Factors

Continuity of Program

The number of instances where a planned fish culture activity has resulted in instant success are rare. Some dramatic successes have resulted from transplanting Pacific salmon (Great Lakes, New Zealand). Such transplant successes must be placed against the huge number of other attempted transplants that have failed (Courtenay and Stauffer 1984). For example, a continuous effort has been made over at least six decades to establish Pacific salmon runs to southern Chile (Davidson and Hutchinson 1940 where freshwater and ocean conditions appear to be at least as favorable as those around the south island of New Zealand where successful introductions have occurred. On the west coast of North America unqualified instant fish culture successes with coho and chinook salmon appear mainly to be associated with sites or drainages that are barren of salmonid populations, or are located directly on or near the open ocean. Successes inland are usually associated with a long period of persistent work to develop a strain of fish that performs adequately both under the specific environmental conditions of the culture station, and the freshwater estuarine, and ocean environments encountered by the smolts. Initial successes can be followed by declines due to the natural invasions of diseases, parasites, predators, etc. to exploit the newly created culture environment. These natural factors then in turn have to be understood for proper management and control. Thus emergent salmonid culturists entering into enhancement or restoration work via fish culture activities should expect that initial efforts may show promise but it probably will require many years before there are consistent results. "Success" should be defined in some realistic terms as previously discussed. For example, the run to the University of Washington hatchery beginning in the fall of 1951, was less than 250 coho and chinook adults combined for over a decade. Now 30 years later the number of returning adults varies between 3,000 and 8,000 fish with all five species of Pacific salmon and steelhead trout (Hines 1975). From an educational and research viewpoint this is a success. From a production viewpoint, it is a success, both in numbers and weight. A formal economic benefit-cost analysis based on contributions to the fisheries for comparison with other stations for which such data have been published would now be a study of great merit in providing economic data necessary for overall benefit-cost evaluations.

Fisheries Management

Although citizens jointly own the anadromous salmonid resource as a "common property", the ownership and uses of the resource are defined by treaty obligation, and by law and policies passed by federal and state legislative bodies and administered by designated agencies. Thus local California programs that are operated by non-state personnel will have to be congruent with fisheries management policies and administration to avoid unnecessary conflicts.

In any newly emerging program, however, there will occur management decisions that initially might appear arbitrary or overly restrictive on local cultural operations (Larkin 1981). I believe a case history might be useful in discussing how a local enhancement program based primarily on artificial propagation can supportive of state salmonid management obligations. The Humboldt Fish Action Council put into operation in the fall of 1983 a permanent fish trapping weir on Freshwater Creek, Humboldt Bay. This facility is part of a long-term enhancement program that started as rearing of coho salmon in ponds located on Cochran Creek, a small stream entering Humboldt Bay north of Freshwater Creek. For a number of years returning adults were trapped in Freshwater Creek by a temporary weir, with eggs incubated and reared to fingerling stage by the Prairie Creek hatchery. Fingerlings were then transferred to Cochran Creek ponds for rearing to smolt size and eventual release into Freshwater Creek. Operating agreement for trapping on Freshwater Creek was for an escapement of 50 percent past the trapping site. This undoubtedly occurred with temporary weirs that routinely washed out with high waters. The permanent weir was designed so that a series of panels, which constituted the weir, could be lowered quickly when high waters brought unmanageable amounts of debris against the panels, then quickly elevated when flow conditions allowed. The system was meant to effectively intercept the run into the creek.

Initial operations in 1983 brought the usual array of mechanical difficulties, most of which were overcome for the 1984 run. In fall 1984, there were 18 days when the weir was not in operation due to high flows that required lowering of the panels and thus allowed for fish passage (Figure 5). Panel lowerings were associated with increasing flows from major storm events when trapping was intercepting the initial surges of fish migrating upstream. Thus the unknown percentage of the fish passing during peak flows with the more efficient trapping system could be of management concern. From the period 2 November to December 21, when the major coho run was migrating upstream, there were 50 total fishing days. With 153 fish actually trapped during this period, the total run during the period probably was around 239 fish (or 36 percent escapement). I estimated the total run size during the 50-day period by a second method. Assuming a normal distribution of numbers of fish passing the weir, with peak of the run around 25 November, I calculated graphically the area under a theoretical curve drawn freehand for those days fished and not fished. This method suggested about 40 percent of the fish escaped past the weir. Both estimates are short of the facilities general operating agareement of 50 percent escapement. Such a shortfall might be a cause of administrative concern, but considering all uncertainty factors probably would be hard to judge negatively. One uncertainty factor is that of the actual summer rearing capacity of the Freshwater drainage for steelhead and coho salmon (and possibly chinook salmon) The most reasonable escapement goal would only be that needed to produce egg deposition sufficient to fill the juvenile summer carrying-capacity of the system.

There are data for a preliminary review of the question. The total run into Freshwater creek in 1984 was in excess of 250 coho salmon. For a stream of comparable size located on Humboldt Bay (Jacoby Creek) Harper (1980) estimated a total run of 123 adult coho salmon (95 percent confidence interval 82-164) in 1977, including 22 coho salmon from Jolly Giant creek releases (Miyamoto 1979). Harper estimated 5,000 smolts from natural spawning was produced by the Jacoby Creek drainage in 1977. Assuming a 1:1 sex ratio, an average fecundity of 2,500 eggs per female, and a run of 100 coho, an estimate of life history parameters would be: survival egg to adult: 0.08 percent, and from smolt to adult 2.0 percent. these values suggest that perhaps 100 fish may be a minimum escapement needed. To proceed further we should know catch of the fisheries, and the contribution to the escapement from artificial propagation and from natural reproduction in order to make a more formal management plan for operation of the weir and the culture program.

A number of actions are suggested by the operation of the 1984 artificial propagation facility on Freshwater Creek:

1. Monitoring yearly variations in run timing. It would have been very interesting to have seen of the late March-April run of coho into the Jacoby Creek drainage also occurred in Freshwater in 1984.

2. Estimating probable normal range of adult anadromous salmonids required to seed the watershed by natural spawning to form the basis for determining the escapement percentage and its eventual administration with fluctuating run sizes.

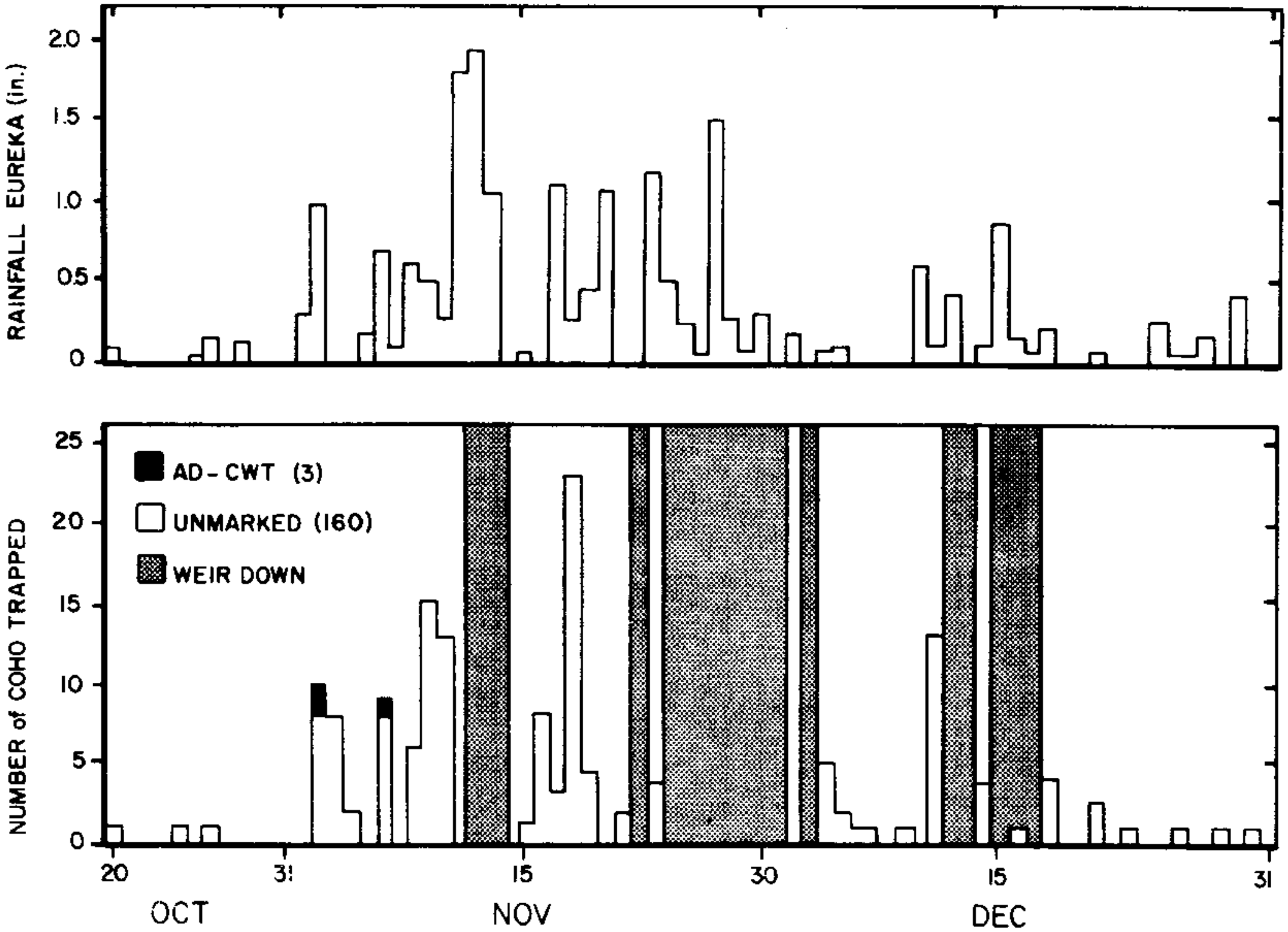

Figure 5. Daily Rainfall and capture of adult coho salmon by Humboldt Fish Action Council weir and trap located in upper estuary of Freshwater Creek, Humboldt Bay, California, fall 1984.

3. Determining the contribution of adults from fish cultural operations compared to adults returning from natural reproduction by marking at least a portion of all artificially produced smolts released into the creek.

4. Counting out-migrating smolts as part of studies on drainage carrying capacity by operation of a smolt trap at the present weir site.

Such a program will require additional manpower and funding, and certainly needs to be done for evaluating the program. Initial restrictions on evaluation and research work using California restoration funds need reappraisal as noted by Hashagen (1984). In addition such stream-specific information, the presence of the permanent weir on Freshwater Creek (apparently operating successfuly for trapping adults on this not-too-large drainage) presents a major opportunity for management to obtain escapement data that are notoriously difficult to obtain (Hilborn et al. 1984). Thus, all adult counting or collecting facilities operated by citizen-based enhancement program have a similar potential to provide increasingly more accurate and comprehensive data on adult escapement. These data can then become increasingly valuable for better management decisions.

In summary, enhancement practitioners should expect some sort of constraint and direction based on legitimate management concerns. For those interested in understanding what this task looks like from atop the hierarchy, I strongly urge reading Schoning (1984), Wright (1981), and papers by Larkin. Of solice to citizen-operated propagation projects is the fact that smaller streams that flow directly into saltwater present less chances for management conflicts and problems of evaluation than for operations further conducted inland on larger streams and rivers.

Environmental Impacts

Recent economic thought and theory have been focusing on impacts of governmental actions or policies that have negative consequences (Derived Externalities) (Wolf 1979). The term, of course, has come from the term "externality" used in studies in analyzing negative environmental impacts by private enterprise activities not measured by operations of the market place. Thus it seems highly likely that fisheries management activities involving fish releases and stream alterations may require closer conformance with the California Environmental Quality Act. I would think this especially so if releasing of cultured fish at the wrong time, size, and place leads to decreases in existing self-perpetuating stocks of anadromous fish, and if, in fact, such releases result in "genetic pollution", however defined (Hashagen 1982). Although probably somewhat a bother to action-oriented programs, all programs could benefit by having mutually acceptable definition of terms that would reduce the appearance of arbitrary decisions. The EIS process could gradually lead to the development of workable fisheries-developed guidelines, including procedures for the "negative declaration" where no appreciable impacts appeared likely. It could also lead to a consistent and unified California program that could bear judicial and legislative review.

A cursory survey of north coastal California hatcheries suggests that at least three existing operations may involve stock management issues that could conceivably fall under CEQA review (Mad River - fall chinook stocks in north fork and mainstem of Mad River; Rowdy Creek - unique late-running fall chinook stock; Prairie Creek - wild stocks eminating from Prairie Creek State and National Park waters) (Table 9). Because of the obvious need to address a variety of impact issues, Arcata included a major section on artificial propagation in an EIS developed for a Pilot Project Marsh experiment

Table 9. Stock/hatchery considerations associated with seven artificial propagation programs in northern California hatcheries.

Hatchery	Location on river system	Salmon or steelhead stocks intercepted in initial operations
Iron Gate	Mainstem below impassable dam	Local upstream migrating stocks.
Trinity River	Mainstem below impassable dam	Local upstream stocks.
Mad River	Mainstem near mouth	Trapped local stocks and in mainstem and tributaries, and used stocks from other drainages.
Rowdy Creek	Mainstem near mouth	Trapped local stock.
Prairie Creek	Mainstem, middle of drainage	Trapped stocks in mainstem and tributaries and reared stocks from other drainages.
Arcata	Estuary (Butcher Slough)	No stocks in creek; all stocks imported from outside Humboldt Bay drainage.
HSU	University campus	Not involved in anadromous stock interception.

(Environmental Analysts 1979). This EIS and EIR process was taken well in advance of any large-scale aquaculture development which would only be made possible by the successful results of a pilot-project study on the consistency to be expected in maintaining water quality through artificial marshes. In summary, the EIS has been a most valuable tool for focusing attention on negative impacts on fisheries values from land-based activities. The same procedure cannot be avoided for water-based activities. During planning of artificial propagation activities in enhancement programs we should welcome such analyses and reviews that are needed to avoid operational short comings or undetected impacts of major consequence.

Evaluation

Evaluation of enhancement efforts requires a long-term committment simply because of the life cycle of the salmon. The shortest life-cycle is that of the coho salmon -- basically one year in fresh water and two years in the ocean. Thus data on ocean recoveries and escapement to fresh water for coho only become available from management agencies beginning in the fourth year. Time is required for analysis, report writing, and then review by peers and administrative authorities. Chinook life cycles extend the time for complete evaluation of programs to at least five years after initiation of a project. Similar time frames for evaluation are inherent in all anadromous salmonid enhancement programs, whether culture-based or habitat-based (Reeves and Roelofs 1979). Evaluation is thus based on integrity and dedication of program leadership that must continue over evaluation periods measured in decades. Where vegetative processes on land coupled to physical process in the stream are to be evaluated, even longer time frames are required. Thus if a artificial propagation related program is integrated into a watershed program, evaluation time frames are even longer (Hassler 1984; Platts 1984a).

The Arcata wastewater aquaculture program can provide an example of evaluation processes. Pilot project studies were required to document activities and results under for both the Sea Grant program, and the California Department of Fish and Game for compliance under Wildlife Conservation Board program objectives, (Allen et al. 1972). Additional periodic reporting of pilot-project studies were submitted to Sea Grant and reporting continued under city funding and administration (Allen 1982, 1984). The most recent reporting was for the initial construction and development of a hatch-box program on Jolly Giant creek as prepared for the 1983 restoration conference. Since the Arcata effort started formally in 1963, the project is 22 years old, with the original aquaculture plan requiring at least another five years before a complete physical facility has even been constructed. Extensive and continued documentation of objectives, results, and future plans have been extremely helpful in program continuity, administrative support, and funding.

In the short-term, exchange of information at annual conferences, seminars, workshops, etc. are extremely valuable for providing the stimulus of new ideas and improvement of technical operations. In the long-term, evaluation over decades requires adequately prepared formal documents adequately stored and catalogued (Wiley 1984). Well designed and appropriately operated local projects should not fear thorough evaluations. Although not made explicit, Deans (1984) suggesteed that highly motivated local project operated with volunteer staffing may have better benefit-cost ratios than larger, high-technology approaches. Establishment of such comparative data should be high priority for the citizen-based restoration program now underway in California. Of solice to citizen-operated programs on drainages with no existing runs is that fact that evaluation will be made simpler by not having a mixture of hatchery and wild stocks in the freshwater environment. Should a site be selected with no existing runs, at least any returns represents some degree of progress!

ARCATA PROGRAM

Anadromous salmonid culture techniques used in the Arcata urban aquaculture and fisheries program are described in detail in Allen (1984). A brief description of the history and operating success of these facilities may be useful to illustrate some of the technical and non-technical constraints involved in restoration of anadromous salmonid populations using artificial propagation techniques.

Wastewater Culture System

History of Development

The Arcata wastewater aquaculture program grew out of a search for a point-of-return for anadromous salmon artificially propagated as part of the educational program in the fisheries department at Humboldt State University (Table 3). DeWitt and Salo (1960) described the HSU hatchery facilities. The hatchery has changed little since 1956 except for the addition of a scaled-down Burroughs pond and installation of a series of 500-gallon redwood tanks for fry rearing. Chinook salmon was the first species cultured in the hatchery (Hayes 1960). This work was part of studies undertaken by Humboldt State College for the California Department of Fish and Game in response to citizen requests for installation of tidegates on Big Lagoon. The requests had been made to the California Wildlife Conservation Board, supposedly to improve fish passage and thus enhance lagoon fisheries. HSU (then college) undertook research on the biology of the salmonid populations of the lagoons as part of the assessment of the proposal. This work was supervised by Dr. E. O. Salo, currently with the College of Fisheries, University of Washington. Fall chinook salmon from the Green River (Washington State) hatchery were available for studying rearing capacity of the lagoon. Every tray and pond at the HSU hatchery was bulging with fingerlings by planting time. On 2 May 1958, 66,000 were released into the Big Lagoon system, followed by 77,000 on 21 May 1959 (Hayes 1960)[1]. Survival and growth of the salmon were followed by seine and gill net sampling in both 1958 and 1959. Both years experienced a delay in the natural breaching of the sand spit of the lagoon from lack of rain (Hayes 1960). A few chinook got into the ocean when the lagoon was briefly opened by hand in 1958, but all disappeared in 1959 before the lagoon opened in late winter. The Green River chinook stock was adapted to an estuarine rearing habitat where there was a guaranteed passage to saltwater but was ill-adapted to the vagaries in openings that can be experienced by northern California lagoons. Needless-to-say, the program of breaching the sandspit at Big Lagoon was dropped. Although I was not directly involved in the study, I followed it closely, often catching fin-clipped chinook as "trout" when fly fishing in the lagoon. My interest, however, in culturing salmon continued after these studies were concluded, and focused on the need for a "home-stream" for anadromous species that could be used in the university educational program.

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[1] In retrospect we now realize this was the waning years of an El Nino period.

I have no written record of when I made a decision to seek an aquaculture system on the mud flats of Humboldt Bay inside the periphery of the Arcata oxidation pond (Allen 1984). In retrospect, however, there were a number of ideas that undoubted were involved in the decision:

1. An oxidation pond had been constructed by the City of Arcata to provide initial treatment to domestic sewage historically discharged directly to Humboldt Bay. The pond was huge in comparison to the population then being served (55 acres for 5-7,000 residents). The pond was needed to protect a newly established oyster industry leasing state lands in north bay.

2. The water quality in winter of the new lagoon was adequate to support salmonids due to the relatively low flow of sewage in relation to the huge amount of rainfall that infiltrated into the sewage collections system. This early work on the lagoon was conducted by DeWitt (1969) and his students (Hansen 1967; Hazell 1963).

3. The Danish trout industry had been competing successfully with the American trout industry. Many of the operations used brackish-water rearing techniques. The trout were held in an environment that was isotonic to the fish's blood. Hence, more of the food fed was being used to produce flesh, rather than as energy to regulate the ionic concentration of the blood and other body tissues.

4. The oxidation pond was located near a number of degraded, and at that time unappreciated, streams that conceivably could be used as points-of-release for smolts reared in the ponds, and as a possible point-of-return for adults.

The California Department of Fish and Game, Wildlife Conservation Board provided funds for capital construction of pilot project ponds in 1969 (Allen et al. 1972). Where the adults might return from smolts produced in initial pond-rearing experiments was not of concern in planning the project, since development of the juvenile rearing program was in itself sufficiently intriguing to proceed. Adults from early smolt releases did return to the creek, with returns monitored by seining or electrofishing. A temporary weir on tidewater followed, with a permanent weir now located two miles inland. A creek restoration program is now sufficiently developed that Arcata is now asking the California Fish and Game Commission to give the creek special status for its research and educational values.

From the beginning, however, a hatchery system, however, had to be available to support the planned project. Although it might have been possible to obtain eggs by removing ripe female fish from local spawning beds and to have built on-site temporary hatching and fry rearing systems, I suspect enough opposition on political and technical grounds would have caused problems. Thus, the availability of local fingerlings for initial work supplied by California Department of Fish and Game hatcheries, and then being supplied with eyed-eggs which were incubated and cultured at the HSU hatchery, were all indispensable to carrying out early pilot-project operations. The support of state and other local hatchery facilities continues to be the essential back-up for the current demonstration phase of the Arcata project since we have not yet been able to develop a self-sustaining cycle from the number of eggs recovered from returning adults at our present levels of smolt production.

Facilities

The Arcata hatchery operation (Allen 1984) now has the following standard hatchery facilities:

1. Two banks of Heath incubator trays (total trays 18) operated with Arcata tap water.

2. Four 1,000-gallon aquaria for rearing yolk-sac fry and swim-up fry, operated with city water, bay water, or pond waters as needed. The tanks have also been used to hold maturing adult salmon and steelhead.

3. Egg-collecting station at the trap located two-miles inland on Jolly Giant creek.

4. Seven ponds totalling about 1.8 acres.

The final facilities needed to complete a salmon culture system based primarily on wastewater reuse is a fishway and holding pond for returning adults. Jolly Giant creek is too small to handle runs of fish of the magnitude foreseen for the level of operation envisioned (Allen 1977). Thus the creek is being developed to support a small run based on natural spawning and to have traps that will recover adult fish straying from the planned wastewater operated fishway (Allen 1984, Figure 6). Development of the fishway and holding facilities has had to wait for completion of an up-graded and improved sewage treatment system which is now under construction. Wastewater for initial studies on imprinting smolts and eventually attracting adult salmon should be available within two years (Allen 1984, Figure 5).

Stream Restoration

The first major effort at an urban stream improvement program by the City of Arcata Department of Public Works centers on Jolly Giant Creek. This is a unique effort to integrate public works and fisheries needs. Natural erosion plus land-use disturbances on the upper Jolly Giant creek watershed annually deposits sediments in the uncovered, unchannelized sections of the stream (Allen 1984). With low flows and long periods of sunlight in summer, heavy emergent aquatic plants quickly fill the stream channel, which in turn traps sediments carried down with the next high flows. City funds have been routinely budgeted to remove sediments by backhoe from those sections of the stream where accumulations have filled the channel to the point that residential flooding is possible. The city is now studying sediment basins to sequester and remove channel sediments. The sediment basin program developed by chance. A bypass channel and sediment basin was constructed to protect a fish trap located on the upper reaches of Jolly Giant creek from peak flood conditions (Allen 1984, Figure 4). A concrete headworks was designed so that water could be shunted into the by-pass channel using a 10-inch high I-beam. The headworks and basin system trapped bed load so effectively that protection is now being afforded to experimental spawning gravels placed in an approach channel to the adult fish trap. An initial stretch of gravel about five meters long installed in 1983 (lower redd, Figure 6) successfully incubated rainbow trout eggs contained in Vibert boxes (Nemeth 1983). In 1984, a second gravel bed (about 3 meters long) was added (upper redd, Figure 6), and a cement-concrete block water level control unit constructed at the lower end of the gravel bed developed in 1983. Gravel depth was less than a foot and channel width averaged about 1.5 meters.

During November-December 1984, nine female coho salmon (Figure 7) spawned totally or partially on the two small sections of the artificial spawning bed (15 and 10 feet in length, Figure 6). We observed a spawning density of two females per section of gravel before reuse of the beds suggested superimposition of eggs and we began removing adults from the creek. We estimated about 11,000 eggs were deposited (Table 10). The

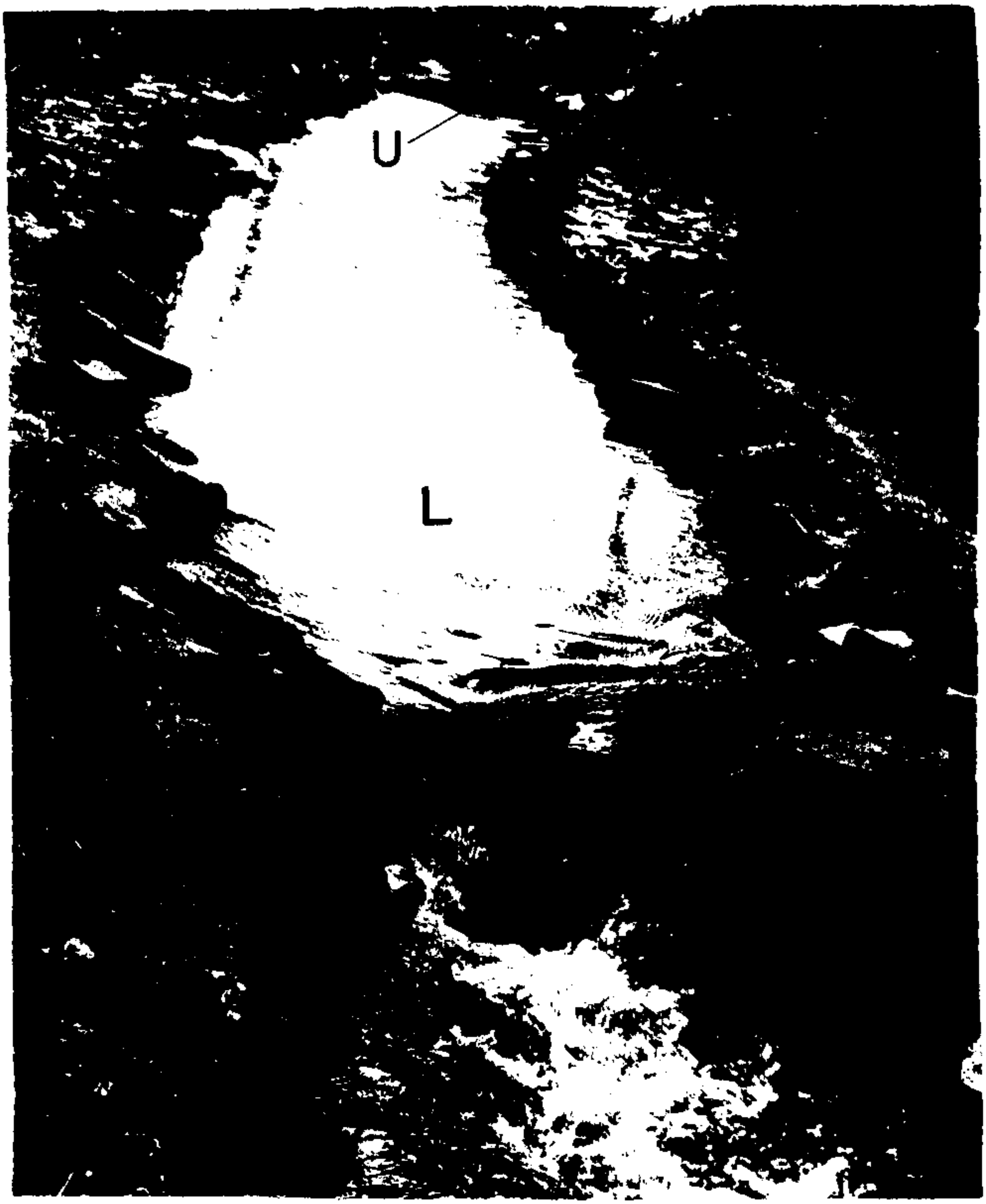

Figure 6. Artificial spawning channel, Jolly Giant Creek, late December, 1984 (U upper redds; L lower redds).

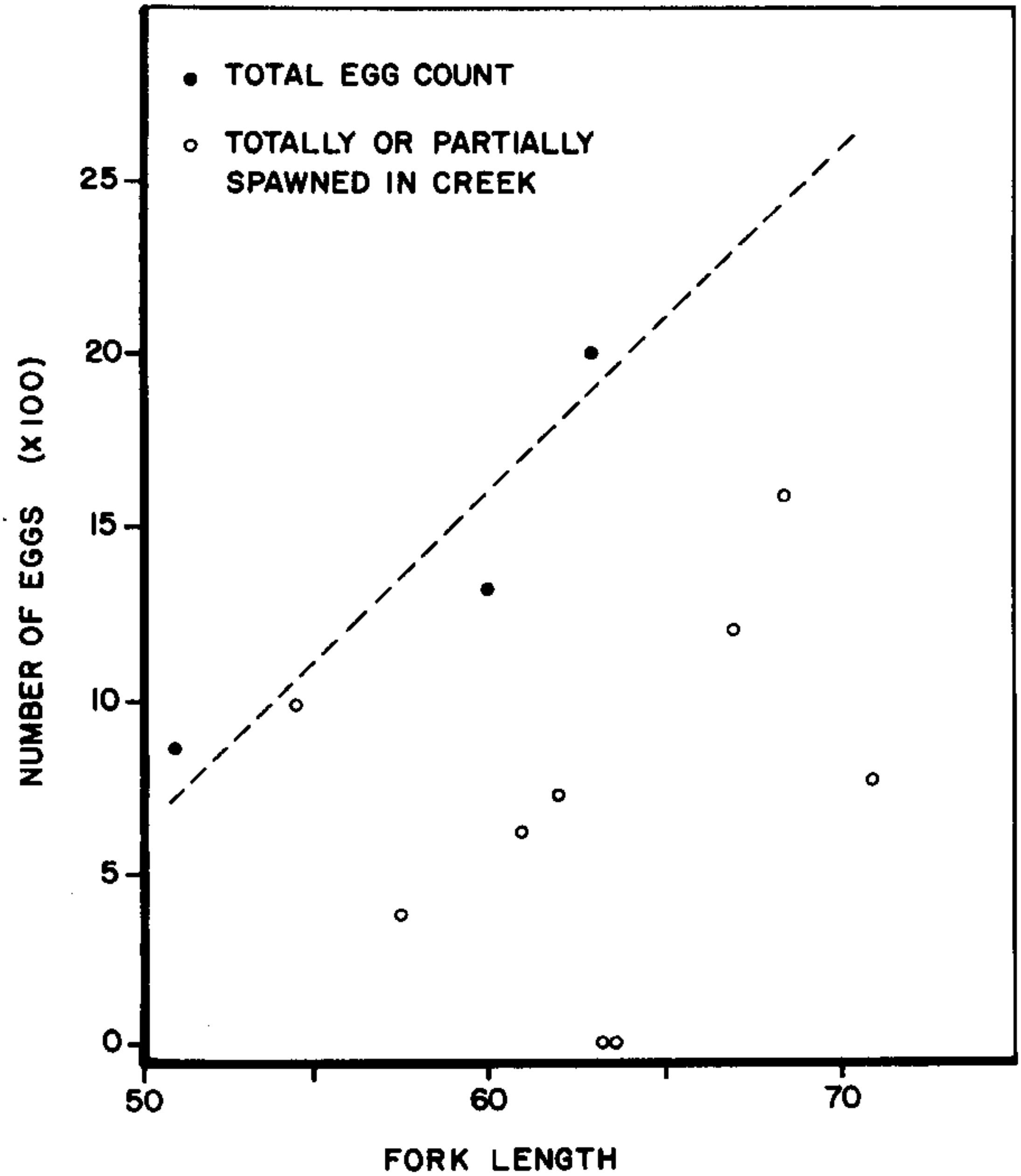

Figure 7. Number of eggs in female coho salmon (1981-brood, Iron Gate stock) recovered from Jolly Giant creek 1984.

Table 10. Fecundity and place of incubation of eggs from 1981-brood year female coho salmon (Iron Gate stock) returning to Jolly Giant Creek, fall 1984.

Factor and Unit	Value
Total number females recovered	12
Mean fork length in centimeters	61.5
Number of eggs recovered for hatchery incubation (hand count, 10 egg lots)	10,600
Estimated number of eggs deposited in spawning channel (from regression analysis Figure 4)	10,400
Total estimated number of eggs in run	21,000
Average number eggs per female	1,750

overall length of the channel available for additional artificial spawning beds is about 48 meters (160 feet). At least six other patches of spawning gravel can be placed into the channel in such a manner as to leave space for "fish refuges" between spawning areas. Thus our spawning bed should be able to receive, without appreciable re-digging of gravels, the eggs from around 15 coho females. At an average fecundity of 2,500 eggs per female, the approximately 500 cubic feet (250 square feet) of 2-3 inch gravel could incubate easily about 40,000 eggs. Jolly Giant creek in its present condition probably does not have summer rearing habitat to allow for the production of more than a few hundred smolts which would not be sufficient to produce the escapement of 30 adults to utilize the beds fully. Plans for constructing an off-stream rearing pond to substantially increase summer habitat in the creek have been developed and have been submitted to the California restoration program for funding.

Both the 1983 study of sedimentation using trout eggs in Vibert-boxes (Nemeth 1983), and present study in 1984 using naturally spawned coho eggs, have occurred during periods of very low rainfall (December-early February periods in both 83-84 and 85-85 study years). Ability of this by-pass channel and sediment basin to protect incubating eggs from sediments associated with severe flood conditions has yet to be tested fully.

The spawning bed developed within the by-pass channel off Jolly Giant creek is similar to major facilities being developed by the California Department of Fish and Game for chinook salmon in the Sacramento River (Parfitt and Buer 1981). Sediment trapping units in advance of rearing ponds, spawning beds, or fish traps may be the key to maximizing the effectiveness of artificially constructed and managed by-pass channel facilities in small drainages.

System Results

The initial culturing of fingerling coho salmon occurred in the Arcata ponds in July 1971, with total mortality of fingerling within three weeks of introduction into the ponds (Allen and Dennis 1974). Pilot-project operations over a five year span finally improved culture success and resulted in our first significant return in the fall of 1977 (Miyamoto 1979) (Figure 8). About 0.5 percent of the smolts planted could be accounted for in the combined escapement in 1977 to Jacoby Creek and Jolly Giant creek. Since 1974-brood smolts were marked only by single-fin clips, there was no opportunity to examine ocean contribution or distribution because single-fin marks were not being recorded from samples of the catch in ocean fisheries. Our next successful adult coho return seemed likely for 1980-brood smolts released in spring 1982. Six single-fin marked coho jacks were recovered at the Jolly Giant trap in the fall of 1982. The fall of 1983, of course, was a low salmon year coastwide due to El Nino conditions (Pacific Fishery Management Council 1985b). No marked adults were seen or trapped in Jolly Giant creek or recovered elsewhere. Fortunately our project had been provided eggs from the 1981-brood returning to Iron Gate. Smolts reared from these eggs were marked with adipose-coded wire tags (Ad-CWT) and released in the spring of 1983. Two jacks (unmarked) were recovered in fall 1983 trapping. Ad-CWT marks began began showing up in CFG sampling of the ocean coho season in late August 1984. Three Ad-CWT salmon were next reported taken at the Humboldt Fish Action trap on Freshwater Creek in early November (Figure 3). Almost simultaneously two marked fish were recovered in Jolly Giant creek (one trapped, one captured by elecro-fishing). With heavy rains in November (15.5 inches) which extended into early December, a total of 23 coho salmon were either removed from the artificial spawning grounds, from other areas of Jolly Giant creek, or were taken in the trap. In February 1985, an additional Ad-CWT fish was taken in Janes Creek. Details of these recoveries are listed in Table 11. Escapement to Jolly Giant Creek of 1981-brood cohosalmon was about 0.5 percent of smolts released (Table 12). Contribution to ocean fisheries was low, and mark recoveries were confined to marked fish reported only from the Eureka statistical area. No marks were reported for areas outside California.

System Analysis

Although the Arcata system has presently advanced to the initial phase of a Demonstration Project the 1981-brood year results provided enough data to undertake a preliminary evaluation of our system based on parameters used in initial planning document (Allen 1977). The feasibility study was based on an assumption that 40 tons of salmon captured at the Arcata site represented the minimal amount needed for a viable small private-enterprise operation as suggested at the World Aquaculture Conference in Kyoto, Japan in 1976 (Pillay and Dill 1979). I used a range in parameter values to determine if sufficient pond rearing space was available at the Arcata wastewater aquaculture site to rear smolts for an operation of the size stated. Some of the values used in the feasibility study and values actually found for the 1981-brood year are compared in Table 13.

Average weight of adult 1981-brood coho (6.0 pounds) was minimal since no correction was made for eggs lost by 10 of 12 female fish that had partially or totally spawned in the creek before capture. The average size of adult coho returning in 1977 was about 8.4 pounds (Miyamoto 1979). Thus a two year average is near the 7.5 pound value used in planning. The highest smolt-to-escapement survival rate used in the feasibility study was 0.5 percent, which is that found for the 1981-brood year. This value

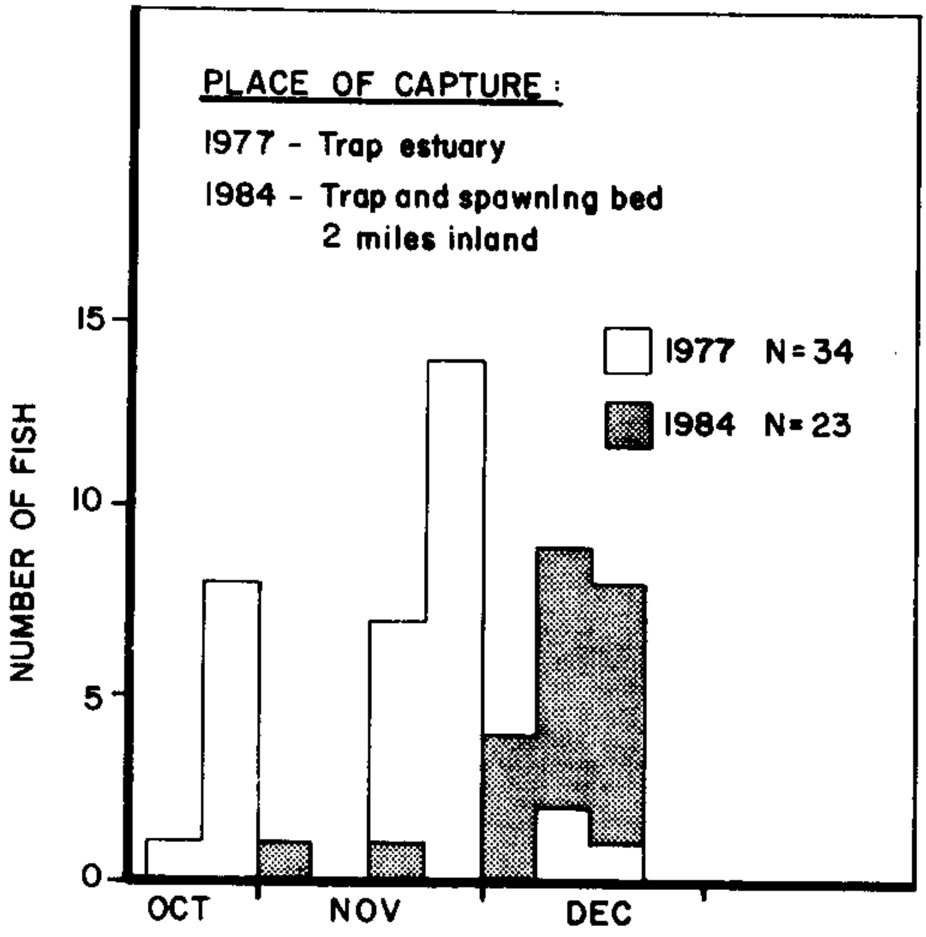

Figure 8. Time of entrance of adult coho salmon into Jolly Giant Creek, Humboldt Bay, California, 1977 and 1984.

Table 11. Actual and total calculated recoveries in 1984 of Ad-CWT and unmarked (UM) 1981 brood coho salmon Iron Gate stock released into Jolly Giant Creek Spring 1983.

	Number of salmon			
	Actual		Calculated	
Recovery location	Ad-CWT	UM[1]	Ad-CWT	UM
Ocean fisheries	2	-	6	2
Freshwater Creek	3	-	5	2
Jacoby Creek	-	-	7	2
Janes Creek	1	-	2	0
Jolly Giant Creek	17[2]	6	17	6
Total	23	6	37	12

[1] Unmarked 1981-brood coho salmon reared in wastewater ponds contributed to smolt production from grade-outs released into Klopp Lake, an experimental group of pond-reared smolts not tagged with coded wire, and a few early smolts found during tagging in the fall of 1982.

[2] A few early-run fish illegally removed from creek by juveniles.

Table 12. Percent return of coho smolts and catch-to-escapement ratio of 1981-brood coho salmon released into Jolly Giant Creek spring 1983 and recovered in 1984.

Comparison	Calculated minimal number of recoveries	Percent of smolts released
Escapement to four streams, Arcata Bay	41	0.8
Escapement, Jolly Giant Creek (point of release)	23	0.5
Catch-to-escapement ratio	0.2:1	

Table 13. Comparison of values for selected variables in Arcata wastewater aquaculture ocean ranching feasibility report and found for 1981 brood year coho release.

Factor	Planning Document (Allen 1974)	1981 Brood year
Average size of returning salmon (pounds)	7.5	6.0
Smolt survival release to escapement to facility (percent)	0.1-0.5	0.5
Catch-to-escapement ratio	2:1	0.2:1

is about the average rate of smolt-to-escapement rate experienced by northern California hatcheries (Table 8). How great local ocean conditions might negatively influence returns of smolts released into Jolly Giant creek are uncertain. The 0.5 percent return in 1977, also an El Nino year, was among the higher rates of return for California and Oregon coastal hatcheries. The largest difference in a planning parameter occurred in the catch-to-escapement ratio (Table 13). This probably was due to the restricted fishing season for coho based on concerns for depressing effects of El Nino ocean conditions (PFMC 1985a) Fishing restrictions that resulted in more-than-expected wild coho returning to Oregon coastal streams (Anon 1985d) could account for the low catch to escapement ratio for the 1981 brood.

From the viewpoint of planning for successful operations as a private venture, initial results from demonstration phase activities completed so far at Arcata still suggest that the project should be able to pay for its operation. For the educational and research opportunities afforded the university, the integrated Arcata system has been a success (Allen 1984, 1985). The State Water Quality Control Board recognized the educational benefit associated with elements of the project (Gearheart et al. 1983; Allen 1984, Appendix III). A major future benefit will be the increased harvest by commercial and sport fishers expected when Arcata undertakes larger smolt releases upon completion of the wastewater-based fishways and holding ponds as noted previously. At least five years will be needed to determine the degree of homing precision of adults to a wastewater-operated fishway prior to initiating major increases in smolt production and release.

These hatchery-based artificial propagation efforts plus the urban stream renewal work on Jolly Giant creek should lead to valuable information on small stream restoration techniques applicable for general use by the California Steelhead and Salmon Restoration Program. Our results illustrate also the degree of program continuity that citizen-based programs should plan for, and for incorporating multiple values to be served in an artificial propagation program.

MANAGEMENT CONSIDERATIONS

Jolly Giant Creek

There are additional biological concepts of general interest provided by the results of the 1984 coho returns that may have value to artificial-propagation based salmonid restoration in California. First, the good return of the transplanted Iron Gate 1981-brood coho stock is congruent with the long-standing knowledge that upstream stocks can be moved to downstream locations (Royal 1972). Second, although the entry conditions into freshwater are markedly different between the Klamath River and Jolly Giant creek, the coho salmon from the donor station (Iron Gate) were sufficiently adaptable in behavior to enter into the stream when conditions became favorable. Such behavior must be possessed by any coho stock in small coastal streams with entrances periodically blocked by sand bars formed during summer low-flow conditions. Similar upstream migrational behavior was shown by 1974 brood coho transplanted from the Noyo River (Miyamoto 1979) (Figure 8). Third, although the Iron Gate coho stock has undergone artificial propagation in the hatchery, the salmon appeared to behave normally in the natural environment of Jolly Giant Creek. Only three of the 23 fish recovered were trapped, the remainder all having to be removed from the creek, primarily on or below the artificial spawning ground (Figure 6). Most coho after moving into the creek in mid-November, sought refuge under banks, over-hanging brush, and holes below culverts. After maturing, adult coho moved onto the spawning gravels at times comparable to early-arriving local stocks. Fry were first observed emerging from spawning gravels on 13 March 1985. Fourth, the timing of the movement into freshwater appeared earlier than for native stocks as measured by runs intercepted in the upper estuary of Freshwater Creek (Figure 5). An early time-of-return was found by Miyamoto (1979) for the 1974 brood Noyo stock coho as compared with naturally-spawned fish returning to Jacoby Creek in 1977 (Harper 1980). Both 1977 and 1984 results are congruent with trends for an earlier date of return for artificially propagated fish as compared to wild stocks in the same drainage as noted widely in the literature (Royal 1972). Whether hatchery or natural stocks were reproductively isolated, however, could not be determined, and so we could not but confirm the difficulties in assigning stock status to coho in small drainages (Ricker 1972). The role played by hatchery selection (breeding) as opposed to environmental conditions in 1981 coho behavior in the creek is not known. Fifth, the average length of the coho in the 1984 run to Jolly Giant Creek may have been smaller than other local coho runs as based on hearsay evidence. Fifth, the rate of return from a small release of smolts from the Jolly Giant creek operation was similar to that for large releases of smolts from Iron Gate (Table 14). Both groups of smolts were from the same brood year and stock (1981, Iron Gate). This result is not at variance with one of the assumptions listed in the evaluation of the British Columbia enhancement program - small operations have the same smolt survival rates as larger ones (Schowenberg 1984). Seventh, the timing of the run into Freshwater Creek in 1984 for coho salmon was very similar to that found for Jacoby Creek in 1977 (Harper 1980, Figure 19). The Freshwater run began December 5, showed peak migrations November 24 and December 10, with fish returning through early January. Eighth, Noyo River 1975 brood coho strayed into Jacoby Creek (18 percent of the run), which representing about a 40 percent homing error from Jolly Giant Creek. Iron Gate 1981 brood strayed into Freshwater Creek (0.3 percent of run), representing a 29 percent homing error to Jolly Giant creek (5/17 AD-CWT fish only, Table 10). In summary, the biology of 1981-brood Iron Gate coho returning to Jolly Giant Creek in 1984 reflects the facts that coho salmon are adapted to survival in small streams, display a remarkable ability for precision in behavior under favorable circumstances, and for versatility under adverse conditions.

El Nino Affects

Operators of anadromous salmonid culture stations have to understand how mortality is distributed between uncontrolled (environmental) and controllable (fishing) factors on their artificially propagated juveniles in order to better evaluate and manage operations. Assigning relative mortality is particularly difficult with changing oceanic events such as during years of abnormally high ocean temperature (El Nino conditions). By coincidence, major releases of coho salmon into Jolly Giant creek were associated with El Nino ocean conditions (1976-1977; 1982-1984). Comparison of the returns from these releases show some interesting results.

The PFMC is required to predict coho salmon population size in order to allocate catches to user groups. California is included in a management area called the Oregon Production Index (OPI) (Anon 1985a, p. 2). Prediction is based on a "jack index", a relationship between the number of precocious males (jacks) and production (catch plus escapement) the following year. Data for three brood years returning to Jolly Giant creek are compared with results for the OPI (Table 15). Jolly Giant creek and OPI were not at variance in 1977 and 1983, but were only partially correlated in 1984 (unmarked jacks returned but no CWT-jacks were recovered). Jack returns to both Jolly Giant creek and in the OPI were high in 1983, and logically should have allowed a prediction of the size of the adult population with a reasonable accuracy. However, adult production in OPI fell

Table 14. Rate of recovery of Ad-CWT marked 1981-brood coho salmon in California commercial and recreational ocean salmon fisheries from smolts released from three north coastal California hatcheries spring 1983.

Hatchery	Month smolts released	Number released	Number recovered in sampling of catch	Recovery rate[1]
Arcata	04	5,030	2	0.4
Trinity River	02	41,452	7	0.2
	02	38,491	4	0.1
	03	31,924	1	0.03
	03	32,692	1	0.03
	04	33,949	8	0.2
	Combined	178,508	23	0.1
Klamath River	02	19,042	5	0.3
(Iron Gate)	03	18,920	9	0.5
	03	19,335	8	0.4
	04	18,870	14	0.7
	Combined	76,167	36	0.5

[1]Number marks recovered per mille x 100 (recovery rates for groups of salmon planted in April underlined).

Table 15. Comparison of jack-to-adult returns for three brood years of coho salmon subjected to El Nino ocean conditions (Oregon data adapted from PMFC 1985a).

Year of Adult Production	Jack index previous year: Oregon[2] coastal (x 1000)	Jack index previous year: Jolly[3] Giant Creek	Number of coho: Oregon Production Index[1] (x 10,000) Expected	Number of coho: Oregon Production Index[1] (x 10,000) Observed	Number of coho: Jolly Giant Creek trap
1977	9.3	3	1.0	1.1	34
1983	9.0	6	1.6	0.6	0
1984	3.3	2	0.7	0.7	23

[1]Oregon production index includes: (1) ocean catches off public Columbia River, Oregon, and California; (2) Oregon and Cali-fornia coastal hatchery returns; (3) Winchester Dam counts; (4) gillnet catches; (5) Bonneville,Willamette, and North Fork dam counts; and (6) hatchery returns to the Columbia River below Bonneville Dam.

[2]See Footnote D, Table III-I, PMFC 1985a, for additional details.

[3]Two of these jacks recovered from Jacoby Creek. Very low flows occurred in Jolly Giant Creek in fall 1976 (see Miyamoto 1979).

to the lowest level on record. No adult coho returned to Jolly Giant creek. An extremely low incidence of jacks was recorded in the OPI in 1984, and a predicted low adult coho abundance in the OPI was realized. In contrast, a complete absence of marked jacks at the Jolly Giant fish trap in 1983 was paired with one of our better percentage returns.

A possible explanation for these results involves depressing influences on survival from El Nino conditions and reduced fishing pressure. Smolts entering the ocean in spring 1982 apparently were not impacted as seen by jack returns in 1982. The feeding adults, however, in the ocean in 1983 were severely impacted by warm ocean temperatures which were much above average (Fiedler 1984; Squires 1983). A greatly reduced ocean survival and generally poor physical condition in returning adults spawners was a widespread for coastal California and Oregon coho (PFMC 1984). Smolts entering the ocean in 1983 were expected to suffer below average survival, and for the general OPI index production continued at an historic low (Table 15) (PFMC 1984). Since jacks may be the faster growing individuals in a population (Allen 1959), smolts entering the ocean during unfavorable conditions should not be expected to produce a high jack return. I postulate that the high adult return to Jolly Giant creek in 1984 probably resulted from ocean distributions related to the occurrence of a small band of cold water that hugged the northern California coast in 1984 (Anon 1985c). A coho stock with a local distribution pattern off Eureka in 1984 would have escaped fishing mortality due to the 1984 fishing closures off northern California imposed for conservation purposes. Jolly Giant creek coho appeared to have such a distribution based on ocean tag returns. It is possible that the good return to Jolly Giant creek in 1977 also may have been aided by a reduced local fishing pressure due to unprofitable levels of coho in the Eureka area in 1977.

Culture Opportunities

Analysis of the coho returns to Arcata, however tentative, suggests that enhancement and restoration schemes for north coastal salmonid stocks carried out by artificial propagation methods might be creatively programmed to benefit local fisheries by use of coho for the following reasons:

1. Coho are typically adapted to small streams and thus suitable for community-based programs using "back-yard" facilities.

2. Coho do not migrate as far in the ocean as chinook due to a shorter life cycle, and thus more likely to be harvested by local users.

3. Coho may tend to remain closer inshore along the northern California coast than chinook during their ocean existence. This may afford some protection from heavy off-shore fishing for chinook.

4. Citizen-operated coho culture projects in "back-yard" urban streams should have strong local support and continuity.

5. Development of locally-feeding coho stocks would be a method to avoid ocean harvest by coast-wide management strategies based on conservation considerations for non-California stocks (Anon 1985b).

6. Breeding and culture strategies using local stocks as recommended for genetic reasons would be most easily achieved with coho where stock concept may not be as critical to local management as chinook (Ricker 1972).

7. Coho stocks have been managed to utilize native tendencies to remain within large bays and estuaries such as Puget Sound, Washington. Thus, San Francisco Bay and perhaps smaller bays such as Bodega and Humboldt Bay, would be amenable to similar programs of artificial propagation in California to develop bay-feeding coho populations.

In contrast chinook salmon have advantages for artificial propagation. Foremost is a much shorter freshwater residence (i.e. out-migration peaks in June and November periods). Chinook, however, appear more adapted to larger drainages or drainages having an extensive estuary. Late-migrating fall chinook stocks from drainages emptying directly into or near the open ocean, however, would be particularly well-adapted for expanded chinook programs along north coastal drainages.

All Pacific salmon are quick to exploit optimal environment conditions (resiliency), and some authors consider chinook the most resilient (Healey 1985). Thus, if the current lack of surplus chinook eggs should be alleviated by ocean harvesting restrictions now underway, some locations might offer optimum sites for restoration work with chinook.

EPILOGUE

The title of a very recent article in the January 1985 issue of Audubon magazine "Blowing Up Dams" just cried out to be read (Johnson 1985), especially for those familiar with the rise and demise of Sweazy Dam on the Mad River. After completely filling with sediment during its second year of life, Sweazy Dam impeded fish passage, especially salmon, due to an inadequate fishway. Johnson writes about the Savage Rapids dam on the Rogue River and how the dam is now seriously being considered for removal. A major point in Johnson's article was that the gain from reduced fishery losses by removing the structure and its fishway and to provide irrigation water by pumping, as determined by benefit-cost analysis, is sufficiently great as to have the Bureau of Reclamation supporting the program. Johnson (1985) wrote:

> Cost-benefit analyses, however disputable their results, have been required of the builders of new dams since the 1960s. It is still highly unusual, however, for partisans of unbounded rivers to compare the costs of existing dams with the benefits which might flow from their disappearance. When such studies were done recently in the Northwest, a significant six or seven major dams proved to be costing more in lost fish and recreation than they were providing in irrigation or power.

Everyone involved in salmon and steelhead enhancement work would have no trouble cheering over such a message, but a word of caution is in order. Intercepting native anadromous salmonid runs to support enhancement activities through artificial propagation, no matter how well intentioned and fortified with legislative direction, should always be subject to scrutining. Criticism, however, needs to be based on well-documented published data. Self-criticism is difficult. Compelling critical questions on salmon restoration and enhancement techniques that continually need addressing include:

1. What are the successful artificial propagation practices and how economically feasible are they to the public that supports the program? (Not a new question)..

2. Are there indeed programs that might possibly be decreasing salmon resources? (An impertinent question).

3. If an ailing or failing propagation program is one assigned to meeting mitigation goals, what can be done to make up perceived differences from planning goals and actual results? (A practical question).

4. Have mitigation and enhancement expectations using artificial propagation been over-inflated in the design stages of our projects, and if so, how should we address the error? (An embarrassing question).

For all groups that have a common interest in increasing salmon numbers for consumptive purposes, a defensible, unified and mutually successful management program must be a part of an overall cooperative approach to resource conservation. I submit that if this does not occur voluntarily and cooperatively, other segments of society interested in non-consumptive, or other general public-oriented uses of the anadromous fish resource, will undoubtedly begin intervening more vigorously in management decisions. Winners and losers may not be readily identified in such an event. We should remember that the carrying capacity of a salmon production systems are not changed by merely shifting catch between user groups based on conservation appeals.

The public is now constantly greeted with articles and pictures on fish culture possibilities such as shown by Jeffery (1985, p. 230; Ford 1984) of large-pen reared Atlantic salmon being fed fish meal. Part of the picture caption in Jeffery states "Aquaculture promises more stability for Maine's chronically cyclic fishing industry." But the professional fisheries biologists counters with a "yes but" (Iversen 1984) a message that all of us in salmon and steelhead enhancement work should heed by tayloring our expectations to reality, and our actions to principles of equity. Also, times are changing and societal needs and conflicts may be pointing to a much larger role for artificial propagation of salmon and steelhead. Salmon production and prices that can once more be competitive with other "meat" products in the food industry plus the increasing attention to non-hatchery fish for non-consumptive recreational uses all appear as increasingly strong societal needs (Smith 1979). It will be interesting to see how California restoration efforts become tailored to meet these apparent, but not necessarily, conflicting trends. We are all now both part of the problem and part of the solution (Figure 1).

Newly arrived practitioners to the art of anadromous salmonid culture in California may be somewhat shocked at first to learn of the array of technical and non-technical constraints to achieving adult returns at some satisfying level. They probably may be even more shocked to learn that well-intentioned efforts could be replacing and/or reducing natural populations. As a future cadre of informed citizenry, however, salmon and steelhead enhancement and restoration personnel can have a crucial public function. The idea of a salmonid advocacy has been powerfully advanced by Deans (1984). A knowledgeable public in British Columbia is now influencing elected officials to act in behalf of back-yard salmonid resources (Rank 1983). The development of a civic responsibility and stewardship by local citizens for local backyard salmon resources as outlined for watersheds (Platts 1984a,b) could very well be a major factor for the long-term well being of salmonid stocks in small north coastal California drainages.

Finally, I would suggest that our artificial propagation efforts might be placed in an historical perspective. McCaughran (1984) writing about halibut fishing states:

> "If one examines the 'circle' hook, the similarities to the ancient Makah Indian hook are obvious. Perhaps there is still much to learn from the old ways when fishing was a matter of survival."

I am looking forward to reading Swezy and Heizer (1984) for additional new direction we might glean from the past concerning salmon management and conservation.

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EDITORS NOTE: Due to space limitations we were not able to include the Appendices mentioned in the text. Those wishing to receive a copy should write directly to Dr. Allen at the address at the beginning of this paper.

SALMON EDUCATIONAL MATERIALS

Vickie Osis
Sea Grant Marine Education Specialist
O.S.U. Marine Science Center
Marine Science Drive
Newport, OR 97365

SLIDE TAPES:

RUN, RIVER, RUN. 25-minute slide tape program discussing streams, stream ecology, and fish using the river.

O.S.U. Extension/Sea Grant Program. Hatfield Marine Science Center, Newport, OR 97365. Free on loan. Uses an Entre Dissolve Unit.

STREAM ENHANCEMENT. 15-minute slide tape which discusses watershed and riprarian zones and their importance to health of streams.

O.S.U. Extension/Sea Grant Program. Hatfield Marine Science Center, Newport, OR 97635. Free on loan. Uses Wallensack Playback Unit.

FILMS:

LIFE OF THE SOCKEYE SALMON. 25-minutes. This film follows each stage in the life of the Sockeye Salmon.

LIVING RIVER. 27-minutes. The story of a Pacific slope river and the life which it supports. Starting high in the mountains, it winds its way to the ocean. We see how the environment, both in and near the river, is shaped and influenced by its existance. The film follows the life cycle of the Pacific Salmon from egg through alevin to fry to adult fish.

TOMORROW'S SALMON. 27-minutes. This film deals with all aspects of the salmon resource, including ecology, biology, economic, cultural, recreational, and political.

BIG QUALICUM RIVER PROJECT. 26-minutes. This film gives a close look at the business of salmonid enhancement while keeping technical and scientific jargon to a minimum. It shows the layout of the facility and various steps taken in the selection of breeding and rearing of salmon by artificial means.

All of the above films available from: Information Branch, Department of Fisheries and Oceans, 1090 W. Pender Street, Vancouver, BC V6E 2P1 (604) 666-3545. All films free on loan.

JOURNEY OF THE KINGS. 15-minutes. Discusses the salmon of the Columbia River. NW Power Planning Council, 850 WS Broadway, Suite 1100, Portland, OR 97205.

SALMON EDUCATIONAL MATERIALS

AUDIOVISUAL MATERIALS

FILMS - continued

DAMMED FOREVER. Shows the negative effects of dams on the salmon and steelhead runs of the Columbia System.

FISH FACTORIES. A look at the operations of the Department of Fish Hatcheries in Oregon.

PASS CREEK. An examination of logging practices on Federal lands and how they affect the fishery resource.

TROUBLED JOURNEY. Steelhead trout life story.

THE WAY OF A TROUT. A film depicting the life histroy of the trout.

The above films available from: The Oregon Department of Fish and Wildlife Film Desk, Oregon Department of Fish and Wildlife, P.O. Box 3503, Portland, OR 97208.

VIDEOTAPES:

SO, THE SALMON WILL ALWAYS RETURN? 14½ minutes. $150.00 purchase. This videotape is from the Alaskan Sea School series. It discusses the Sockeye Salmon, its natural history, fishery and management problems. International Telecommunication Services, 2492 Freetown, Reston, VA 22091.

POSTERS

SALMON POSTERS. BC Wildlife Federation, 5659 176th Street, Surrey, BC V3S 4C5. Set of 6 posters. $4.00 per set for schools. (604) 576-8268.

Full-color 18' x 21' posters of the five Pacific Salmon species and Steelhead.

SALMON EDUCATIONAL MATERIALS

CURRICULA MATERIALS

CLEAN WATER, STREAMS AND FISH. Wendy Borton, Lavonne Bucher, Claire Dyckman, Art Johnson, and Bill Way. Hatfield Marine Science Center, Newport, OR 97365. $10.00 Elementary. $10.00 Secondary.

Characters on salmonids, habitat, threats, solutions, roles and issues. Well-designed interdisciplinary activities for upper elementary and middle school students. A similar curriculum for secondary students is also available. Adapted for Oregon. Uses Oregon maps and river systems, etc.

SALMONIDS IN THE CLASSROOM. BCTF Lesson Aids, B.C. Teachers Federation, 105-2235 Burrard Street, Vancouver, BC V6J N3P. 1982 (revised). $85.00.

Extensive curriculum on salmonids that includes lesson plans, activity sheets, reference material, film, hands-on project suggestions, catalogue, evaluation activities, teacher answers, and bibliography. Separate packets for upper elementary and secondary school students.

LIFE CYCLE OF THE SALMON. Kathy Tarabochia. Pacific Science Center/Sea Grant, 200 Second Avenue North, Seattle, WA 98109. 1980, 125 pages. $5.00

Presents eight activities on salmon and their life cycles, habitats and journeys. Includes slide show script.

ALASKA SEA WEEK CURRICULA GUIDE - GRADE 5. $11.50. Alaska Sea Grant College Program, 9990 University Avenue, Suite 102, Fairbanks, AK 99701.

This material examines the commercial fishing techniques and commercial species of fishing in Alaska. Includes bibliography and workbook section for students.

THE EARLY FISHING PEOPLES OF PUGET SOUND. Jenifer Katahira. Pacific Science Center, 200 Second Avenue North, Seattle, WA 98109. $5.00.

This curricula guide discusses early Indian tribes of the Puget Sound area. It is a well-illustrated publication showing fishing techniques used by Indians. It includes hands-on activities for children, to make fishing equipment used by Indians.

THE CREEK BOOK and THE ESTUARY BOOK. Western Education Development Group, University of British Columbia, Vancouver, Canada V6T, 1W5. $6.00 each.

Well-illustrated books which describe creatures and ecological relationships in small streams and estuaries.

EDUCATIONAL GAMES

SALMON GAME. Western Education Development Group, University of British Columbia, Vancouver, Canada, V6T 1W5. $7 50.

A board game which follows the Sockeye Salmon life cycle.

REARING SESSION I

Fish Trapping

Facilitator: Scott Downie
Eel River Restoration Project
P.O. Box 278
Redway, CA 95560

This session focused on considerations for siting, building, and operating fish traps to obtain eggs from local sources. Scott Downie described his group's experiences on Redwood Creek in the Eel River Basin. A diagram of his trap and description of operations is included in Attachment A. Gary Peterson described the experiences of the Mattole Watershed Salmon Support Group, including the design of their fish trap (similar to Downie's) and siting considerations and problems other groups should consider. His group had identified the optimum trapping locations on the river, but was unable to secure permission from the owner to trap there. They have been forced to trap fish in a more difficult location, and some of their problems were described. Gary also discussed the Washington Department of Fisheries use of a fyke for trapping (Attachment B) and a trap design used by the Canadian Salmonid Enhancement Program.

Jerry Boberg gave a slide show which described the trapping operation at the Horse Linto Creek project, which is operated through PCFFA and the Salmon Stamp Committee. He also distributed handouts which described the Bertoni fish weir used by the Alaksa Department of Fish and Game (Attachment C).

Jud Ellinwood described a permanent fish trap and holding facility operated by the Humboldt Fish Action Council on Freshwater Creek. Bob Hannah described the use of gillnets for egg-taking by the Hoopa Tribal Fisheries Program.

EEL RIVER SALMON RESTORATION PROJECT

SPONSOR PCFFA

P.O. Box 278
Redway, CA 95560

We added a hinged door on the fyke and a hinged 2' x 8' mesh lid to the top to prevent jump-outs. The fyke door has a 14" x 45½" frame with a 2" x 2" mesh cover.

Other considerations include:
1) Staff gauge.
2) Plywood for providing rest zones.
3) Lanyard for tripping fyke door.
4) Harness to tie guy line to trap.
5) Chicken wire for bottom skirt on weirs and trap.

6' x 4" weir panels are secured with twine to steel fence posts. 3/8" nylon rope is laced through the panels from each streambank to mid-stream and secured to tree or other anchor. In case of blow-out panels will drift into banks and be salvaged. The trap itself is guyed to bank and will also drift in if your site is wide enough. Finally, a bright light (500 watt flood) on a mast makes a major difference, if power is available.

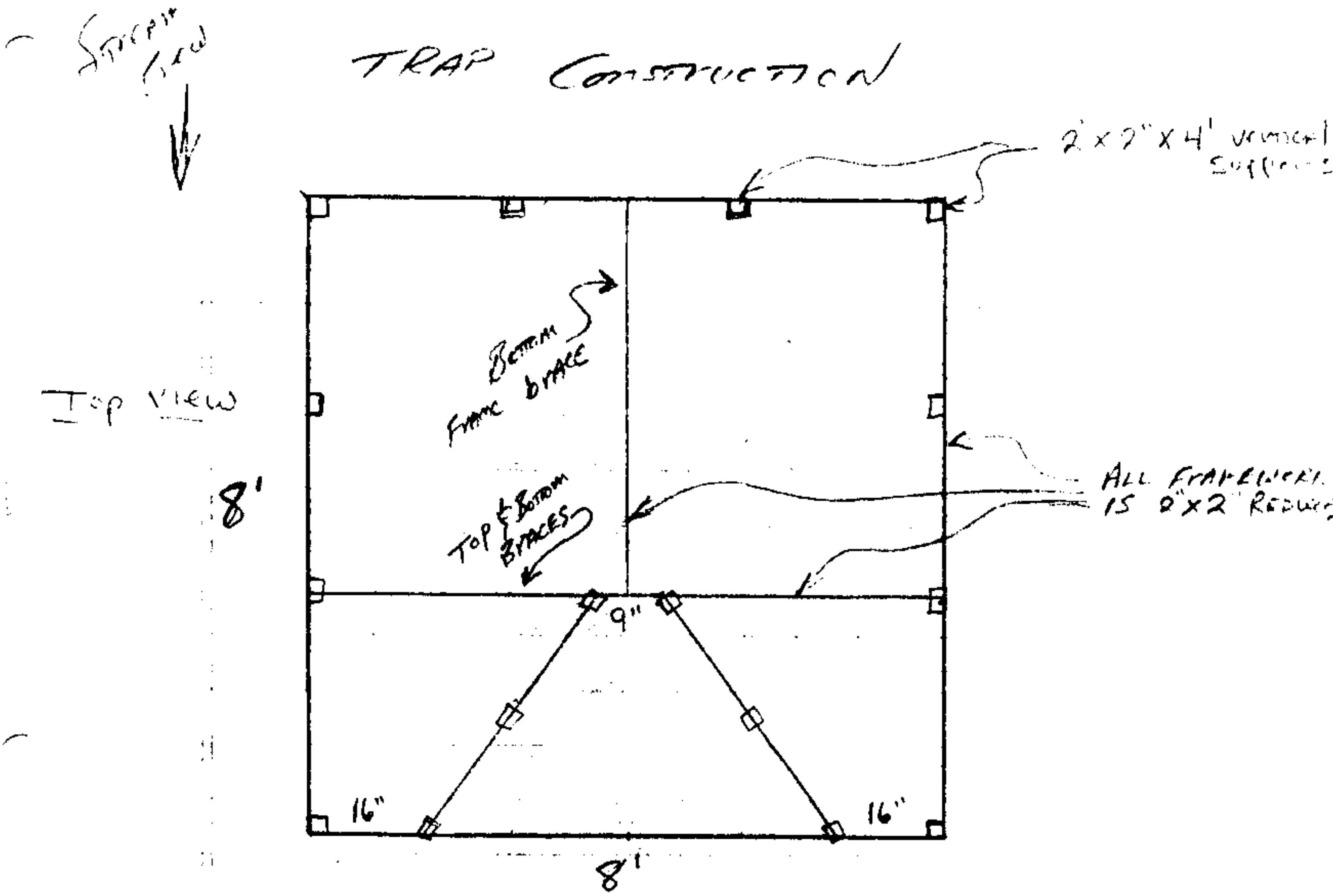
Site selection is by far the most important aspect in trapping.
1) Wide flat profile desired.
2) At top of long or hard riffle.
3) At bottom of pool area (just above "critical" flow in sub-critical zone).
4) Access is necessary. Also accomodations.
5) In or near thalweg, depending on velocity, is best area for trap.
6) Current must be such as to keep the fish nosing upstream, but not so fast as to exhaust them. Baffles can be used to provide rest area. You may have to move your trap according to flows to attain good attraction location and flow in fyke.

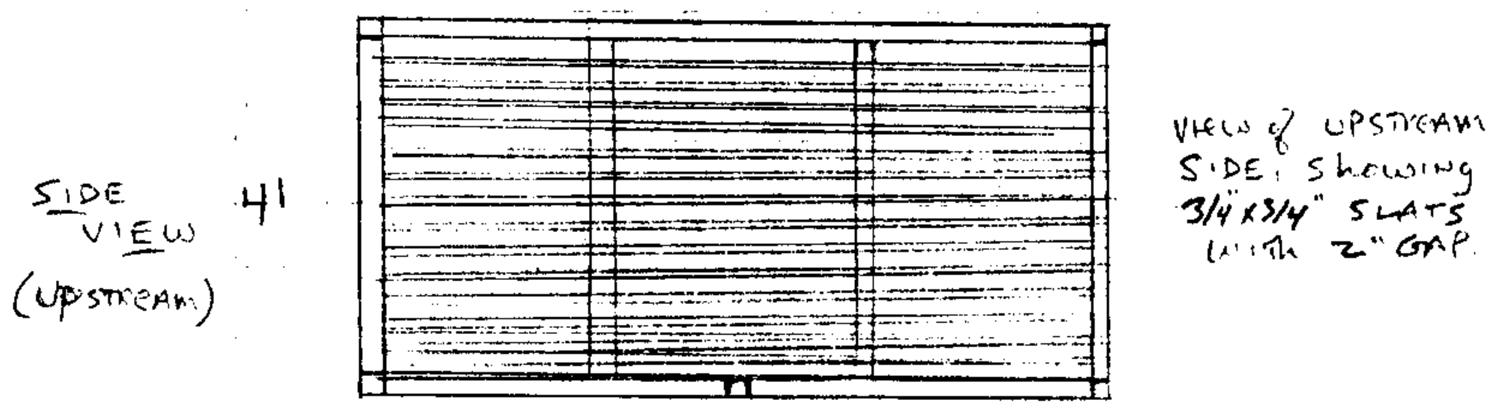
Staffing the trap is a real consideration: location will dictate whether you can use many volunteers or pay one man, or arrive at some other arrangement. Remember, in order to catch well, your trap must be in continuously.

Stream and conditions at Redwood Creek site:
-21 square mile basin.
-22 stream miles suited for salmon.
-trapping flow varies, but "average" is 118 CFS.
-mean velocity: 1.03 ft per second (range: 0-1.8 ft. per second).
-70' wetted perimeter (WP), 2' average depth.
-low trap flow: 50' WP, 1' average depth
-flood flow: 100' WP, 8' average depth.
-trap velocities at average trap flow: 2' average depth
1.03 ft. per second average velocity
1.7' trap depth
-Velocity in trap fyke is 1.25 ft. per second.
-Velocity in resting zone: 0.15 ft. per second.

In this setting we had to remove the trap at 2.4' trap depth. Redwood Creek is flashy. On 2 December it rose 3' at the trap in one hour. Obviously you must monitor precipitation and stream rise carefully. A staff gauge is a valuable aid.

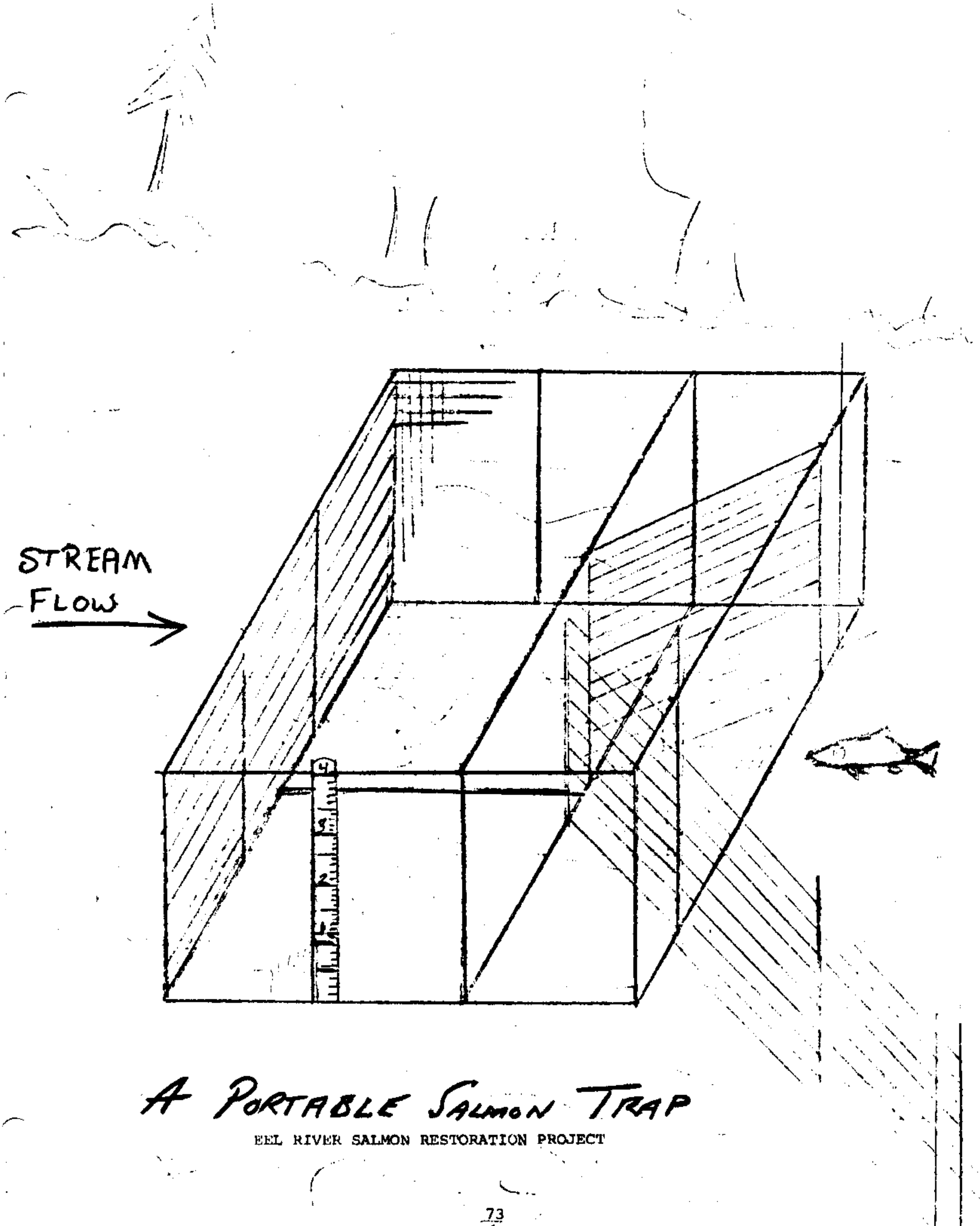
TRAP CONSTRUCTION





FRONT WALL, FIKE WALLS, & Weir Panels Also use horizontal 3/4"x3/4" Slats.

Sides, bottom & top (optional) are enclosed with 2" square welded mesh (light duty).



A PORTABLE SALMON TRAP

EEL RIVER SALMON RESTORATION PROJECT

ADULT SALMON CAPTURING METHOD IN LARGE RIVERS

by
Lee Blankenship

When the wild stock coho trapping and tagging project switched its emphasis from Puget Sound to the Grays Harbor tributaries on the coast, major differences were encountered. The differences were due to the much lower density level of smolts and the greatly increased water fluctuations and flows.

The lower density of smolts meant that to capture sufficient numbers of smolts, we had to trap larger streams with greater flows. We handled the increased flows for the downstream smolt trapping with "W"-shaped weirs and blow-out panels. The smolts we encountered were significantly larger which allowed us to increase our weir mesh size from 1/3 inch to 1/2 inch.

The increased flows in the coastal streams presented a real problem, however, for adult trapping. The temporary weirs we had used in the relatively smaller streams in Puget Sound were out of the question.

Even in Puget Sound we would tag the captured adults prior to release in anticipation of losing the weir, so that we could conduct stream surveys and make a Petersen or stratified estimte of the total population. Getting our hands on even enough fish to make a Petersen-type estimate seemed questionable if not impossible economically. We did see one bonus feature in the Oakville Indian fishery, however. All our Chehalis River smolt trapping had occurred above the Oakville Indian net fishery. We felt we could utilize the Indian catch as our second sample for a Petersen-type estimate. Stream surveying would not have to be done so we could spend our available resources experimenting with different types of gear.

We tackled the gear problem with a shotgun approach: trying a variety of gear to see what, if any, would work. Our initial ideas included any gear we found in the literature which was economically feasible. This included beach and purse seines, drift and set gill nets, fish wheels, and wire fyke traps. The more we investigated the gear and the physical characteristics of the river and its flows, the less our gear options became.

Mike Eames and Mark Hino had very limited success in the lower river using beach and purse seines along with drift gill nets. Adequate sites did not appear to be available upstream either, and there were numerous stumps, logs, car bodies, etc., in the marginal sites. Fish wheels were rejected prior to construction due to marginal sites and extreme fluctuations in flows. That left us with set gill nets and wire fyke nets. The set nets were labor-intensive, and we had never seen or heard of wire fyke nets for adults.

The wire fyke nets looked intriguing but sure didn't look like they could catch fish except that the literature said they had been used as a commercial gear on the Sacramento River 40 or 50 years ago. They had been declared illegal, so they must have been somewhat efficient. A California report (Calif. Fish and Game, Vol. 43, No. 4, pp 271-298) describes the construction and operation of these traps.

From: Washington Dept. of Fisheries Prog. Rep. No. 206 (1984).

We used the report as a basis for building three traps at a cost of approximately $800/trap. The traps are cylindrical in shape, about 25 feet long and 10 feet in diameter. They are open at one end and contain two funnels which act as a one-way passage for fish into a pot. The traps are fished with the open end downstream. The two funnels face the same way with the small openings upstream. The funnels and exterior are covered with wire mesh and the frame consists of five galvanized 3/4-inch pipe rings held rigidly together with six 2X4 wooden stringers which extend the length of the trap. Captured fish are removed with a dip net through a door which opens into the net. We fished the three traps for one month, October 13-November 18. During that period we caught 198 adult coho and 166 jacks. We also caught 45 chinook, 30 chum, 12 steelhead, 22 cutthroat, 450 suckers, crappie, bass, and whitefish. We also fished a set gill net at night during this period and found that one 8-hour period of night net fishing produced about the same numbers of adult fish as one fyke trap fished for 24 hours. The set nets were much more labor-intensive, however, and there was some mortality with the set net and none with the fyke net.

A simple Petersen estimate of the Oakville fishery showed that we caught approximately 2% of the adult coho population.

These traps, like most traps, are site-specific. They work best fished next to shore with a steep bank in 10 feet of discolored water. When we installed the traps, one was in 10 feet of water and the other two were only in 6-7 feet of fairly clear water. Surprisingly, we caught fish in the clear water. The traps that were only 2/3 submerged caught fish but not as many as the fully submerged traps. We experimented with leads from the shore to the nearest trap edge and felt that they helped increase the catch. Next year we plan on employing 5-6 traps and experiment more with the type of fishing area, such as direct current vs. back eddies, etc. We also plan on trying longer leads.

These traps were employed this year to catch live adults for tagging which would enable us to make a Petersen-type estimate. We were able to make a population estimate of adult coho escapement for the upper Chehalis watershed. It will also enable us to estimate escapement of the various coded-wire tagged wild fish and off-station plants. This gear also has potential for brood stock collection, and even for commercial fishing where species conflicts would otherwise prohibit fishing in mixed-stock river fisheries.

THE BERTONI FISH WEIR

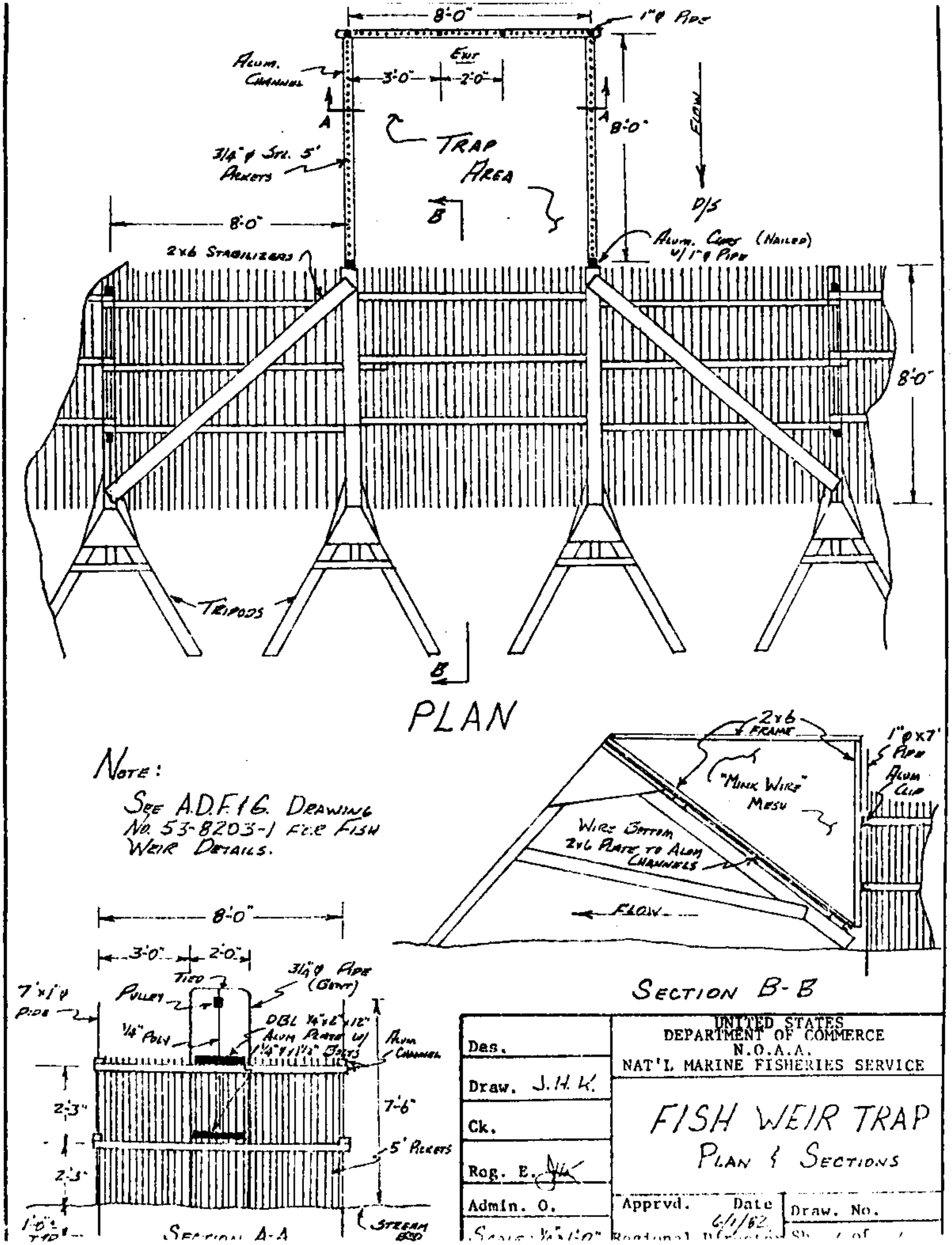
The following fish trap and weir design was developed by the Division of Fisheries Rehabilitation Enhancement and Development, (F.R.E.D.), Alaska Department of Fish and Game. This design is used extensively in Alaska with excellant results under most flow conditions trapping chum, coho and chinook salmon.

The weir is capable of withstanding flows over the top of the pickets, if properly placed and secured. Wider stream areas where stream gradients are less with rock and gravel stream bottoms are preferred placement sites. Weir support tripods are secured with cable to bedrock or stakes driven into the streambed.

Generally, the trap is constructed of conduit pickets, aluminum channel and iron pipe. The trap entrance is established by the removal of weir pickets or through the construction of a fyke type entrance in the weir. The trap is placed in the deepest part of the stream or known fish migration corridors.

More specific information about weir and trap design, construction and placement may be obtained by contacting:

Sam Bertoni
F.R.E.D. Division
Alaska Department of Fish
and Game
P.O. Box 20
Douglas, Alaska 99824
(907) 465-4230


8'-0"
1"φ Pipe
Alum. Channel
Exit
3'-0"
2'-0"
A
8'-0"
Flow
Trap Area
3/4"φ Stl. 5' Pickets
B
D/S
8'-0"
Alum. Clips (Nailed) w/ 1"φ Pipe
2x6 Stabilizers
8'-0"
Tripods
B
PLAN
Note:
See A.D.F.&G. Drawing No. 53-8203-1 for Fish Weir Details.
2x6 Frame
1"φx7' Pipe
Alum Clip
"Mink Wire" Mesh
Wire Bottom
2x6 Plate to Alum Channels
Flow
Section B-B
8'-0"
3'-0"
2'-0"
Tied
3/4"φ Pipe (Bent)
7'x1"φ Pipe
Pulley
1/4" Poly
DBL 1/4"x2"x12" Alum Plate w/ 1 1/4"x1 1/2" Bolts
Alum Channel
2'-3"
7'-6"
5' Pickets
2'-3"
1'-0" Typ.
Section A-A
Stream Bed
UNITED STATES
DEPARTMENT OF COMMERCE
N.O.A.A.
NAT'L MARINE FISHERIES SERVICE
Des.
Draw. J.H.K.
Ck.
Rcg. E.
Admin. O.
FISH WEIR TRAP
Plan & Sections
Apprvd.
Date 6/1/62
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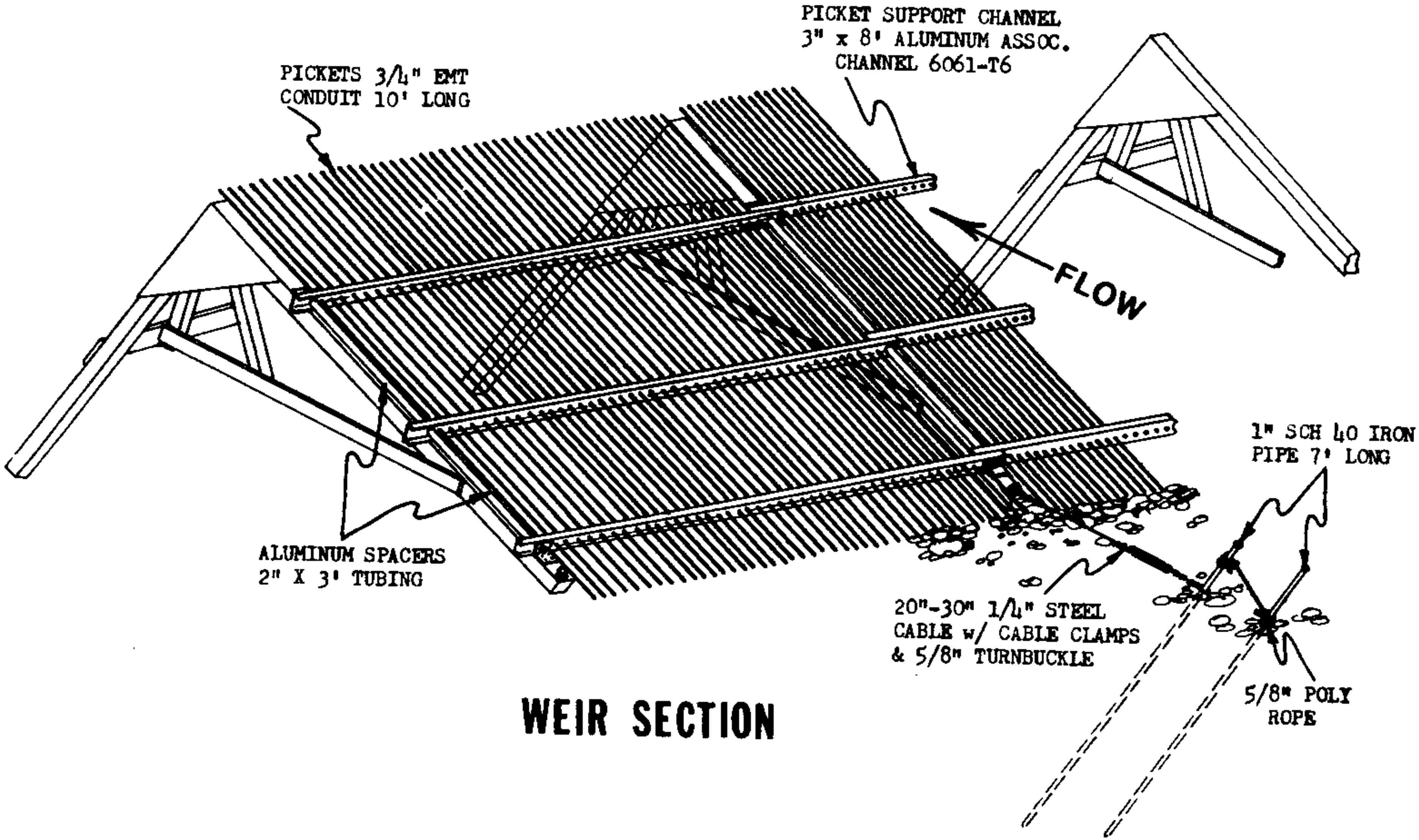
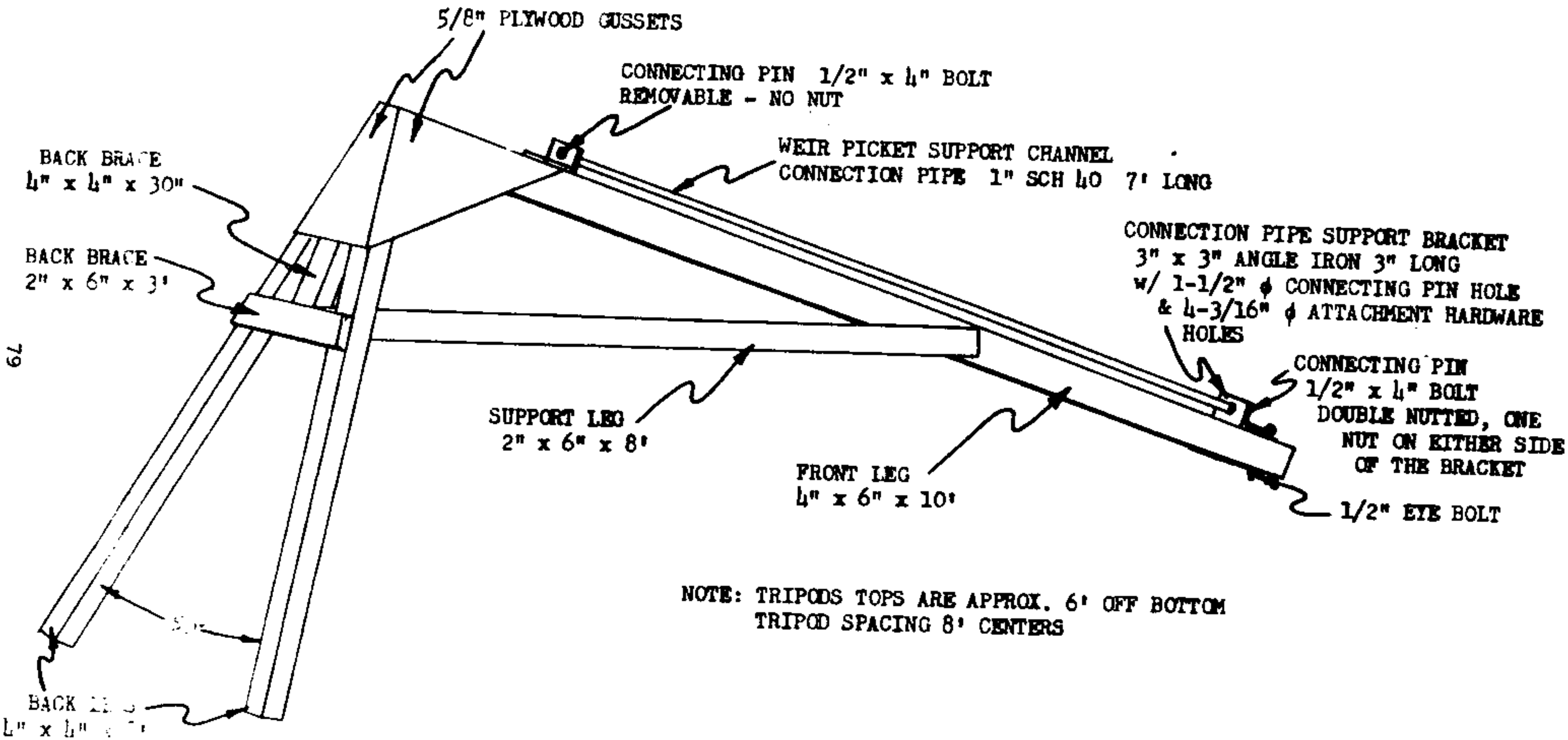
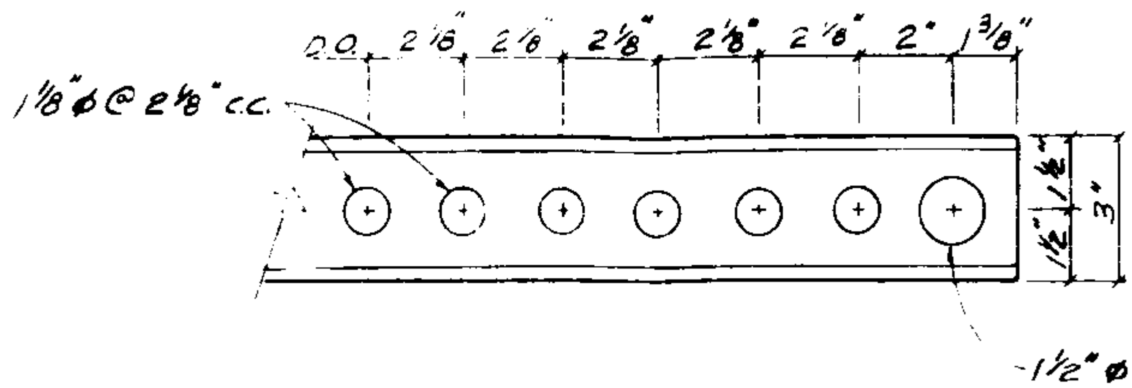


WEIR SECTION



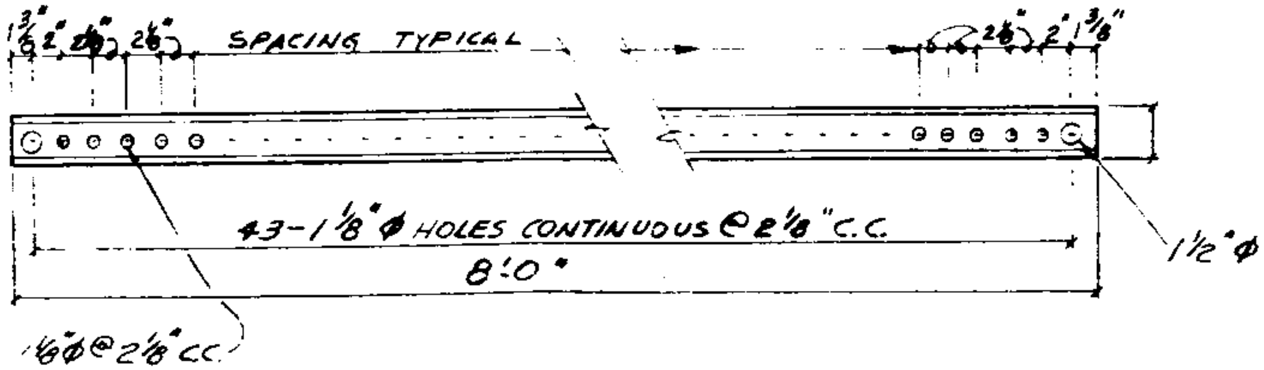
NOTE: TRIPODS TOPS ARE APPROX. 6' OFF BOTTOM
TRIPOD SPACING 8' CENTERS

WEIR TRIPOD



HOLE DETAIL

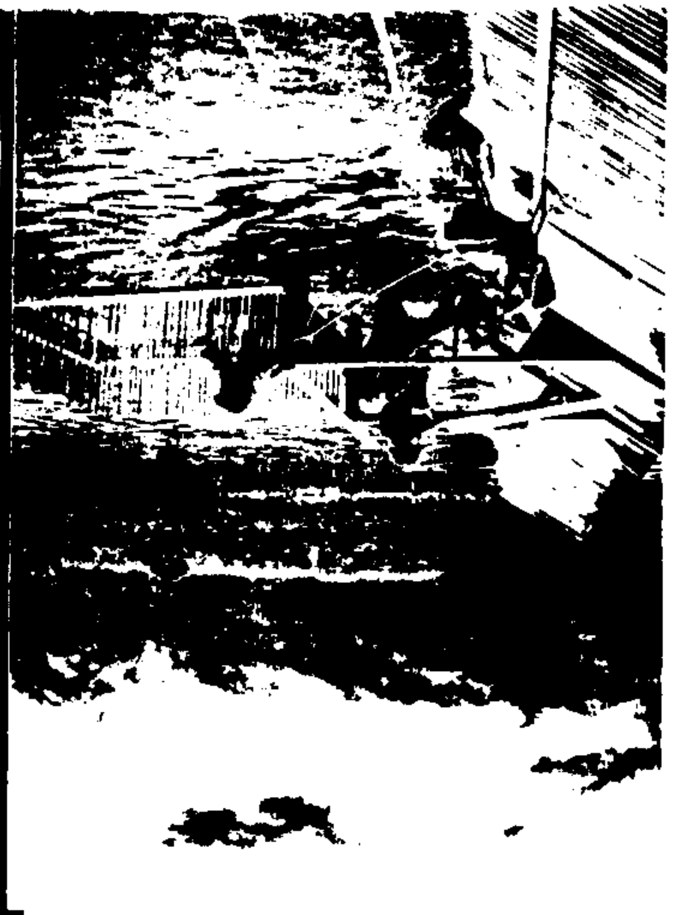
TYPICAL BOTH ENDS
3" = 1'-0"

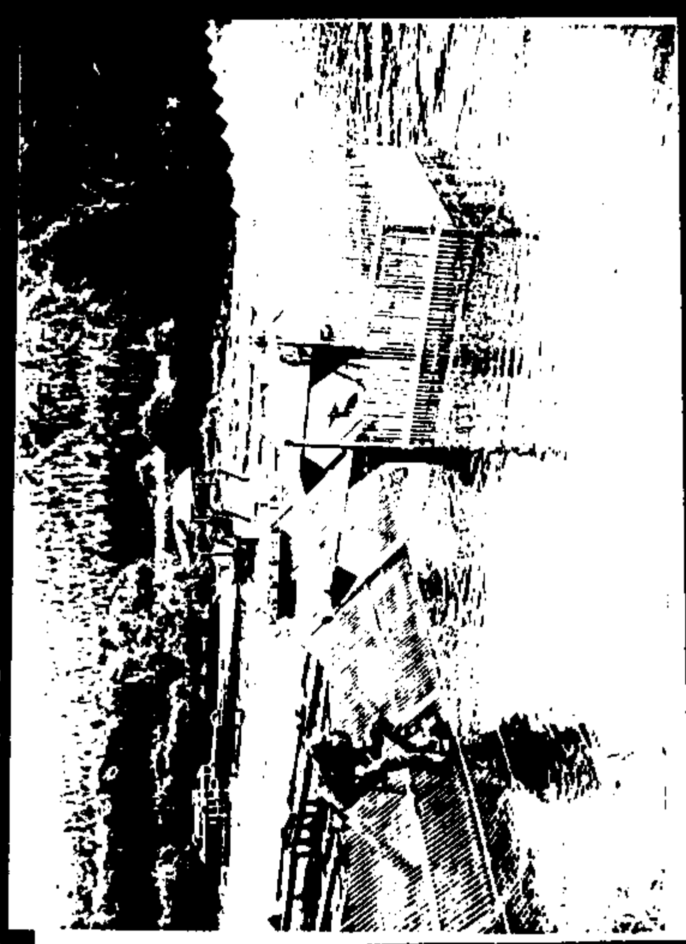


WEIR PICKET SUPPORT CHANNEL

ALUMINUM ASSOCIATION CHANNEL 6061-T6
1" = 1'-0"

ALASKA DEPARTMENT OF FISH AND GAME F. R. E. D. SOUTHEAST REGION			
WEIR PICKET SUPPORT			
DRAWN BY hww	CHECKED BY	DATE	SHEET 1 OF 1
DESIGNED BY		SCALE AS NOTED	NUMBER 53-8012-1






REARING SESSION II

Fish Diseases

Facilitator: Dr. Gary Hendrickson
Fisheries Department
Humboldt State Univ.
Arcata, CA 95521

This session focused on a description of Proliferative Kidney Disease (PKD) and its effects by Dr. Ron Hedrick of U.C. Davis. This disease struck Mad River Hatchery, the state's only enhancement hatchery, in 1983. Since 1983, however, PKD has not been detected at the Mad River Hatchery. Descriptions of the disease and hatcheries affected by it in California are included as Attachments A and B.

A panel which included Dr. Hedrick, Dr. Hendrickson, Bill Wingfield (CDF&G Pathologist), and Bruce Barngrover(CDF&G Mad River Hatchery Manager) then answereed questions from representatives of enhancement groups regarding problems at ponding projects. Prevention and treatment of "ich" was one of the main topics.

COOPERATIVE EXTENSION
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NEWSLETTER
December 1983
CA-83-5

CONTENTS

PROLIFERATIVE KIDNEY DISEASE (PKD) OF SALMONID FISH

Introduction

Proliferative kidney disease (PKD) was first described (Plehn 1924) among European brook and rainbow trout. The disease appeared as an "amoeba-like" organism in the fishes' kidney tissue and the condition was termed "amoebiasis". Today the disease is recognized internationally as catastrophic in nature and one of the major problems in the European trout industry. Since 1977 PKD has been reported in major trout growing areas including France, Italy, and Ireland; and surveys in England and Wales indicate that the disease was present in 20 out of 45 farms examined.

The first report of PKD in North America was among rainbow trout at the Hagerman Federal* Hatchery in Idaho (Smith et al., 1982) and was later reported from the nearby Hagerman State Fish Hatchery. The disease was thought to be confined to this drainage, but now has been reported at several additional sites in Idaho.

Two more recent events have had a more significant potential impact on the California rainbow trout industry and the Pacific salmon industry. Proliferative kidney disease was reported for the first time in Pacific salmon and steelhead rainbow trout in an outbreak occurring at the California Department of Fish & Game (CDF&G) Mad River Hatchery in northwestern California. Losses began in late June among chinook salmon (Oncorhynchus tshawytscha) and were soon followed by mortalities in steelhead rainbow trout (Salmo gairdneri gairdneri), an anadromous form closely related to other subspecies of rainbow trout. Mortalities appeared in late July among coho salmon (O. kisutch). Approximately 95% of the chinook, 20% of the steelhead, and 10% of the coho succumbed to the disease. The disease was confirmed as PKD by CDF&G pathologists in July, and stock destruction and hatchery disinfection were initiated.

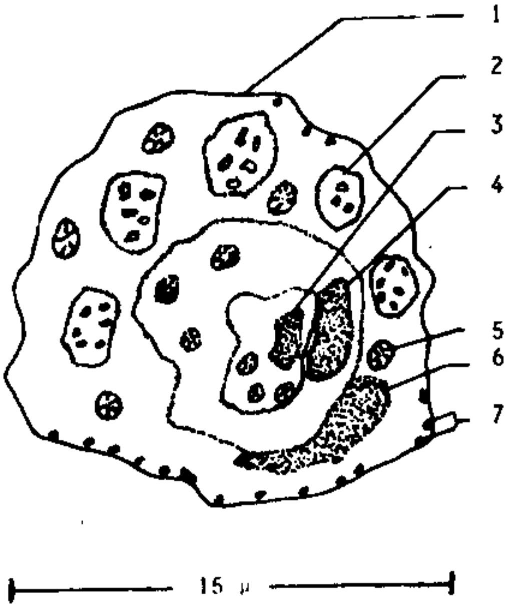
Prior to the correct diagnosis of PKD at the Mad River Hatchery, 700,000 chinook salmon were released in the lower Klamath River and 637,000 fish were released in the Mad River. Attempts to recover the fish were made after the disease was confirmed at the hatchery. Some hatchery fish were recovered from the Mad River, and these fish exhibited the parasite in the kidney. The only fish recovered from the Klamath River were hatchery fish released from the Iron Gate Fish Hatchery located on the Klamath River. The total number of fish destroyed at the Mad River Hatchery is approximately 1.3 million. Research on PKD has been initiated by CDF&G pathologists and pathologists at UCD's Bodega Marine Laboratory. Precautions are being taken to prevent PKD from affecting the commercial trout industry, which regularly undergoes certification of trout and egg products.

*Erratum - Not reported from Hagerman Federal Hatchery. (Added at Richmond.)

Characteristics and Detection of PKD

PKD has been reported as a seasonal disease with highest mortality recorded in the late summer months when water temperatures reach 15-17 °C. The fish characteristically show grossly enlarged, grey, swollen kidneys, and protozoan parasites can be seen by microscopic examination. The examination is conducted by phase-contrast microscopy of fresh squashes of affected kidney tissue. The amoeba-like cell (PKX) measures 10-20 μ in diameter and is characterized by its granular appearance and the presence of one or more internal secondary cells.

FIGURE 1. Diagram of PKX as observed by electron microscopy, tertiary and secondary cells within the primary cell.



1) cell membrane of primary cell
2) vesicles
3) nucleus tertiary cell
4) nucleus secondary cell
5) mitochondria
6) nucleus primary cell
7) haplosporosomes

The PKX organism can also be observed in stained kidney sections or imprints observed by light microscopy. In light infections, histological examination may be required to establish PKX as the primary cause of infection. The amoeboid stage of PKD is similar to that of Marteilia sp., which are known pathogens of European oysters (Ostrea edulis). However, in the oyster the Marteilia organism goes through several spore stages that aid in determining the proper taxonomy. Because spore forms have not been detected in PKD-infected trout, it is difficult to properly assign the parasite to the Haplosporidia or the Myxosporidia.

Host Range

Rainbow trout fingerlings are the primary species affected by PKD. Infection among Atlantic salmon and grayling, however, has been reported in Europe. The brown trout is apparently resistant. The experience in California indicates that both chinook and coho salmon are also susceptible.

Pathology

Externally, infected fish show darkening in color, ascites or fluid retention, exopthalmia, and often a lateral swelling of the body near the lateral line. Fish will often feed until death, and both large and small fish will be affected. These fish, when stressed by netting or crowding, will often begin to die.

An internal examination reveals a grossly swollen kidney that appears pale to greyish with bulbous ridges. This swelling of the kidney in extreme cases causes the lateral swelling of the body wall seen externally. The spleen may or may not be swollen, and greyish patches which also can occur on the liver may be noticed. The affected fish are quite anemic (hematocrits of 11% compared to 28-30% in normal fish), and this is readily observed by an examination of the gills which will be pale in color. The stomach and intestines are usually filled with food.

The kidney and spleen are the main sites of histopathological damage. Interstitial nephritis is observed with massive infiltration of macrophages and lymphocytic cells. A proliferation of the hematopoietic tissue of the kidney contributes to the overall swelling characteristic of the disease. PKX organisms may be seen in the interstitial areas of cellular reaction or in the epithelial cells of the kidney tubules. The number of tubules and gromeruli in affected kidney tissues are greatly reduced. Similar changes in the spleen and, to a lesser extent, in the liver may also be seen. The pancreas, intestine, dorsal musculature, and gills may also experience changes due to infection.

Epizootiology

PKD is typically a seasonal problem among rainbow trout farms which utilize water from open rivers or streams. The disease increases with severity in the late summer and early autumn when water temperatures rise to

15-17 °C. When water temperatures decline to 9-11 °C, the disease is rarely seen. Ferguson and Ball (1979) have described PKD outbreaks in several Irish trout farms. In each case fish were hatched in spring water and in May were moved to the farm. Mortalities due to PKD would begin in 6-7 weeks. Fish moved to lower water temperatures (9-11 °C), or to the laboratory where clean water (16 °C) was available, did not contract the disease. However, fish held for a short time and transferred to the laboratory and held at 16 °C did develop clinical PKD. Fish moved to the farm in July did not suffer mortality to PKD, but by histological examination 50% of the fish harvested later were found to be infected. These observations have led to a management practice that allows fish to be moved to the farm in July rather than in May. These fish are then harvested prior to warm water periods the following summer when PKD deaths might be expected to occur.

The PKD epizootic at Mad River Hatchery had variations among similarities reported for outbreaks in Idaho (Anon., 1983). The Mad River Hatchery utilizes a recirculating water system with a 15% makeup system from wells next to the river. On June 24 when the first mortalities were observed the water temperature ranged between 11-16 °C. However, prior to this, water temperatures between May 27 and about June 5 reached 20 °C, during a period when the makeup water system was shut off to initiate algal control. When the process was finished, the makeup water was re-established and temperatures dropped to 13 °C. During the peak mortalities temperatures ranged between 14-17 °C.

The question of whether birds contribute to the disease through fecal droppings as indicated by Idaho scientists (Anon., 1983) requires further study. Although the grow-out systems in the Mad River Hatchery are "bird-wired", the exclusion is not complete as herons perch above the filter beds, and this is said to be a consideration for contamination. In addition, in contrast to the Idaho incidents, chinook, coho, and steelhead at Mad River Hatchery were not found to have complicating infections with other bacterial or viral pathogens.

Mortality due to PKD is variable, with rates from normal to 75% at certain farms. In California, mortality rates approached 95% for chinook salmon. Steelhead and coho salmon were less affected. Even in the absence of significant mortality, morbidity may be high; and certainly this affects the fishes' performance, growth, and survival.

Fish that survive initial infections seem to be resistant to second infections, but whether they are carriers that may later transmit the disease to uninfected fish is not known. It is possible that an intermediate host may be involved, perhaps a crustacean, mollusc, or insect that releases an infectious stage of the parasite into the water. Further studies are necessary to determine the presence and characteristics of this stage of the parasite. Experimental transmission of the disease by feeding or injecting kidney tissues containing the parasite into uninfected fish has been reported, but waterborne challenges have not been successful. Once the fish becomes infected, water temperature seems to influence the course of the disease which develops considerably slower at or below 15.5 °C.

Treatment and Control

There are no treatments available for PKD infection. Routinely used anti-microbial drugs have no effect on this protozoan parasite. In this respect PKD is similar to other protozoan and virus diseases where control relies on avoidance rather than treatment. The management practices described previously in trout farms in Ireland are helpful in preventing mortality but not infection, as studies have indicated that up to 50% of fish treated in this manner are infected with the parasite.

(Article by Ronald P. Hedrick, Pathologist, University of California Bodega Marine Laboratory, Bodega Bay, California)

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Attachment B

COOPERATIVE EXTENSION
UNIVERSITY OF CALIFORNIA

CALIFORNIA SEA GRANT
COLLEGE PROGRAM

CALIFORNIA AQUACULTURE

NEWSLETTER
October 1984
CA-84-3

1984 PROLIFERATIVE KIDNEY DISEASE OUTBREAKS

Proliferative kidney disease (PKD) of salmonids can be a serious disease threat to both private and public hatcheries and production units. For a review of the disease, see CA-83-5. As discussed in the earlier newsletter, PKD was reported from the California Department of Fish & Game (CDF&G) Mad River Hatchery in 1983. The Department is conducting an extensive survey for PKD at its other salmonid installations, and preliminary surveys have found the disease problem in a number of the State's facilities. There is also indication that PKD has been present at one CDF&G installation since the 1960s when an unknown disease was reported and named "Lupus" by CDF&G pathologists.

With better methods of identification developed in recent years, CDF&G pathologists re-examined slides made from the "Lupus"-diagnosed animals and discovered the previously unknown agent to be PKD. The Department is conducting an extensive examination of the data being gathered from the hatchery and production installations and will consider various options to deal with the problem. To date, positive identification for PKD has been obtained from the following CDF&G facilities.

1. Nimbus Salmon and Steelhead Hatchery: PKD was observed in steelhead only; chinook salmon were planted prior to discovery of infection. However, a small lot of chinook salmon had been taken to the University of California at Davis for unrelated study and these have been found positive. Examination of material on hand dating back to 1966 indicates that this disease has been prevalent at least since that date.

2. American River Trout Hatchery: PKD was observed in all lots of fish on hand except several small, recently acquired groups. Examination of material on hand dating back to 1981 indicates prevalence since that date with no reason to suspect that it hasn't occurred at some level since construction of the hatchery in the

3. Feather River Salmon and Steelhead Hatchery: PKD was observed for the first time this year with no evidence of prior involvement; however, no absolute data are available. It was observed in both steelhead and chinook salmon.

4. Merced River Fish Installation-Salmon (Snelling): PKD was observed for the first time this year with little information regarding prior years.

5. Calaveras Trout Farm (Snelling): PKD was observed in several groups of rainbow trout for the first time this year. There is little information regarding prior years.

As of September 1984 the following CDF&G facilities have been examined with no PKD reported:

1. Crystal Lake Trout Hatchery
2. Mt. Shasta Trout Hatchery
3. Trinity River Salmon and Steelhead Hatchery
4. Coleman NFH - Salmon and Steelhead
5. Mokelumne River Salmon and Steelhead Hatchery
6. Moccasin Creek Trout Hatchery
7. San Joaquin Trout Hatchery
8. Hot Creek Trout Hatchery
9. Mojave River Trout Hatchery
10. Mad River Salmon and Steelhead Hatchery (Although the incidence at this facility was extremely high in 1983, it did not recur in any of the production fish or any of the several test groups during 1984.)

Surveys of the remaining CDF&G facilities will continue.

REARING SESSION III

Facilitator: Dave Ickes
Calif. Dept. of Fish & Game
364 Yellowstone Dr.
Vacaville, CA 95688

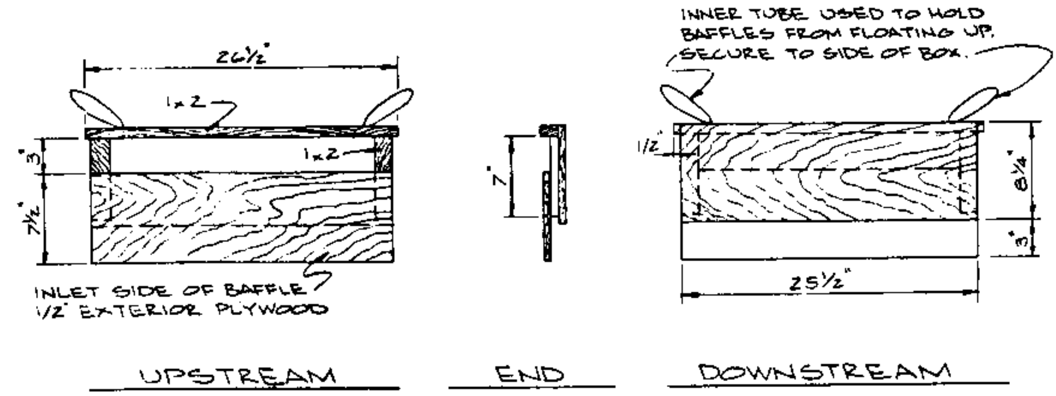
This session was designed to give participants an overview of considerations and techniques for setting up a hatchbox program. Leo Cronin of Trout Unlimited and the Corte Madera Creek Project gave an overview of the basic operations of a hatchbox and siting considerations. Special emphasis was given to the need for multiple water intakes.

Scott Downie of the Eel River Restoration Project described his group's hatchboxes on Redwood Creek and showed several slides. He emphasized back-up water sources and the filtration system also. The many variations in hatchbox designs were also addressed, including upwelling vs downwelling boxes and the use of gravel vs the use of egg baskets with no gravel.

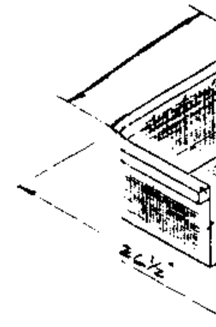
Nat Bingham gave a slide presentation on hatchboxes built by the Salmon Restoration Association on Johnson Creek, a tributary of Big River. Nat's talk gave a historical perspective to the use of hatchboxes in California as this was apparently the first location at which the Department of Fish and Game allowed their use. In addition to design considerations, the need for maintenance and caretaking was stressed. This location was considered ideal by S.R.A. in part because of the extremely cooperative landowners who kept an eye on the boxes.

Jerry Boberg presented slides showing hatchboxes on the South Fork of the Salmon River operated by PCFFA and the Salmon Stamp fund. This site has a somewhat unique problem with cold temperatures during the winter. The water may freeze and is always cold, which slows down hatching and development. An insulated metal shed was built around the hatchboxes and the filtration barrels and pipes were also insulated to prevent this.

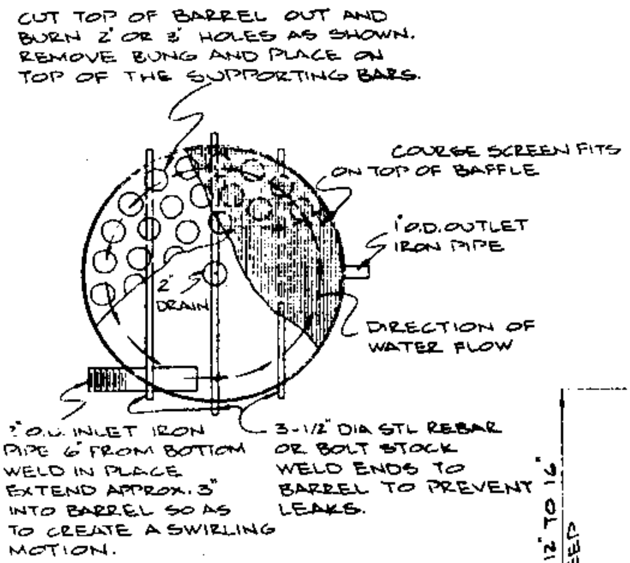
No handouts were distributed at this session but one design for an upwelling box is included as Attachment A and a design for a downwelling box is included as Attachment B. Both designs have been used successfully in northern California.



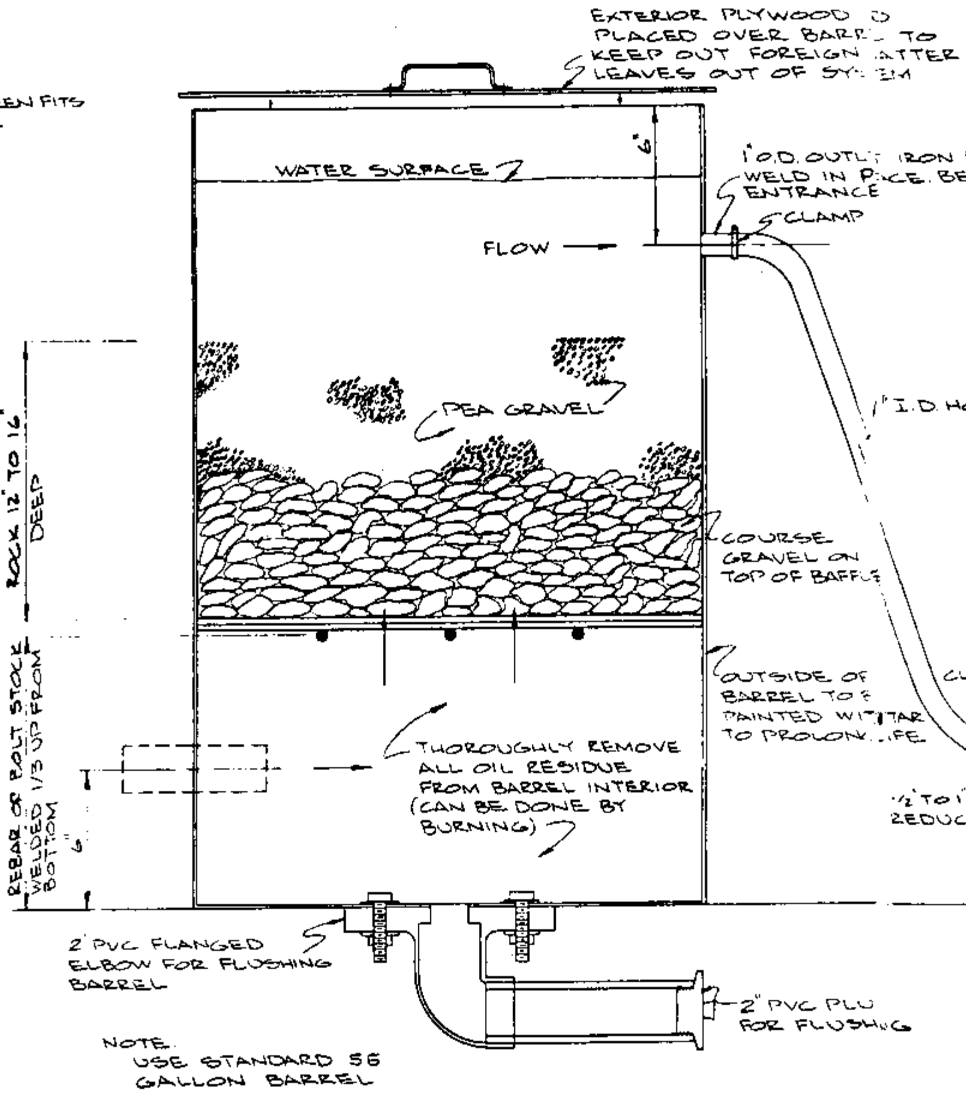
BAFFLE
3 REQ'D 3/4"=1'-0"



EGG
2 REQ'D



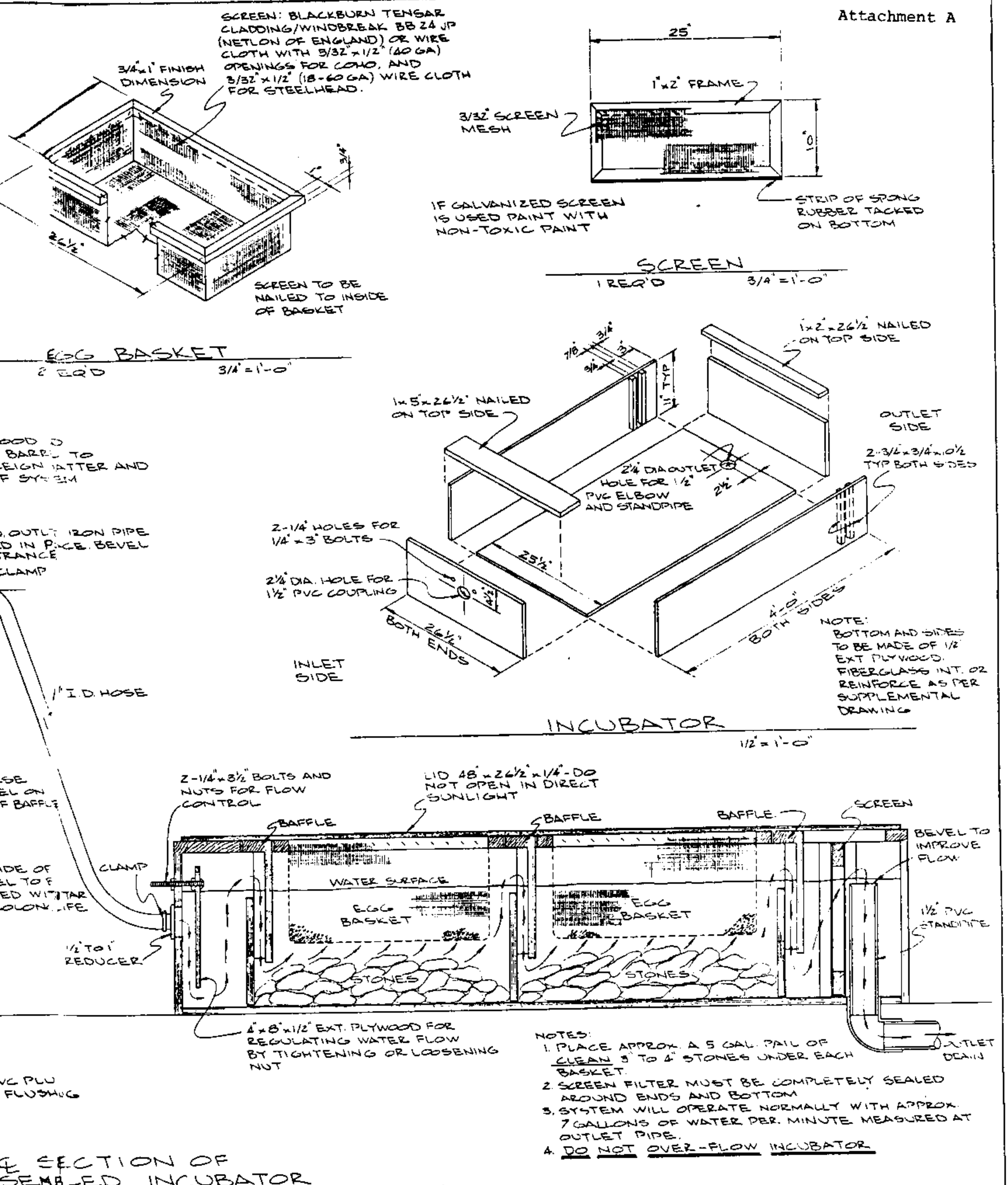
TOP VIEW
3/4"=1'-0"



℄ SECT
ASSEMBLED

DESIGN BY ROB JUNG
BANDON FISHERMAN'S
P.O. BOX 1274 BANDON

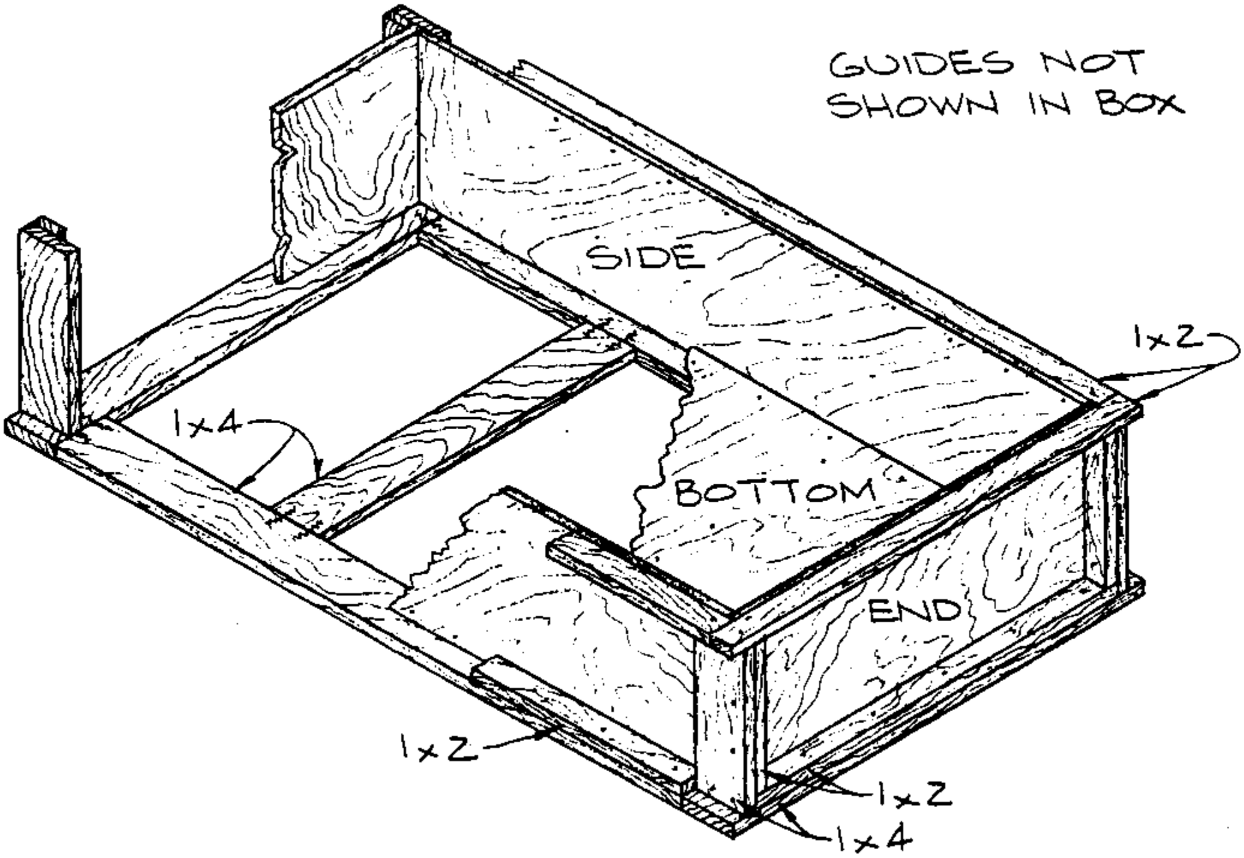
Attachment A

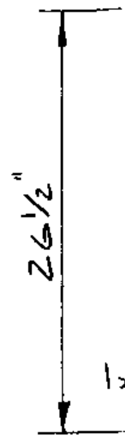


BY ROB JUNGE FISHERMAN'S ASSOC. 1274 BANDON ORE. 97411

STREAMSIDE INCUBATOR FOR SALMON AND STEELHEAD

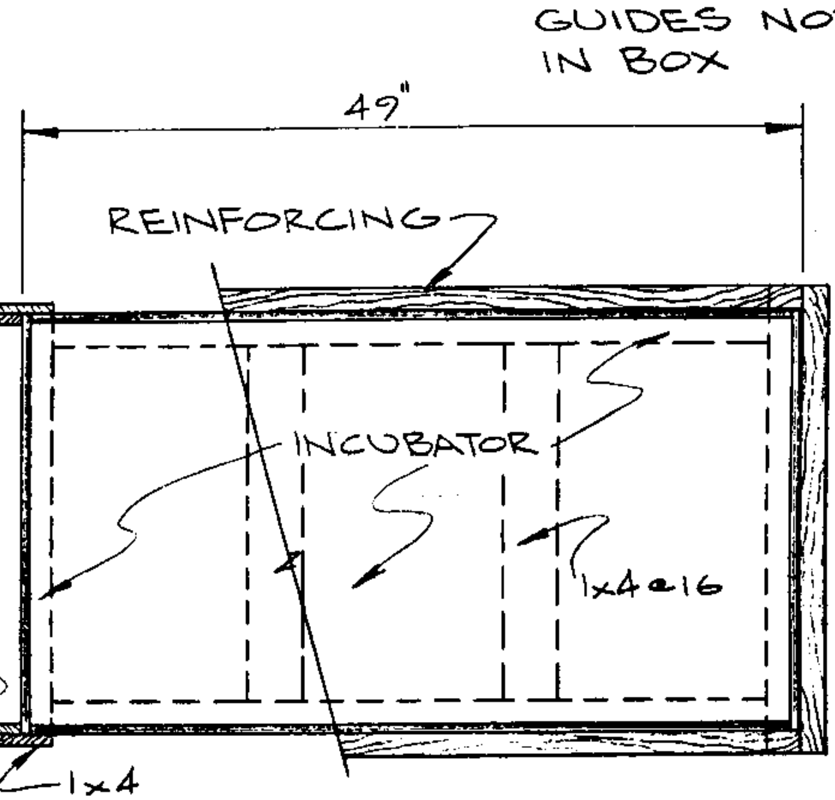
DRAWN BY OREGON DEPT OF FISH AND WILDLIFE APRIL 14, 1981



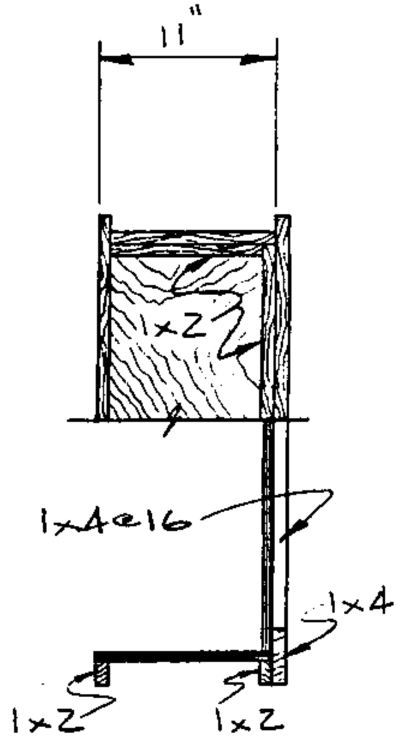


INCUBATOR R
(NON FIBERGL

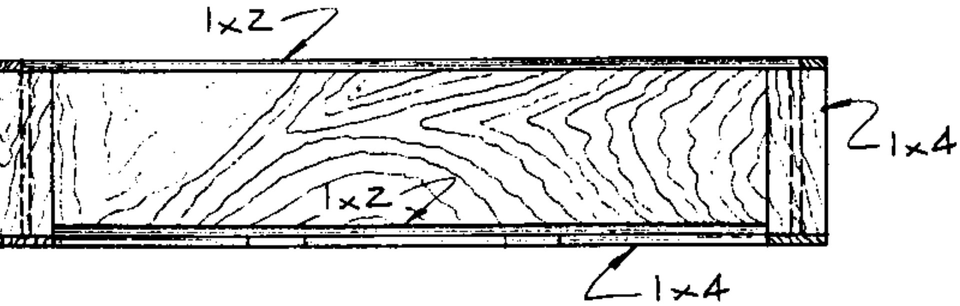
DESIGN BY ROD JUNGE BANDON FISHERMAN'S ASSOC. P.O.BOX 1274, BANDON ORE. 97411	STREAMSIDE I FOR SALMON AN SUPPLEME



TOP VIEW



END VIEW



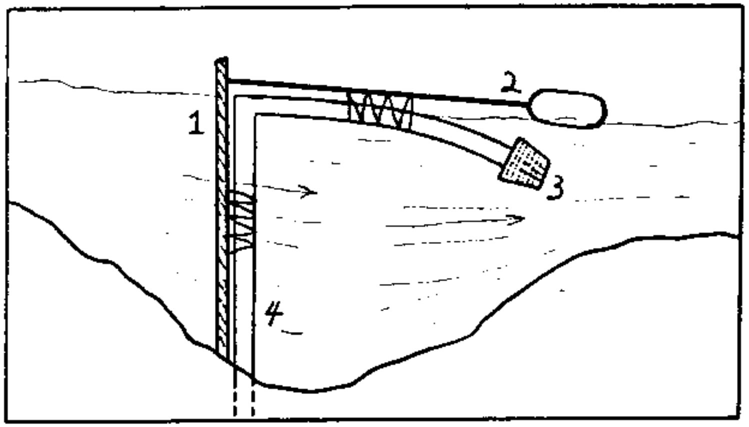
SIDE VIEW

INFORCEMENT
S INCUBATOR)

CUBATOR
STEELHEAD
TAL

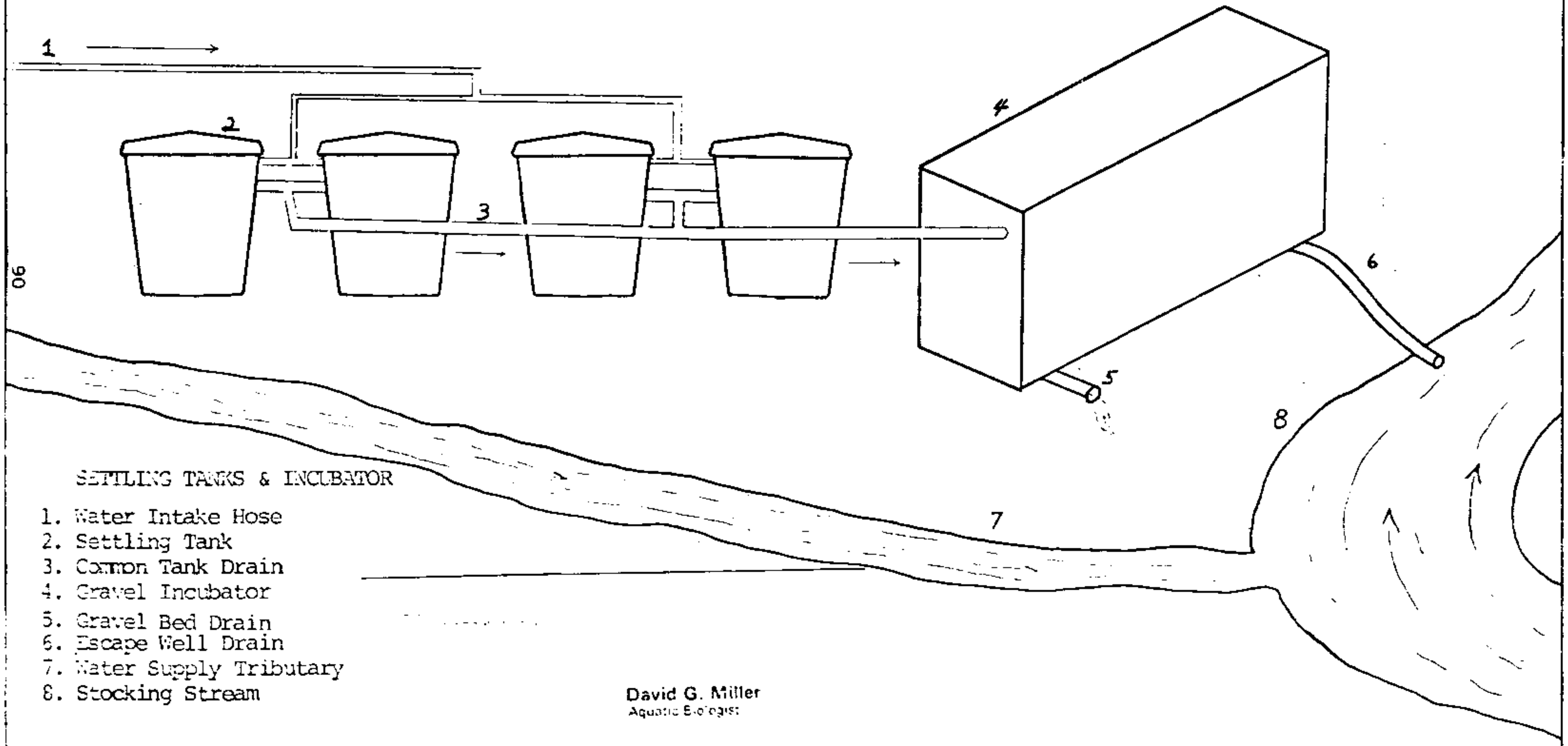
DRAWN BY OREGON DEPT.
OF FISH AND WILDLIFE
APRIL 14, 1981

STREAMSIDE GRAVEL INCUBATOR SYSTEM



GRAVITY WATER INTAKE

1. Support Stake
2. Float-ball Pivot
3. Screened Foot-valve
4. Poly Pipe Hose



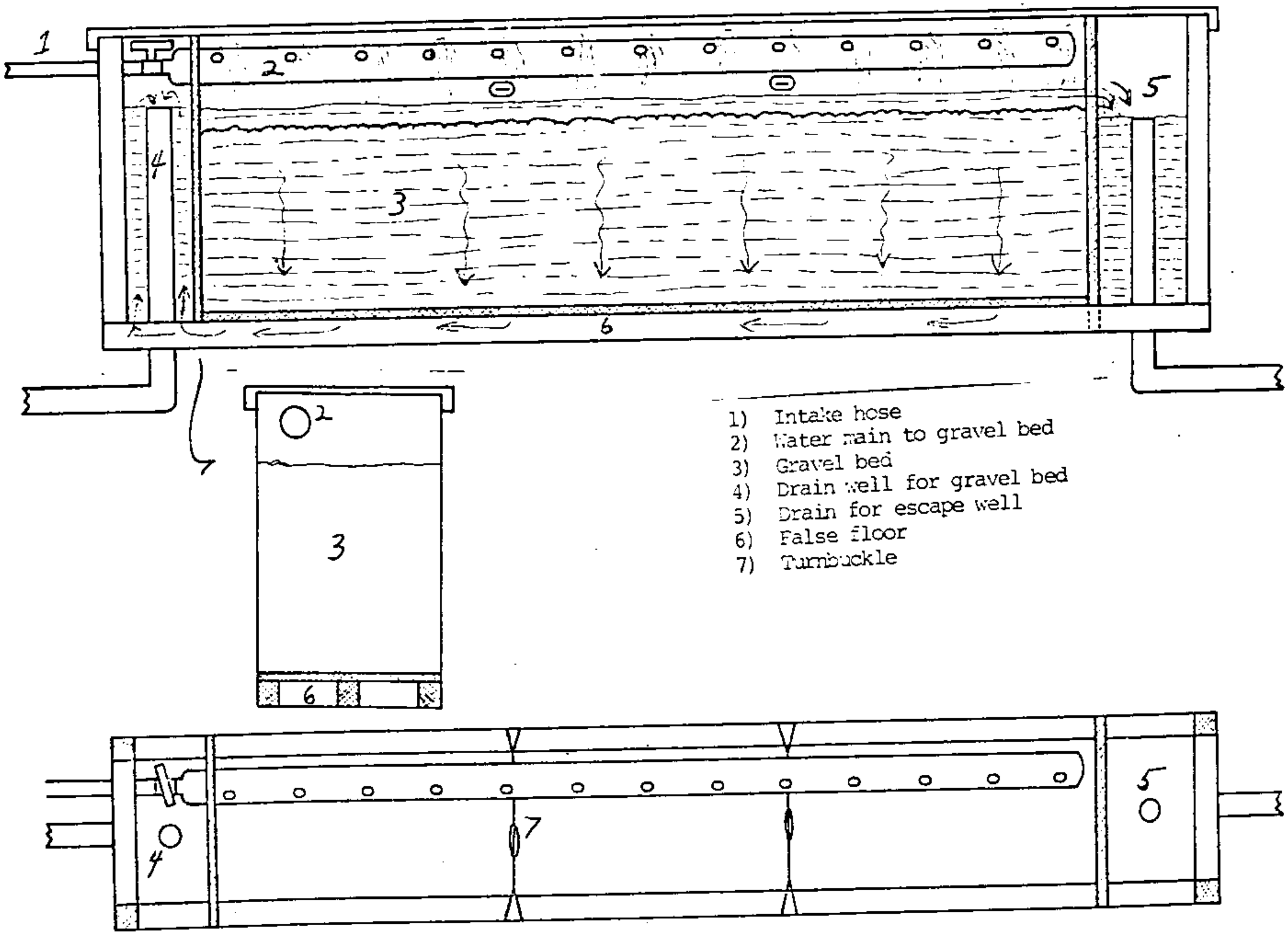
SETTLING TANKS & INCUBATOR

1. Water Intake Hose
2. Settling Tank
3. Common Tank Drain
4. Gravel Incubator
5. Gravel Bed Drain
6. Escape Well Drain
7. Water Supply Tributary
8. Stocking Stream

David G. Miller
Aquatic Biologist

Simpson Timber Company
California Operations POST OFFICE DRAWER A

Gravel Incubator



1) Intake hose
2) Water main to gravel bed
3) Gravel bed
4) Drain well for gravel bed
5) Drain for escape well
6) False floor
7) Turnbuckle

HABITAT SESSION I

Instream Structures

Facilitator: Michael Bird
Department of Fish & Game
5553 Elm Lane
Redding, CA 96001

This session consisted of a panel of four speakers. Three of the speakers were from the U.S. Forest Service and one from the University of California at Davis. In addition, three of the enhancement groups (New Growth Forestry, Trinity River Fisheries Association and the CCC 201 Project) gave a slide presentation on instream structure work that they had been involved in.

The following is a brief summary of the panels and the enhancement groups' presentations:

Mike Henry: Eldorado National Forest. Grass roots or nuts and bolts aspects of installing log structures were presented. This involved placement as well as the type of material and equipment to be used in this type of construction (Attachment A).

Jack West: Klamath National Forest. This presentation involved the placement of large boulders for habitat diversification. Several important rules that were discussed were: Don't try to fix something that isn't broken; Never operate heavy equipment in an anadromous fish stream prior to June 15 or after October 1; Always obtain the necessary permits; Always monitor improvements or you may perpetuate failures; and none of the preceeding is gospel, experience is your best teacher. (Attachments B, C, and D)

Kerry Overton: Six Rivers National Forest. This presentation involved how to, and when to, use gabions for fish habitat improvement. A checklist or cookbook-type guide was presented that will enable beginners at gabion work to eliminate a lot of trial and error. In addition, the specifications for two types of gabion wire baskets were provided. (Attachments E, F, and G)

Joe DeVries: U.C. Davis Water Resource Division. In this presentation, stream hydraulics related to fish habitat improvement were discussed. In addition, comments on each of the presentations, as they related to engineering, were made. (Attachment H)

New Growth Forestry. Slides were presented of their work on Redwood Creek, Mendocino County. This involved the use of log Hewitt ramps to stop the downcutting behind these structures and to provide fish passage through these areas. Some of the problems encountered in this work were shared with everybody.

Trinity Fisheries Improvement Association. Slides showed the use of large boulders, placed as if in a jigsaw puzzle, to develop pools to pass fish through barrier areas such as dams and culverts. In addition, this group had their chainsaw operated winching equipment on display, which they had used in moving these large boulders into place.

California Conservation Corps 201 Projects. CCC's gave a slide presentation on the use of gabions to try and stop movement of slides into creeks, and their use in catching and holding spawning gravels. There were some failures involved in this work and they were pointed out so that this would not happen again.

Log Weir Structure Cost Estimate

The log structures can be made by hand or with a small backhoe. If the work is to be done by hand, a minimum of a six man crew is recommended. The three log structures which were shown in the presentation were constructed by hand in a one week period with an eight man crew. These could have been done with a backhoe, and two crewmen, in three days. The following is a cost estimate for the materials and rental of a backhoe for construction of the weirs:

MATERIALS

1.) Erosion cloth - Mirafi 600X
12.5 ft. X 360 ft. roll = $470 ($.94/sq. yd.)
enouth for 18 structures
Mirafi 700X
6.0 ft. X 300 ft. roll = $260 ($1.30/sq. yd.)
enough for 7 structures

<u>Approximately $35/ structure</u>
(27 sq. yd./ structure)

2.) Fencing material - horse fence
5 ft. X 100 ft. roll = $90
3 structures/ roll

<u>Approximately $30/ structure</u>

3.) Miscellaneous hardware - <u>$5/ structure</u>

<u>TOTAL =$70/ structure for materials</u>

BACKHOE RENTAL

Rental of a Case 1150 track-mounted backhoe costs about $65/ hour. Two weir structures can be completed in a 10 hour day using this piece of equipment. It usually costs $200 - $300 for move-in expenses for the equipment. It could cost from $300 - $450 per structure using a backhoe, but the structure may of better quality than if it were constructed by hand.

FURTHER DETAILS - CONTACT:

Mike Henry
Fishery Biologist
Eldorado National Forest
100 Forni Road
Placerville, CA. 95667
916 622-5061

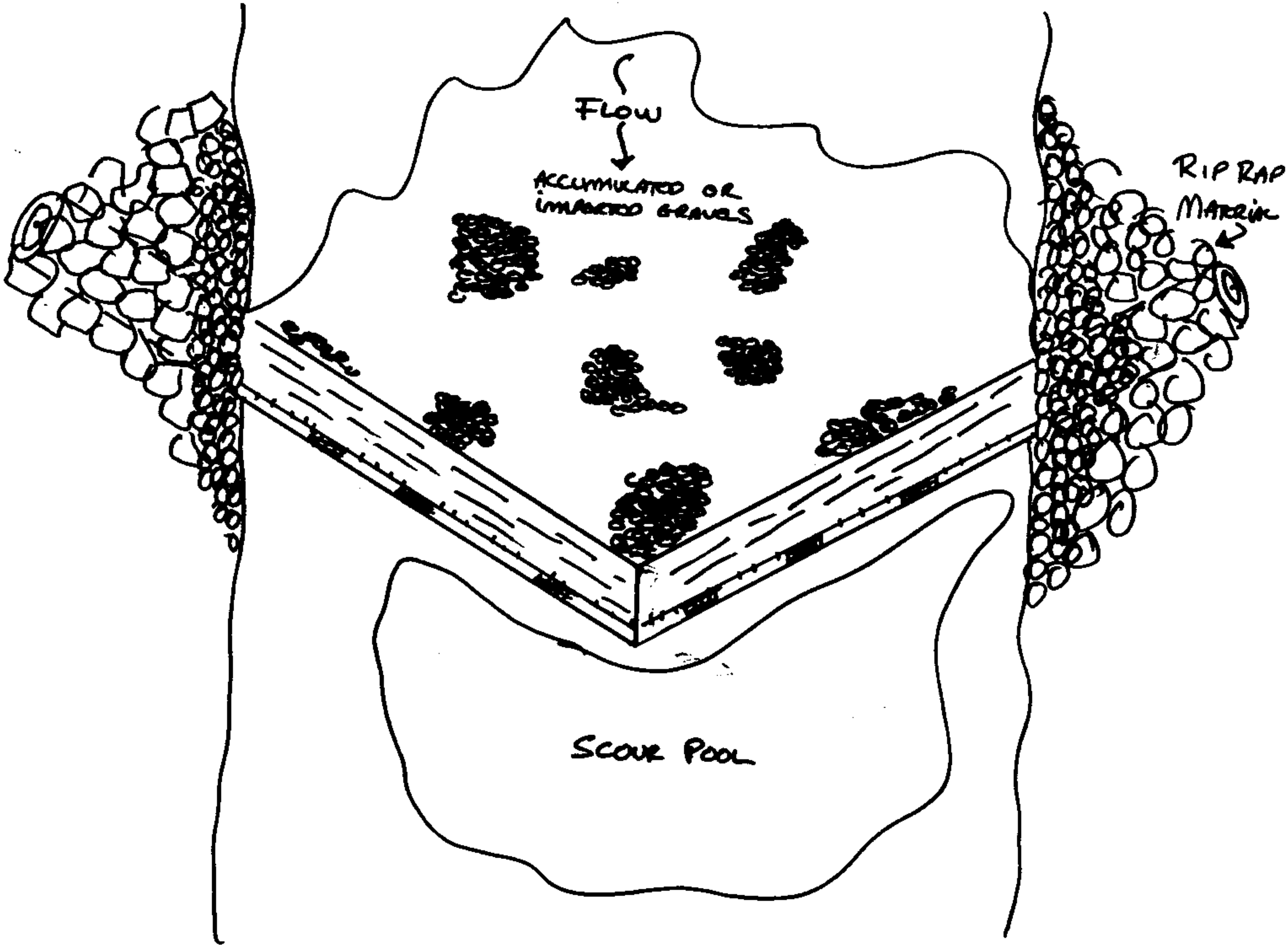


Fig. 1. Top view of completed log weir structure.

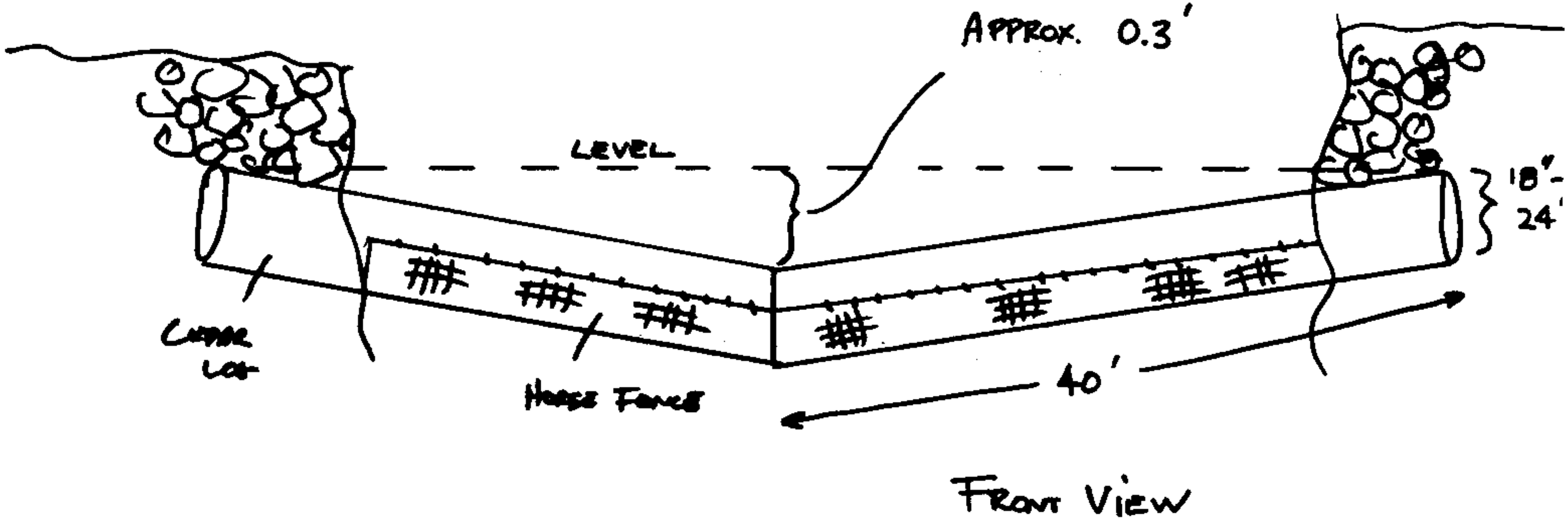


Fig. 2. Front view of completed log weir structure.

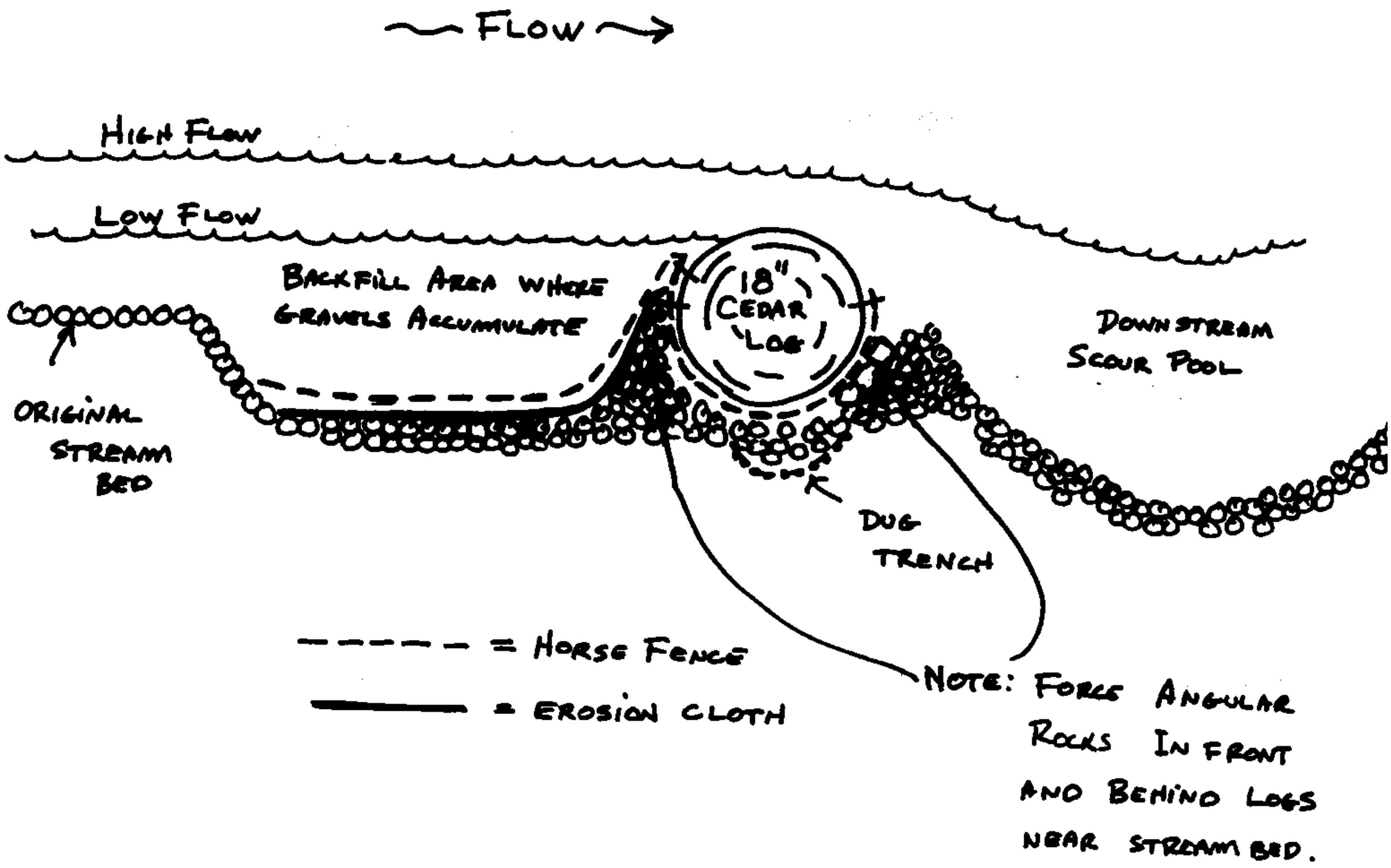


Fig. 3. Cross sectional view of log weir structure.

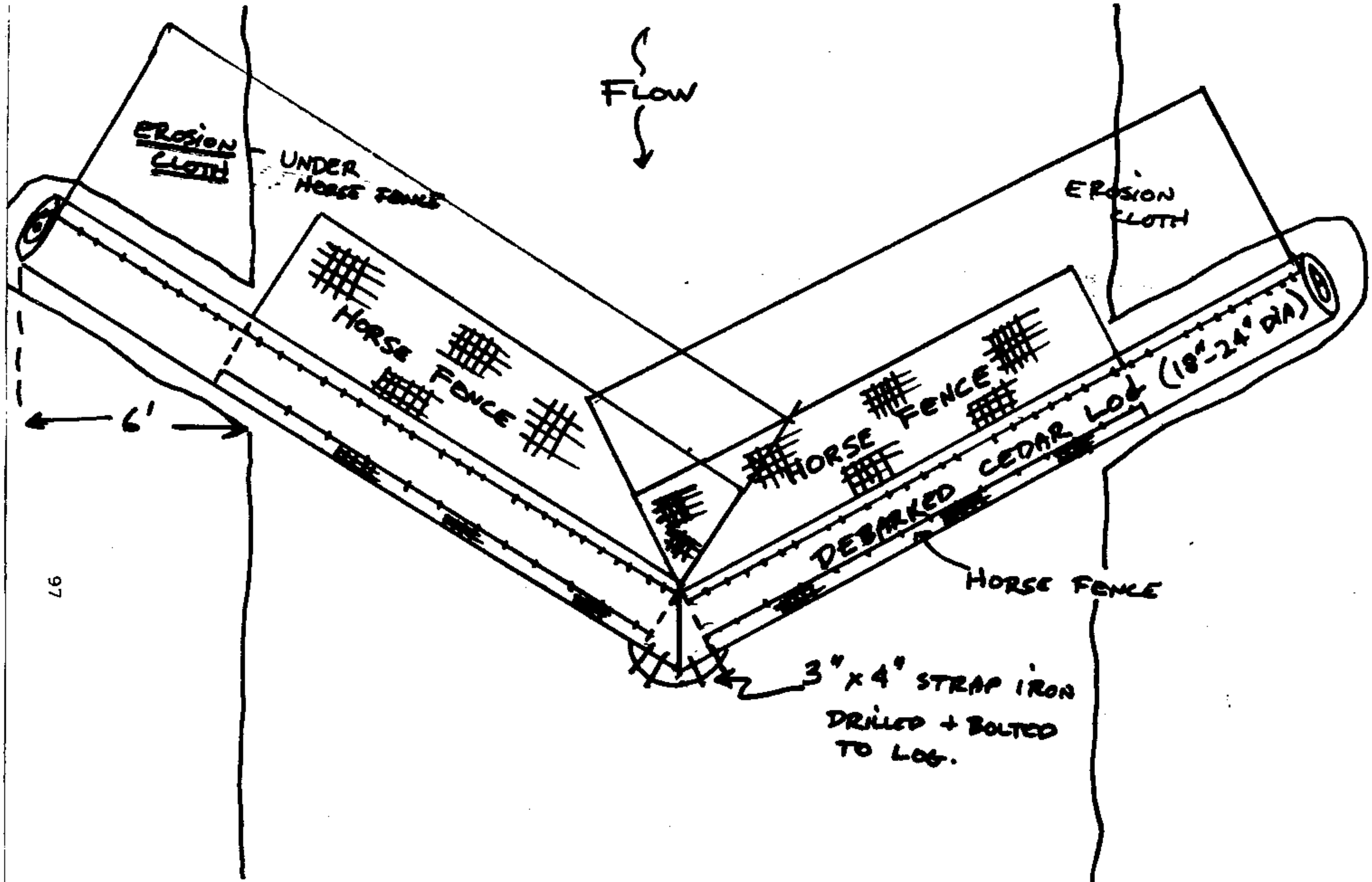


Fig.4. Top view of log weir structure showing construction techniques.

INSTREAM SALMONID HABITAT WORK: BOULDER PLACEMENT FOR HABITAT DIVERSITY

Jack West, USFS Fisheries Biologist
Klamath National Forest
Salmon River Ranger District
P O Box 280
Etna, CA 96027
(916) 467-5757

INTRODUCTION

A recommended format for instream habitat improvement and/or restoration projects is outlined below, specifically for diversifying salmon and steelhead habitat with boulder placement. This format provides a summary of general procedures which I employ and may not encompass some specific features necessary for consideration on a particular project. Excerpts of pertinent publications are attached for your information. Common to any type of technical work, practical "hands-on" experience will be your most valuable learning tool. Start small-scale and be alert enough to recognize your mistakes and eliminate them.

RULE #1 - DON'T TRY TO FIX SOMETHING THAT ISN'T BROKEN!

Step 1 Stream habitat and fish production diagnosis; or is there something wrong here?

Assumption: Habitat ailments should be reflected by fish use and physical habitat features.

A. Poor spawning conditions (especially critical for chinook, not usually critical for coho or steelhead).

1. Biological - spawner utilization of existing habitat low compared to other stream reaches.

2. Physical - accumulations of spawnable gravels low or restricted in size and/or lack of cover for spawners.

B. Poor rearing conditions (especially critical for coho and steelhead; not usually critical for chinook).

1. Biological - low numers of juvenile salmonids aged 1^+ and 2^+ (3"-10") utilizing riffles, comparatively high numbers of juvenile salmonids utilizing few existing pool areas.

2. <u>Physical</u> - riffle substrate is predominated by rubble and cobble, obviously lacking large 'cover' objects (boulders, logs, rootwads, etc.); pool: riffle ratio is less than 50:50 (riffles predominant); distance between pools is greater than 7 channel widths.

<u>Step 2</u> Prescribe habitat restoration or enhancement

Assumption: Through Step 1, you have determined that fish production is being negatively influenced, at least in part, by poor habitat condition.

A. <u>Poor spawning conditions</u> (if weir installation is not feasible or desirable). Prescribe placement of boulder groups to scour pockets, provide instream cover for spawners, and collect gravel patches. Best results in relatively flat gradient riffles (1/2% to 1% channel gradient). Boulders in each group should touch; flat convex triangle shape traps largest gravel patch. Guide flow between opposing 3-boulder groups downstream into a larger 5-boulder group. Lateral spacing between opposing groups should be 1/4 to 1/3 the channel width. Longitudinal spacing between deflecting groups should be 1/2 to 1-1/2 channel widths (Figure 1).

B. <u>Poor rearing conditions</u> prescribe boulder groups to scour pockets and provide instream cover. Best results (deepest pool development) in steep riffles (1% to 4% channel gradient) relatively confined by stable banks and little or no adjacent flood plain. Boulders within each group may touch but perform best with 1/2 to 1 foot spaces between them; sharp convex triangle shape provides best cover and fair pool development. Lateral and longitudinal spacing same as in 2A. Use groups to guide flow from one group into the next (Figure 1).

<u>Step 3</u> Construction planning

Assumption: Habitat prescription is completed, planning is the same for either prescription.

A. Visit project site and adjacent stream reaches during as many flow levels as possible to anticipate highwater velocities.

B. Visit project site during summer base flow period to locate thalweg. Observe natual features that appear to be "permanent", e.g. what size is the smallest boulder that doesn't normally move (a rolling stone gathers no moss).

C. Plan to use boulders at least as large (preferably twice as large) as those identified in 3B. Angular and sub-angular boulders remain in place best.

D. Plan to use the right sized equipment based on the size and weight of boulders to be moved. (Mass = Volume x Density) I use an average density of 150 pounds/cubic foot though some rocks are heavier and some are lighter:

Diameter (ft)	Volume (cu ft)	Mass (lbs)
2.0	4.2	627
2.5	8.2	1224
3.0	14.1	2115
3.5	22.4	3359
4.0	33.4	5014
4.5	47.6	7139
5.0	65.3	9793

E. Use rubber-tired equipment, if possible. Track-laying equipment is too slow, unless boulders are stockpiled immediately adjacent to placement areas. I commonly use CAT 956, 966 and 980 rubber-tired front-end loaders. A 3-in-1 or clamshell bUcket is handy but not necessary, espeically if it costs extra.

F. Boulder source near project site is preferred but development costs may be prohibitive. Importing boulders may be necessary. Try to get price quotes by-the-rock, not by the cubic yard, so you have tight control over the minimum and maximum size rock you pay for.

RULE #2 - NEVER OPERATE HEAVY EQUIPMENT IN AN ANADROMOUS FISH STREAM PRIOR TO JUNE 15 OR AFTER OCTOBER 1 (EARLIER IF SPRING CHINOOK ARE PRESENT)

RULE #3 - ALWAYS OBTAIN THE NECESSARY PERMITS

Step 4 Construction

A. Specify no fuel, lubricant, or coolant leaks and a relatively clean machine for whatever equipment will operate in the stream.

B. Production rate- plan for placement of 7 boulders per hour with a skilled operator on a rubber-tired loader, if boulders are stockpiled less than 1,000 feet from worksite and obstacles in the haul path are not a problem.

C. Direct the placement of each boulder to suit the need.

D. If feasible, work from the upstream end of the project area downstream. This allows you to accurately place groups in newly created velocity chutes.

E. It is unnecessary to excavate any type of bed for boulder placement, they will embed themselves.

F. 1984 prices: CAT 966 w/operator = $112.50/hour
Boulders, 3 to 4-1/2 foot diameter (70 mile round trip haul) = $25 each

Obviously, particular site conditions as well as other factors will cause price fluctuations.

RULE #4 - ALWAYS MONITOR IMPROVEMENTS OR YOU MAY PERPETUATE FAILURES

Step 5 Minimum monitoring; 'seat-of-the-pants' method

A. Measure length, width and average depth of the project site and a similar 'control' area before construction and annually thereafter.

B. Count salmonid redds in project and control area at least one season (preferrably several) before construction and annually thereafter.

C. Count 1^{+}-and-older juvenile salmonids in project and control area before construction (July is best if flows permit), two weeks after construction is completed and annually thereafter. Visual counts using mask and snorkel is economical and relatively accurate (with some practice).

RULE #5 - NONE OF THE PRECEEDING IS GOSPEL, EXPERIENCE IS YOUR BEST TEACHER

STREAM ENHANCEMENT GUIDE

Government of Canada
Gouvernement du Canada

Fisheries and Oceans
Pêches et Océans

Province of British Columbia
Ministry of Environment

KERR WOOD LEIDAL ASSOCIATES LTD.
CONSULTING ENGINEERS

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BIOLOGICAL CONSULTANTS

Vancouver, British Columbia · March 1980

12. STREAM CHANNEL IMPROVEMENTS

Physical conditions within stream channels can be modified to improve or increase particular habitat for salmonids. However, *if such modifications of the channel are to have any degree of permanence and success, they must incorporate the principles of stream hydraulics.* The end result will also depend on correct identificaton of the factors limiting freshwater production of the species in question. For example, there would be no benefit from increasing spawning area for a coho salmon or steelhead trout population if the stream's juvenile rearing capacity were the factor actually restricting production.

In British Columbia, experience in stream channel improvement for salmonids has been somewhat limited. The most common activities have been log jam and debris removal, restoration of obstructed side channels, and measures to stabilize unstable reaches of streams affected by floods. However, several channel improvement concepts developed for eastern North American conditions are currently being evaluated and adapted to suit the more rugged environment of coastal British Columbia.

Physical Processes in Streams

The two principal forces acting on water in a stream channel are gravity and friction. Gravity causes water to move downstream, while friction between water and the stream bed and banks resists this downstream movement. The velocity of the water depends not only on slope and roughness of the streambed, but also on the depth of flow. A large, deep river with the same gradient as a small, shallow stream will normally have a much greater velocity.

Resistance to flow, in either natural or man-made water courses, is influenced by the following factors:

- size of material which makes up the bottom and banks of the stream;
- amount and type of vegetation along the stream banks, including vegetation within the wetted area;
- degree of curvature and the frequency of pools and rapids, all of which affect the uniformity of the stream bottom; and
- obstructions to flow, such as rock outcrops and log jams.

As water velocity increases, these factors provide progressively more resistance to the flow. This causes eddying, local reverses in flow, hydraulic jumps, chutes and waterfalls, which may dislodge and move the resisting object downstream. Resistance to flow tends to increase as the square of the velocity, a factor which applies to all turbulent flow conditions. For example, as the flow doubles the drag forces on an object will increase by a factor of four. In this regard, it is the peak or dominant discharge that governs the physical processes in streams.

To appreciate the capabilities and limitations of a particular stream enhancement technique, one should have a fundamental knowledge of the factors described above, as well as an understanding of stream geometry and flow. Natural streams are seldom straight over a distance greater than 10 channel widths. Three general terms are used to define the basic types of stream forms:

Straight	— applies mainly to *relatively straight* or *non-meandering channels.*
Braided	— channels which successively meet and redivide.
Meandering	— single channels with a high degree of sinuosity or an *S-shaped* channel pattern.

The sinuosity of a meandering channel is defined as the ratio of the distance measured along the centreline of the channel to the distance measured in a straight line across the bends (Fig. 12.1). Streams with sinuosities of 1.5 or more are classed as *meandering*, those below 1.5 are classed as *straight*.

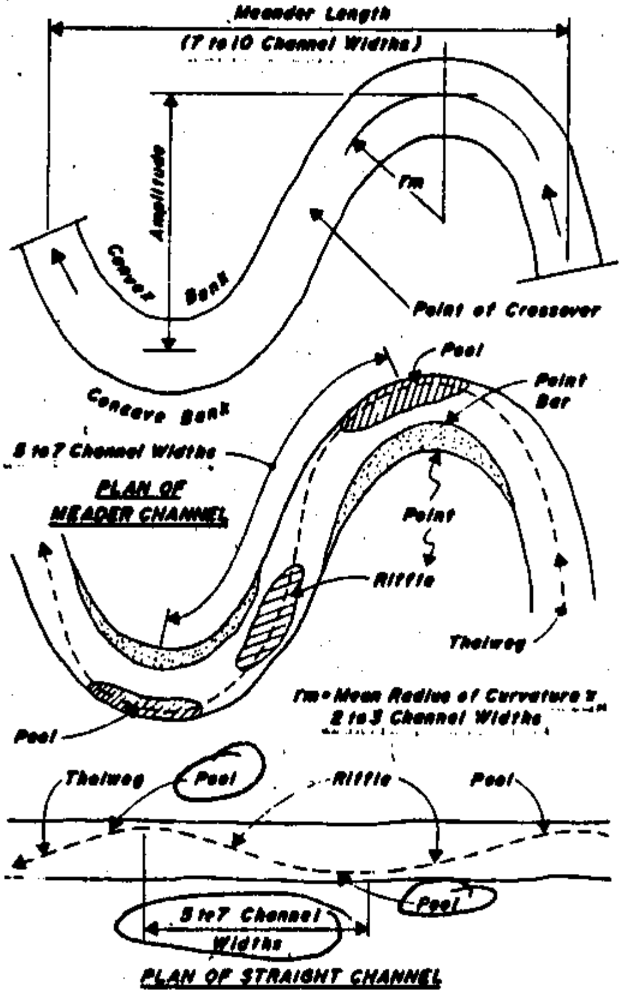


Figure 12.1 Elements of various channel forms and their physical relationships.

A stream will always attempt to maintain a meander shape, as this is the type of curve involving the least work in turning and therefore the most likely path for water to follow. Even where the channel appears straight, the line of maximum depth, called the *thalweg*, wanders back and forth across the channel in a meandering pattern (Fig. 12.1). Where obstructions to flow cause a stream to depart from this normal meander shape, the stream will always tend to restore this natural configuration.

In view of the importance of the meander configuration and the *thalweg* concept to stream enhancement work, a few general *rules of thumb* governing meander shape have been summarized below and illustrated in Fig. 12.1.

(1) Channel width, meander length and radius of curvature are closely related.

(2) Meander length ranges from 7 to 10 times channel width as measured in a straight line. When measured along the centreline of the channel, the length between identical points on the meander waves varies from 10 to 16 times channel width.

(3) Successive crossovers (2 per meander) are spaced 5 to 7 channel widths apart. This is similar to the spacing of successive riffles in a stream.

Two cross sections of a meander channel are shown in Fig. 12.2. One is taken at a point downstream of the axis of the bend and shows the transverse spiral flow developed at the curve of a meander. The transverse flow proceeds along the bottom of the channel towards the inside of the curve and then on towards the outside bank. This transverse flow at a bend results in bedload deposition at the point of a meander, and subsequent creation of a point bar (Fig. 12.1). Floating debris accumulates on the outside of the curve.

The tranverse flow in a straight section of channel is also shown in Fig. 12.2. In a straight section of channel the transverse flow converges at the surface near the center of the stream as two spiralling cells.

These flow characteristics for straight and meandering sections of a stream are some of the important factors to be considered when locating water intakes or carrying out stream enhancement work. For example, if a water intake were located on the inside or convex bank of a curve, the intake would be eventually buried by bedload deposition. Conversely, if the intake were located on the outside of a curve, a trashrack and screening system would be necessary to minimize problems with floating debris.

As noted in the following section, the pool and riffle regime in a river is one of the most important physical influences on the natural production of salmonids. A straight, non-meandering channel usually has an undulating bed that alternates between pools and riffles at a repeating distance of 5 to 7 channel widths. This frequency also applies to a meandering stream, where pools occur at every curve and riffles at each point of crossover. This alternating pool and riffle sequence, present in practically all channels having bed material larger than coarse sand, is characteristic of most salmonid streams in British Columbia.

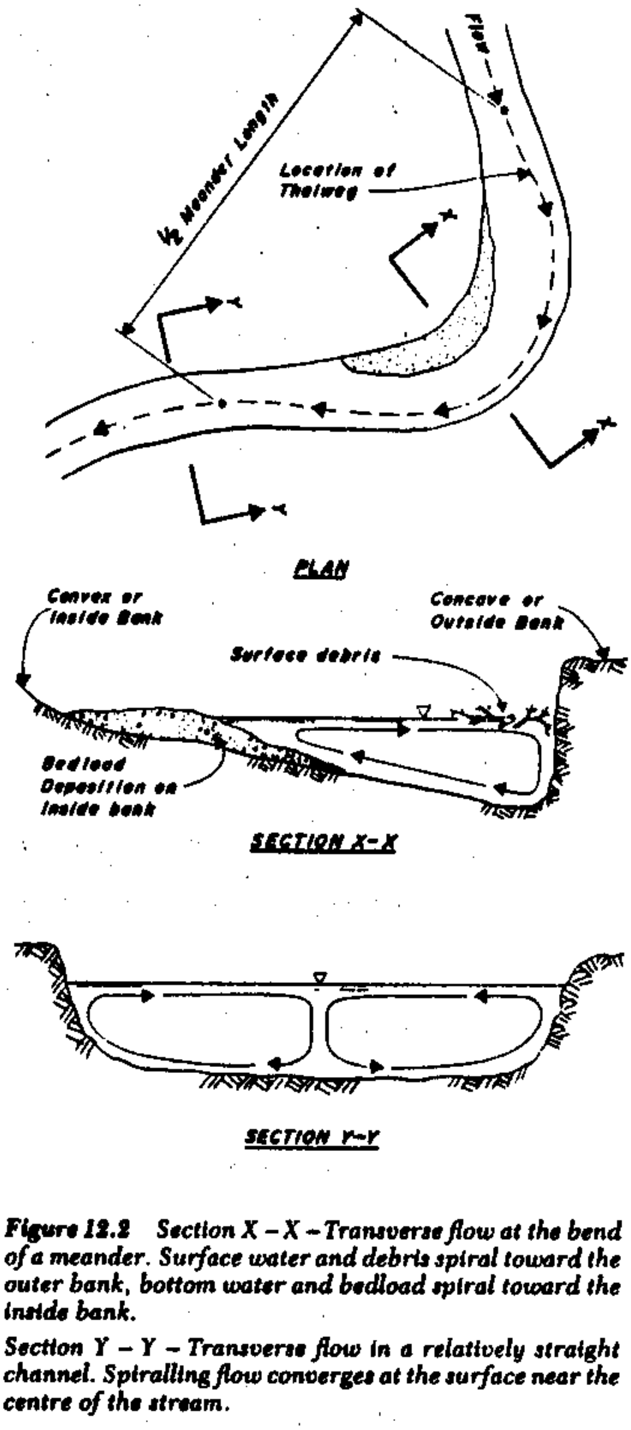


Figure 12.2 *Section X – X – Transverse flow at the bend of a meander. Surface water and debris spiral toward the outer bank, bottom water and bedload spiral toward the inside bank.*

Section Y – Y – Transverse flow in a relatively straight channel. Spiralling flow converges at the surface near the centre of the stream.

In addition to the physical characteristics of the stream channel, erosion and movement of sediments should also be considered when manipulating a stream to enhance salmonid production. Channel shape and cross-section will vary considerably, depending on the characteristics of the bank material. When stream banks become more resistant to erosion, because of the size and gradation of

Table 4. Transport velocities for various classes of streambed materials.

Material	Diameter	Transport Velocity
Silt	0.005 - 0.05 mm (0.00002 - 0.002 in.)	15 - 20 cm/sec (0.49 - 0.66 ft/sec)
Fine to Coarse Sand	0.25 - 2.5 mm (0.01 - 0.10 in.)	30 - 65 cm/sec (0.98 - 2.13 ft/sec)
Fine to Coarse Gravel	5.0 - 15 mm (0.2 to 0.6 in.)	80 - 120 cm/sec (2.62 - 3.94 ft/sec)
Fine to Coarse Stone	25 - 75 mm (1.0 - 3.0 in.)	140 - 240 cm/sec (4.59 - 7.87 ft/sec)
Cobbles	100 - 200 mm (4.0 - 7.8 in.)	270 - 390 cm/sec (8.86 - 12.80 ft/sec)

the natural bank material or due to reinforcement by man, the hydraulic forces of the stream will scour a deeper channel. In general, the shape of the the cross-section of a stream channel is determined by the discharge and the characteristics of the materials that make up the bed and banks of the channel, as well as the type of vegetation within and adjacent to the channel.

As discharge increases in a stream channel, not only does the water level rise at a specific point, but the streambed may be lowered due to scour. For gravel streambeds, the scour depth may be only minor. However, in streams with sandy bottoms the streambed scour will be much greater relative to the rise in water surface level. Streambeds with sandy bottoms will often scour to a depth of about one third the overall rise in water level. This factor is very important when carrying out stream enhancement work, particularly in stream channels formed in silt, sand or other fine materials. Rock weirs and bank revetments, gabion wing dams and other structures described in later sections of this manual, will be unstable if located on sandy stream bottoms. There will be a tendency for structures to be undermined, resulting in the lowering, breakup and downstream movement of the various components of the installation.

Also, pools which are incorrectly located will fill with bedload material. Structures such as diversion weirs, screening facilities, sumps and other portions of facilities within the stream may become buried or partially filled as a result of bedload deposition. In British Columbia, bedload deposition commonly causes either complete loss or reduced performance of an instream structure.

Streams subject to large freshets or fluctuations in water levels will have higher rates of erosion and greater sediment transport. The basic premise that a particle requires considerably more force to initiate its movement than to keep it in motion is evident in any stream with widely fluctuating flows. The extreme peak flows initiate particle movement, while the lower flows have sufficient carrying power (transport velocity) to keep the particle moving.

Uniformity of particle size is also a key factor in bedload movement. For two samples of bed material with the same average size of particle, the sample with less uniform particle size will be more stable, because the smaller particles will fill the voids and thus lock the larger grains in place. Summarized in Table 4 are the minimum transport velocities for various sizes of particles.

Table 4 can also be used to estimate the velocities that usually occur in a river channel, simply by inspecting the river bed materials. If the channel consists of cobbles with very little gravel or sand, the stream regularly has velocities in excess of 200 to 300 cm/sec (8-10 ft/sec). Alternatively, if the maximum velocity of a specific section of channel is known, a rough estimate of the size of bed material that will be relatively stable in that section can be determined. This is particularly important where gravel or cobbles are being added to a stream channel to improve spawning conditions or to modify stream characteristics.

The average velocity for any given length of channel can be readily estimated by placing a small, nearly submerged float in midstream and timing its passage over a measured distance. This will give a slightly high estimate of average velocity. One can then estimate stream discharge or flow by multiplying the average velocity by the wetted width of the stream times the average depth.

The foregoing information on bedload transport velocities and approximate methods for determining river flow and velocity can be used to make a cursory assessment of any section of channel prior to carrying out stream enhancement work.

Also, stream improvement structures should be planned and designed so they do not create the undesirable hydraulic conditions discussed in the section on obstructions to adult migration (Section 11). A man-made weir and pool installation often works well for one season, but as sand and gravel from upstream fill in the pool area, a hydraulic jump may form and create an undesirable situation for fish.

Improvement of Rearing Habitat

Juvenile salmonids that rear in the stream require physical habitat which satisfies three basic requirements; (1) a feeding location with suitable water velocity, near a

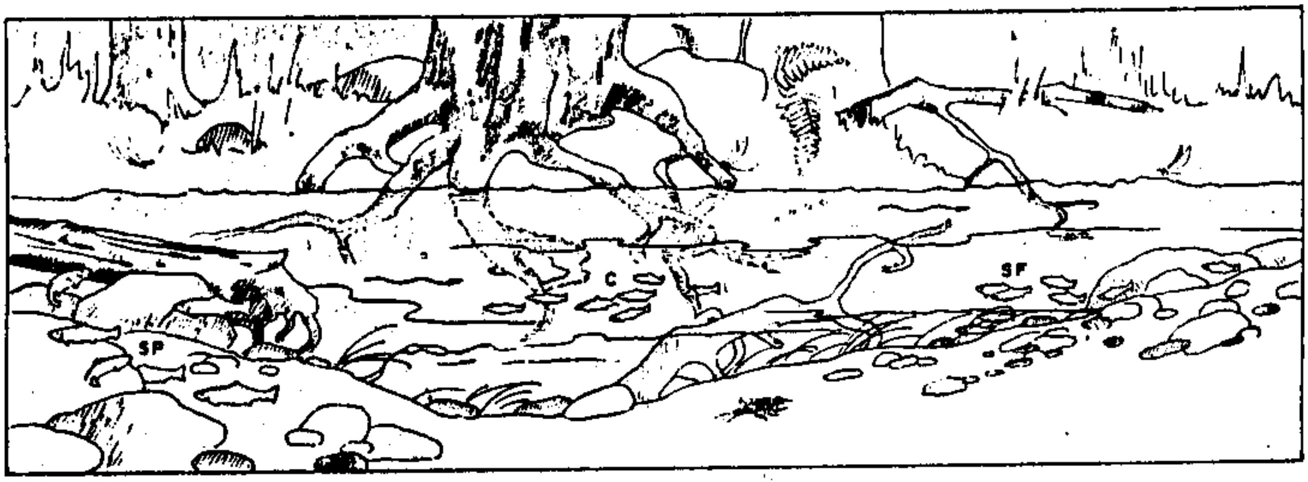


Figure 12.3 An example of differences in summer habitat preferences of juvenile salmonids, related to species and life stage. One year old steelhead parr (Sp) occupy bouldery fastwater locations at head of the pool. Coho fry (C) seek deeper, slower areas of the pool close to bank cover, and steelhead trout fry (Sf) are found in the shallower tail of the pool where the water accelerates into a riffle.

strong current carrying an abundance of drifting insect food; (2) concealment from predators and competitors; and (3) a sanctuary from extremes of flow and ice formation. As they grow, juvenile salmonids seek progressively higher water velocities, often shifting from areas near the stream margin to midstream locations. The advantage of this behaviour is thought to be an increase in access to insect drift food. During winter, all species tend to seek areas of lower water velocity. Presumably this favours conservation of energy reserves during a period of poor growing conditions, and also enables the animal to cope with winter extremes such as ice and floods.

Though their basic requirements are the same, the species differ in the type of habitat they utilize. Even within a single species, habitat preferences change as the fish grow. Fig. 12.3 depicts these differences in habitat preference for coho salmon and two age groups of steelhead trout

Habitat Requirements

Juvenile coho salmon tend to rear in pool areas of moderate velocity (less than 30 cm/sec) during the summer. The preferred habitat is a pool or backeddy in association with an undercut bank, submerged tree roots, branches or logs. In winter, coho shift to slower and deeper pools, or to side channels and pools off the main stream. At this stage of relative inactivity, they seek cover under rocks, tree roots, logs, debris, and in log jams.

The habitat requirements of juvenile steelhead trout must be considered in both their first year of life, as underyearlings or fry, and in the second and subsequent years of rearing, at the *parr* stage. During their first summer the underyearling steelhead are generally found in relatively shallow areas, over a cobble or boulder bottom at the tail of a pool, or in a riffle less than about 60 cm deep. In winter, they hide under large boulders in shallow riffle areas. Preferred summer habitat of steelhead parr includes stable log jams, heads of pools, runs, and riffles. Large boulder substrate is important in runs and riffles. Surface turbulence or white water is an important feature of the overhead cover in these areas. During winter, steelhead parr are found in pools, under debris, logs and boulders, usually associated with bank cover.

Cutthroat trout generally inhabit streams with lower gradient than those which support steelhead. However, the habitat requirements of juvenile cutthroat appear to be generally similar to those of steelhead.

Dolly Varden fry and parr are found in the same general type of habitat, ie. riffles and runs, as juvenile steelhead.

Chinook salmon juveniles rear in relatively large streams. During the early stages of stream life, their habitat requirements appear to be similiar to those of coho salmon. Immediately after emergence as fry, they are found along the stream bank, close to cover such as undercut tree roots or logs. As the young chinook salmon grow, they tend to move into locations of higher velocity either along the stream margin or in bouldery runs away from the shore.

For species such as steelhead and cutthroat trout, which generally reside in the stream for two or more years before migrating out to sea, stream improvement efforts should focus on creating or improving both summer and winter habitat for parr. It is at this life stage that the available habitat will most likely limit smolt production,

General Guidelines

Enhancement techniques to improve rearing habitat must be applied with care, because poorly planned work may cause damage to the natural stream. The following general guidelines must be considered before modifying existing features of the stream.

(1) Pool and riffle areas repeat at approximately 5 to 7 channel widths, regardless of whether the stream has a meandering or straight configuration. This natural stream form must be maintained, and the addition of any devices to improve the rearing habitat must compliment the natural stream configuration.
(2) Devices in streams must be located to avoid backflooding the section immediately upstream. Riffles can be flooded out and pools can be reduced to a velocity which is no longer acceptable to rearing salmonids. In general, stream devices should guide the current rather than dam the flow.
(3) All stream devices must be constructed in low profile to permit free passage of drifting logs and debris.
(4) All structures should be built solidly, and of sufficient size to withstand the normal flood flows. They must also be effective during low flow conditions.
(5) Construction materials should be natural, wherever possible, should be durable enough to withstand freeze-thaw cycles and hydraulic forces, and must be reasonably resistant to decay.
(6) Devices to improve a specific section of stream must be installed in a manner which will not damage adjacent areas of high value to fish. When heavy equipment is used, it is especially important to avoid traversing good, stable areas of natural stream to reach the section being improved. To destroy 50 metres of stream in order to enhance 10 metres is obviously not prudent.
(7) All stream work, particularly where heavy equipment is involved, must be timed to avoid conflict with the spawning and incubation periods of the various salmonid species.
(8) Stream banks must be well protected (reveted) if a stream device accelerates the flow or turns the flow toward a bank. This is particularly important where there is a possibility of damaging existing fish habitat or private property.

In the following sections, various types of stream devices for enhancing salmonid rearing habitat are described. However, the general guidelines noted above must be kept in mind when locating and constructing the various installations.

Creating Pools or Runs

Wing-deflectors are a common device for modifying or improving stream channels. They are installed along the upstream edge of a point bar as an erosion-resistant leading edge. A well-constructed system of wing deflectors, alternating from one side to the other, will maintain the normal meander pattern (Fig. 12.4). Due to the resultant concentrations of flow, pools at bends will become deeper, the banks will undercut more, and the resulting sands and silts will be deposited at the downstream end of the wing deflectors as point bars (Figs. 12.1 and 12.5).

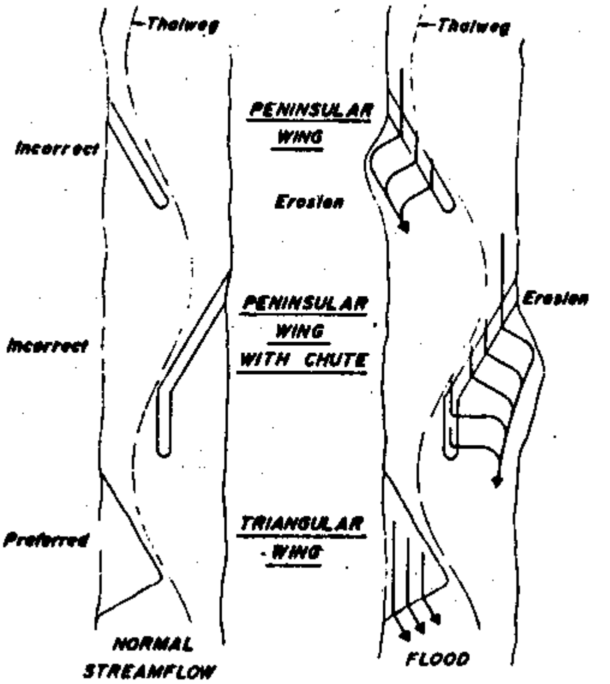


Figure 12.4 Performance of various kinds of wing deflectors under normal stream-flow and flood conditions. Water course is straightened to simplify the diagram (Adapted from White and Brynildson, 1967).

A few general *rules* must be considered when installing a wing deflector to create pools and runs:

(1) Avoid installations in unstable floodplain or braided channel reaches of stream. In these areas structures may rapidly become ineffective or may add to existing instability.
(2) Locate the deflector well down the riffle to avoid impounding water upstream.
(3) Deflectors should form an angle with the stream bank of 45 degrees or less. Experience indicates that this improves their performance. The appropriate angle and length of wing will be specific to each site, and should generally conform to the natural meander sequence of the stream.
(4) Boulders and/or rock-filled gabions are best suited for construction of wing deflectors. When individual rocks are used, the size of individual boulders will depend on the characteristics of the stream. Generally, rocks for wing deflector construction should not be less than 0.6 m in diameter.
(5) Where the wing deflector connects to the river bank, the point of connection *must be protected by rip-rap or gabions* to above the flood level, so as to prevent the river from washing around the end of the deflector (Fig. 12.6). Similarly, the bank opposite the deflector must also be protected to eliminate erosion

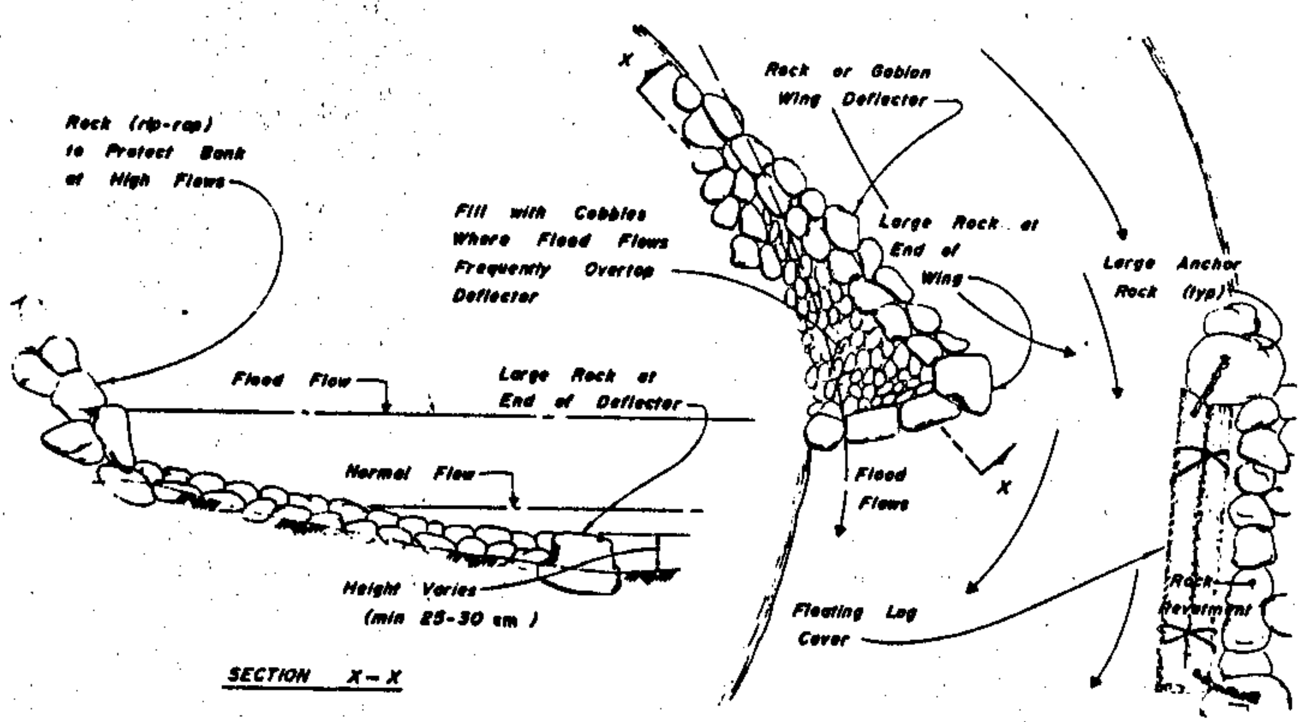


Figure 12.5 Typical wing deflector constructed from rock. The current will scour a deeper pool on the opposite bank. Two logs lashed together with cable provide floating cover. Anchor cable must be located to avoid snagging debris.

that could be harmful to fish habitat or streamside property.

(6) To minimize scour of the foundations of wing deflectors constructed with large rock, always use a minimum of two rows of rock, with the joints staggered. The second row should be set into the bottom of the river with the top slightly lower than the first row of rock, and the deflector should be triangular in shape (Fig. 12.5).

(7) If possible, securely cable log cover (preferably cedar) to the revetment on the opposite bank to provide additional cover and accelerate scour of the pool or run.

(8) Where the stream bottom is composed of coarse material, pre-excavation of the intended pool or run will be required to speed up the natural erosion process and to ensure development of suitable habitat.

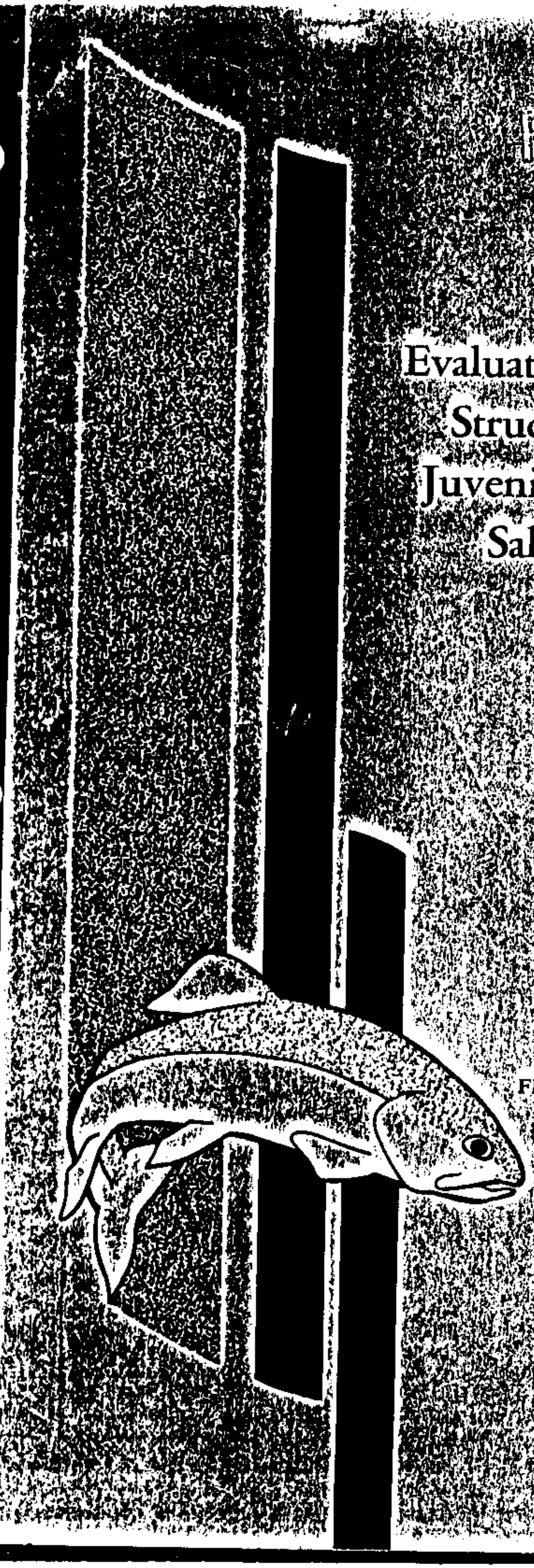
(9) The height of the wing deflector should be set so that at peak flows it is sufficiently submerged to pass logs and debris. If the deflector is set too high, severe bank and channel erosion could result.

Other devices have been used to form and maintain small pools or *pockets* in a stream channel. In British Columbia, grouping of boulders have been found to be the most effective method of increasing rearing habitat for juvenile coho and steelhead. These installations consist of carefully placed boulders generally located at the upstream end of a very shallow pool or run area, and favouring the outside of a curve. Other effective locations are at the middle and downstream portions of a riffle.

Three to five large, well-placed boulders, normally 0.6 to 1 m in size for most small streams, will create a stable run area within the riffle as well as provide cover for rearing salmonids (Fig. 12.7). In large streams, boulder groupings can be repeated in a staggered arrangement down the length of a riffle, thus maximizing fish production. If correctly placed, the combined action of turbulent flow around the boulders and the transverse flow which develops on a bend will minimize bedload depositon downstream of the rock grouping. In some locations a short wing deflector may be required in conjunction with the rock grouping to prevent gradual deposition of bedload material around the individual boulders. Suitable rock is often available from quarries operated by forest and mining companies. Large boulders can also be obtained at the base of talus slopes.

These rock grouping installations require minimal maintenance because minor movements of individual rocks do not seriously reduce the installation's effectiveness. However a suitable spacing (2-3 m) must be maintained between the individual rocks to avoid accumulating debris and trapping bedload material. Where the stream substrate is coarse, some pre-excavation may be necessary to ensure a *pocket* forms adjacent to the individual boulders. This is particularly important for obtaining utilization by coho salmon, but it appears that it may

Attachment D



Evaluation of In-stream Enhancement Structures for the Production of Juvenile Steelhead Trout and Coho Salmon in the Keogh River: Progress 1977 and 1978

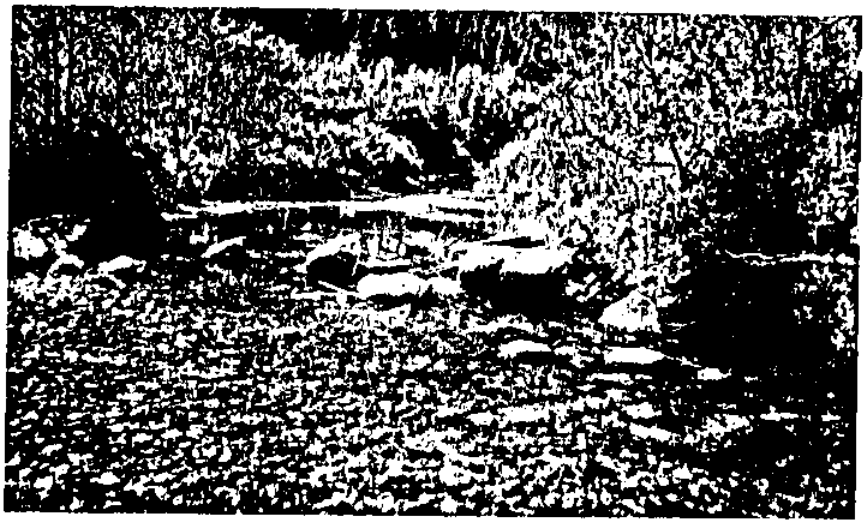
by

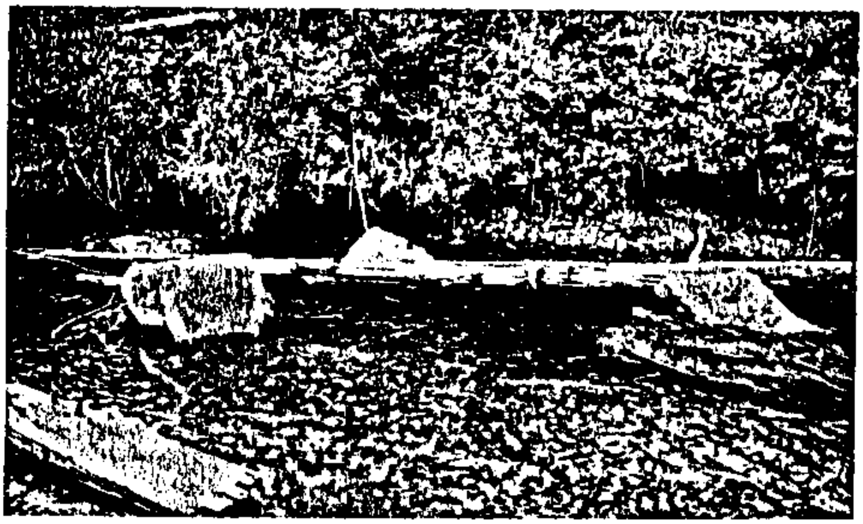
B. R. Ward and P. A. Slaney

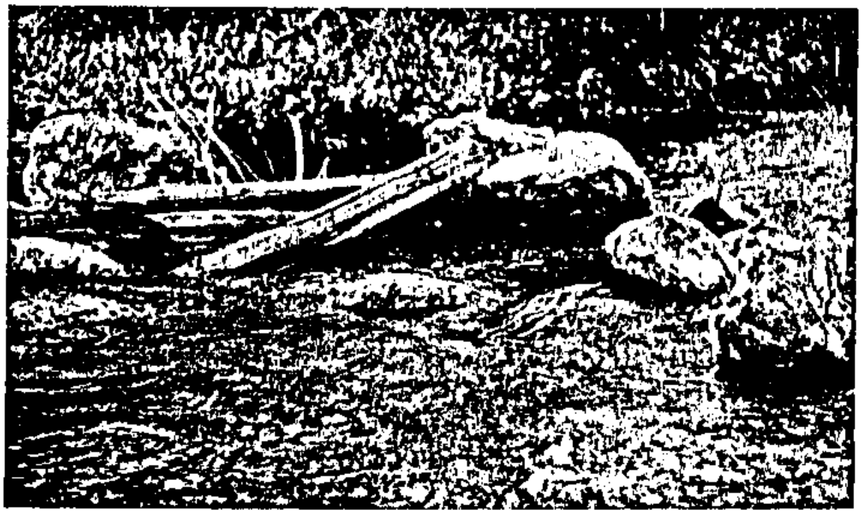
FISHERIES TECHNICAL CIRCULAR No. 45

1979

Province of British Columbia
Ministry of Environment







Appendix 3a. Three boulder grouping sites with log cover cabled tightly into the lead rock, increasing habitat complexity. Each boulder caused deepening of the site, but largely maintained the turbulent surface. This design was the most highly utilized by rearing salmonids and the most cost-effective.

Appendix 6. Guidelines for in-stream structures to improve steelhead parr and coho fry rearing habitat

In this study, boulder groupings were the design most highly utilized by salmonids and, in addition, the most cost-effective. Several guidelines are evident from the experience gained in selecting sites, placing structures and evaluating durability and fish utilization. These guidelines are directed at boulder groupings and secondly to wing deflectors where the latter is necessary to ensure channel stability and durability of groupings. Guidance from a biologist or technician who has experience in this type of stream enhancement technique, is advisable both in the prescriptive and installation phases.

PRESCRIPTIVE PHASE

1. Determine, *apriori*, if fry density (i.e., fry recruitment) is adequate to completely utilize existing and potential rearing habitat. Efforts to increase summer and winter habitat of steelhead parr and coho underyearlings could be unsuccessful or premature if few fry are initially available to utilize or subsequently move into the structures.

   Critical levels of fry abundance, either in density or biomass, are difficult to ascertain, but an estimate could be made by systematic electro-fishing and/or pole seining in 100 m sections of diverse pools and riffles. There is no definitive level and it would vary, regardless, as a function of stream benthic productivity, complexity of rearing habitat and expected magnitudes of freshets. Based on preliminary data from the Keogh River, average minimum densities of steelhead and coho fry during July that appear minimal relative to subsequent smolt production are $0.2/m^2$ ($20/100\ m^2$) and $0.3/m^2$ ($30/100\ m^2$) respectively. Comparative lineal densities would be 1.7/m and 2.6/m respectively. The latter would vary with stream width and be more useful on larger streams, where fry utilize margins more exclusively. Also, for steelhead, comparison of age 0+ and 1+ densities can be instructive, unless the stream has had poor fry recruitment for more than one year.

2. The stream should be inspected during average summer flow and, if possible, maximum and minimum flow to record the dominant thalweg, unstable sections and to quantify available rearing habitat. Each reach should be classified into pool, run or riffle, estimating by area (more detailed division by gradient, depth and width is desirable):
   a) length of pool, run or riffle
   b) mean depth of each habitat class
   c) percent in-stream protruding boulders (> 30 cm, creating rearing space behind them)
   d) percent in-stream logs and debris
   e) percent over-stream 'cover' > 1 m from the surface; cutbanks, over-stream logs and roots, and vegetation

   Ground and low level aerial photography is useful in reaches where the stream is visible through the forest canopy. The latter can be used for mapping sites for various structures.

3. Prescribe in-stream enhancement structures for sections of stream reaches that have; a) a dominance of riffle over pool, and b) where riffles are comprised of coarse gravel to cobble substrate, with few boulders and other associated 'cover'.

4. Prescriptions should emphasize multiples of boulder groupings within the wetted width of the stream, utilizing other designs, i.e., wing deflectors, only to ensure stability of the thalweg.

SITE SELECTION FOR BOULDER GROUPINGS

Each section of stream will require modification of techniques according to channel configuration, stability and velocity.

1. Avoid braided, unstable sections because durability of structures could be less than five years.

2. Minimize placements throughout slow velocity areas, i.e., shallow, non-turbulent pools or 'flats'. Structures in these areas will not significantly increase summer habitat of steelhead although may be beneficial for increasing over-winter survival. This also applies to deep pools and deep runs, because no correlation has been evident between summer carrying capacity of parr and frequency of boulders in the middle or head of pools and runs (Keogh River, data on file).

3. Large boulders (> 0.6 m diam) are recommended owing to their stability during freshets, and effectiveness both for use by steelhead parr and for scouring of rearing 'pockets' in the substrate. In sections where substrate is comprised mainly of cobble, velocities of 3 to 4 m/sec can be predicted for peak flows from standard hydraulics information. Boulders > 0.6 m are not transported at these velocities (placement of large boulders by helicopter requires a machine with a lift capacity of 800 kg or 1800 lbs).

4. Boulders must be placed in higher velocity areas that lack in-stream cover, i.e., within riffles and very shallow runs. Stream gradient at the proposed structure site must be greater than 0.2% to be most effective.

5. Avoid placement of structures, particularly boulder groupings, near the upper end of riffles. This will cause diversion around the structure and 'backwatering'. It is also desirable to maintain sufficient (e.g., 5 m) riffle leading into structures to maximize insect drift.

6. Establish in which direction the thalweg of the stream tends to turn and concentrate the groupings on the outside of the bend to minimize probability of the stream shifting, decreasing durability.

7. Boulders in groupings should cover the wetted width and be well spaced (ca. 1 m between boulders). Three to five boulders in a triangular configuration in staggered groups or clusters along the riffle or very shallow run appear to be most effective because each group guides turbulent 'overhead cover' into a downstream group.

8. In coarse substrate, i.e., cobble, pre-excavation of material at lower sides and downstream of boulders is necessary to create 'pockets', although preliminary data from 1979 suggests this is only a necessity for juvenile coho salmon.

9. Small log cover, cabled securely and tightly into the lead boulder in each grouping may promote higher utilization although this has not been confirmed. No log ends should project during higher water levels because serious snagging of floating debris will occur.

DEFLECTOR PLACEMENTS

Boulder groupings were found to be more cost-effective than deflector designs. However, in some hydraulic conditions (undefined or multple thalweg) it can be advantageous to use a small wing deflector to guarantee high durability of groupings. Guidelines are as follows:

1. Keep the wing profile low to minimize bank scour and avoid catching debris (0.5 m maximum).
2. Locate the deflector down the riffle to avoid impounding of water.
3. Peninsular deflectors are more prone to bank and side erosion (creating backwaters) than triangular deflectors. The deflector will guide the current into the area where deepening is desired, amongst the groupings.
4. Deflector angle should be 45° if scouring is desired.
5. Revet the opposite or outside bank with 'rip rap' and place several larger boulders in the wetted channel to maximize salmonid habitat. In some locations, where the opposite bank is comprised of large stable materials, revetment is unnecessary, but addition of boulder cover is required.
6. Log cover, cabled securely and tightly into the lead boulders will tend to increase salmonid carrying capacity of the revetment. Potential for snagging floating debris can only be minimized by ensuring the cover is submerged at high flows.

Accordingly, structures should be designed and located to maximize structure durability and salmonid utilization. Cost effectiveness, compared to other enhancement options, can only be attained where there is adequate fry recruitment, a significant lack of in-stream cover, particularly few boulders in extended riffles, and a stable thalweg within the stream channel.

GABION USES IN ANADROMOUS

FISH HABITAT IMPROVEMENT

Kerry Overton
Six Rivers National Forest

I. Gabion Basket

- Rock-filled wire mesh basket that comes in several sizes.
- Used as building blocks to construct variable shaped structures that require a lot of mass.

II. Gabion Uses

- Spawning habitat: collection and stabilization of spawning size gravels.
- Rearing habitat: create shelter, pools and a variety of depths and velocities.
- Sediment reduction: separate erosive water forces from unstable-eroding surfaces.

III. Advantages

- Flexible, inexpensive durable building blocks.
- Simple construction procedures.
- Easy to transport.

IV. Disadvantages

- Unnatural appearance.
- Galvanized wire in the stream.
- Maintenance required.

V. Siting Criteria

- Need a knowledge of channel forming and flood recovery processes.
- Need a knowledge of fish needs, habitat types and availability.

* Rules of Thumb for Site Selection for Spawning Habitat:

1. Select a straight stream reach that is wider than the average channel width.
2. Stream banks should be low and gradually sloped with an overflow plain.
3. Stream gradient 1-3% with a substrate slightly larger than desired materials.
4. Place weirs in tandem with a heel-to-toe relationship (bottom of upstream weir level with top of downstream weir), or place in the tail of a pool.
5. Banks need to be stable or riprapped to prevent erosion around the ends, weirs extend ten feet back into the banks.

6. Place a few large boulders (1+cubic yard) or a gabion block (3x3') upstream of weir to provide shelter for spawning adults.

* Rules of Thumb for Rearing Habitat Development:

1. Place weirs and deflectors in wide, shallow, and fast velocity stream sections with large gravel/ruble substrate and armored banks.
2. Structure spacing is important. Avoid flooding out structures upstream by maintaining at least a heel-toe relationship and prevent directing scour flows at bank ends of adjacent structures.
3. Stream structures should be blended into the banks. Banks upstream and downstream need to be protected to prevent cutting around the bank ends of structures.
4. Structures should maintain a low profile to reduce stress on the structure and allow for logs and debris to float over the top.
5. Structure size and mass should be of sufficient size to withstand high flows. Look at the size of existing structures within the stream that have survived through several years and then construct 1 1/2 to 2 times the mass, if practical.
6. Evaluate a stream section for structure placement between meander bends or channel control points, as the channel will be affected upstream and downstream of the structures.

VI. Gabion Construction
(see enclosed sheets)

- Assembly - insure all sides are even and that wire ties are double rapped at 4 inch intervals or laced with double wraps every 4 to 6 inches.

- Filling - Rock is laid down in layers, insuring that all voids are filled and meshed together. This prevents shifting of fill material when water is moving through the gabions. To maintain gabion shape, internal spacing wires must be placed after baskets are 1/3 and 2/3's full. Angular rock is preferred to river run rock as a fill material, as it locks together.

- Insure the basket top is flush with the sides. This often requires stretching the top with pry bars. Secure the top with tie wire lacing, with double wraps averaging 4 inches.

GALVANIZED GABION SPECIFICATION

SCOPE

This specification covers the use of galvanized steel wire mesh baskets filled with stone used as retaining walls, slope paving, river bank protection, outfall structures, weirs and drop structures, etc.

DEFINITIONS

a) Gabions are defined as galvanized steel wire mesh box-shaped baskets, of various sizes. The baskets are filled on site with clean-hard stones.

b) The selvedges of the gabions are the thicker perimeter and edge wires to which the wire mesh is securely tied to withstand sudden or gradual stress from any direction.

c) Reinforcing wires are the thicker wires incorporated into the netting during fabrication.

d) The diaphragms are internal wire mesh partitions which divide the gabion into cells.

e) Lacing or binding wire is the wire used to assemble and join the gabion units.

f) Connecting wires are the internal wires used to prevent the gabions from bulging.

FABRICATION

Galvanized Steel Wire Mesh Gabions. Gabions shall be fabricated in such a manner that the sides, ends, lid and diaphragms can be assembled at the construction site into rectangular baskets of the sizes specified and shown on the drawings. Gabions shall be of single unit construction; the base, lid, ends, and sides shall be either woven into a single unit or one edge of these members connected to the base section of the gabion in such a manner that strength and flexibility at the connecting point is at least equal to that of the mesh. Where the length of the gabion exceeds one and one-half its horizontal width, the gabion shall be divided by diaphragms of the same mesh and gauge as the body of the gabions, into cells whose length does not exceed the horizontal width. The gabion shall be furnished with the necessary diaphragms secured in proper position on the base in such a manner that no additional tying is required at this juncture.

Non-Raveling. The wire mesh is to be fabricated in such a manner as to be non-raveling. This is defined as the ability to resist pulling apart at any of the twists or connections forming the mesh when a single wire strand in a section of mesh is cut.

MATERIALS

Galvanized Steel Wire Mesh Gabions. Gabion basket units shall be of non-raveling construction and fabricated from a double twisted hexagonal mesh of hot dipped galvanized steel wire having a diameter of 0.118 inches (Approx. US gauge 11) after galvanization. The steel wire used shall be galvanized prior to weaving into mesh. All gabion diaphragm and frame wire shall equal or exceed Federal Spec. QQ-W-461H, possess soft tensile strength, and a Finish 5 Class 3 zinc coating of not less than 0.80 oz/sq. ft. of uncoated wire surface. The weight of zinc coating shall be as determined by ASTM test designation A-90. Mesh openings shall be hexagonal in shape and uniform in size measuring not more than 3¼ inches by 4½ inches approximately (±9 sq. in. area opening). Selvedge or perimeter basket frame wire shall be of a heavier gauge than the mesh wire with a diameter of 0.150 inches (Approx. US gauge 9) after galvanization. Lacing and connecting wire shall meet the same specifications as the wire used in the gabion body except that its diameter shall be of 0.0866 inches (Approx. US gauge 13½) after galvanization.

All of the above wire diameters are subject to tolerance limit of 0.004 inches in accordance with ASTM A-641.

GABION STANDARD SIZES

Letter Code	Dimensions	No. of Cells	Capacity Cu. Yds.
A	6'x3'x3'	2	2
B	9'x3'x3'	3	3
C	12'x3'x3'	4	4
D	6'x3'x1'6"	2	1
E	9'x3'x1'6"	3	1.5
F	12'x3'x1'6"	4	2
G	6'x3'x1'	2	0.666
H	9'x3'x1'	3	1
I	12'x3'x1'	4	1.33

Tolerances. All gabion dimensions shall be within a tolerance limit of ± 5% of the manufacturer's stated sizes.

MESH DEFORMATION

The wire mesh shall have deformability sufficient to permit a minimum mesh elongation equivalent to 10% of the unstretched length of the mesh test section without reducing the gauge or tensile strength of the individual wire strands to values less than those for similar wire, one gauge smaller in diameter.

GABION FILL. The material used for gabion fill shall be clean, hard stone with pieces ranging from three (3) to eight (8) inches in greatest dimension.

ASSEMBLING AND PLACING

a) Each gabion shall be assembled by tying all untied edges with binding wire. The binding wire shall be tightly looped around every other mesh opening along the seams in such a manner that single and double loops are alternated.

b) A line of empty gabions shall be placed into position according to the contract drawings and binding wire shall be used to securely tie each unit to the adjoining one along the vertical reinforced edges and the top selvedges. The base of the empty gabions placed on top of a filled line of gabions shall be tightly wired to the latter at front and back.

c) To achieve better alignment and finish in retaining walls, gabion stretching is recommended.

d) Connecting wires shall be inserted during the filling operation in the following manner:

36" Gabions

I) Gabions shall be filled to a depth of twelve (12) inches.

II) One connecting wire in each direction shall be tightly tied to opposite faces of each gabion cell at a height of twelve (12) inches above the base.

III) Gabions shall be filled with a further depth of twelve (12) inches, and two connecting wires shall similarly be tied at this level.

(IV) Gabions shall be filled to the top.

All connecting wires shall be looped around two mesh openings and the ends of the wires shall be securely twisted to prevent their loosening.

18" and 12" Gabions

Connecting wires are not necessary unless the eighteen (18) inch size is used to build vertical structures; in this case, two wires, one in each direction, at nine (9) inches from the base, must be placed as above.

e) The gabions in any row shall be filled in stages so that local deformations may be avoided. That is, at no time shall any gabion be filled to a depth exceeding one foot more than the adjoining gabion.

f) When a gabion has been filled the lid shall be bent over by hand until it meets the front and ends. Then the lid shall be tightly bound to the rest of the basket with the lacing wire along all edges and internal cell diaphragms in the same manner described above for assembly.

FILLING

Gabions may be filled by hand or by mechanical means. Every effort shall be made to keep voids and bulges in the gabions to a minimum in order to ensure proper alignment and a neat, compact, square appearance.

TERRA AQUA Inc.
A SUBSIDIARY OF
MACCAFERRI GABIONS INTERNATIONAL
5 Thomas Mellon Circle, Suite 248
San Francisco, CA 94134
(415) 468-5080

P.V.C. GABION SPECIFICATION

SCOPE

This specification covers the use of P.V.C. coated steel wire mesh baskets filled with stone used as retaining walls, slope paving, river bank protection, outfall structures, weirs and drop structures, etc.

DEFINITIONS

a) Gabions are defined as P.V.C. coated steel wire mesh box-shaped baskets, of various sizes. The baskets are filled on site with clean-hard stones.

b) The selvedges of the gabions are the thicker perimeter and edge wires to which the wire mesh is securely tied to withstand sudden or gradual stress from any direction.

c) Reinforcing wires are the thicker wires incorporated into the netting during fabrication.

d) The diaphragms are internal wire mesh partitions which divide the gabion into cells.

e) Lacing or binding wire is the wire used to assemble and join the gabion units.

f) Connecting wires are the internal wires used to prevent the gabions from bulging.

FABRICATION

P.V.C. Coated Steel Wire Mesh Gabions. Gabions shall be fabricated in such a manner that the sides, ends, lid and diaphragms can be assembled at the construction site into rectangular baskets of the sizes specified and shown on the drawings. Gabions shall be of single unit construction; the base, lid, ends, and sides shall be either woven into a single unit or one edge of these members connected to the base section of the gabion in such a manner that strength and flexibility at the connecting point is at least equal to that of the mesh. Where the length of the gabion exceeds one and one-half its horizontal width, the gabion shall be divided by diaphragms of the same mesh and gauge as the body of the gabions, into cells whose length does not exceed the horizontal width. The gabion shall be furnished with the necessary diaphragms secured in proper position on the base in such a manner that no additional tying is required at this juncture.

MATERIALS

P.V.C. Coated Wire Mesh Gabions. Gabion basket units shall be of nonraveling construction and fabricated from a double twisted hexagonal mesh of galvanized and P.V.C. coated steel wire. The galvanized wire core shall have a diameter of 0.1063 inches (Approx. US gauge 12). All wire used in the fabrication of the gabion shall comply with or exceed Federal Spec. QQ-W-461H, possess soft tensile strength, and a Finish 5 Class 3 zinc coating of not less than 0.80 oz/sq. ft. of uncoated wire surface. The P.V.C. coating shall be extruded onto the wire core prior to weaving the coated wire into a double twisted hexagonal mesh having uniform openings of 3¼ inches by 4½ inches approximately (± 9 sq. inch area opening). The overall diameter (galvanized wire core plus P.V.C. coating) shall be 0.1363 inches. Selvedge and reinforcing wire shall be of heavily galvanized wire core, 0.1338 inches in diameter (Approx. US gauge 10), coated with P.V.C. and having an overall diameter (galvanized wire core plus P.V.C. coating) of 0.1638 inches. Lacing and connecting wire shall be of heavily galvanized wire core, 0.0866 inches in diameter (Approx. US gauge 13½), coated with P.V.C. and having an overall diameter (galvanized wire core plus P.V.C. coating of 0.1166 inches.

All of the above wire diameters are subject to tolerance limit of 0.004 inches in accordance with ASTM A-641.

GABION STANDARD SIZES

Letter Code	Dimensions	No. of Cells	Capacity Cu. Yds.
A	6'x3'x3'	2	2
B	9'x3'x3'	3	3
C	12'x3'x3'	4	4
D	6'x3'x1'6"	2	1
E	9'x3'x1'6"	3	1.5
F	12'x3'x1'6"	4	2
G	6'x3'x1'	2	0.666
H	9'x3'x1'	3	1
I	12'x3'x1'	4	1.33

Tolerances. All gabion dimensions shall be within a tolerance limit of ± 5% of the manufacturer's stated size.

P.V.C. (Poly Vinyl Chloride) Coating. The protective P.V.C. plastic coating shall be suitable to resist deleterious effects of natural weather exposure, immersion in salt water and shall not show any material difference in its initial compound properties.

A - INITIAL PROPERTIES

A.1 - Specific Gravity

Shall be 1,30 to 1,35 Kg/Dm^3, in accordance with ASTM D 792-66 (79).

A.2 - Durometer Hardness

Shall be 50 to 60 Shore D, in accordance with ASTM D 2240 - 75 (ISO 868 - 1978).

A.3 - Volatile Loss

At 105°C for 24 hour = shall not be higher than 2%
At 105°C for 240 hours = shall not be higher than 6%
in accordance with ASTM D 1203-67 (74) (ISO 176-1976) and ASTM D 2287 - 78.

A.4 - Tensile Strength

Shall not be less than 210 Kg/cm^2 in accordance with ASTM D 412 - 80.

A.5 - Elongation

Shall not be less than 200% and not be higher than 280% in accordance with ASTM D 412 - 75.

A.6 - Modulus of elasticity at 100% of elongation

Shall not be less than 190 Kg/cm^2 in accordance with ASTM D 412-75.

A.7 - Resistance to abrasion

The loss of weight shall not be more than 0.19 g in accordance with ASTM D 1242 - 56 (75).

A.8 - Brittleness Temperature

Cold bend temperature = shall not be higher than -30°C in accordance with BS 2782 - 104A (1970)
Cold flex temperature = shall not be higher than + 15°C in accordance with BS 2782 - 150B (1976)

A.9 - Creeping corrosion

Maximum penetration of corrosion of the wire core from a square cut end shall be 25 mm when the specimen has been immersed for 2000 hours in a 50% solution of HCl (Hydroclorich acid 12 Be).

Namely, variation of the initial properties will be allowed, as specified hereunder, when the specimen is submitted to the following accelerated aging tests:

B - ACCELERATED AGING TESTS

B.1 - Salt Spray Test

According to ASTM B 117 - 73 (79)
Period of test - 1500 hours.

B.2 - Exposure to ultraviolet rays

According to ASTM D 1499 - 64 (77) and ASTM G 23 - 69 (75) apparatus type E.
Period of test = 2000 hours at 63°C

B.3 - Exposure to high temperature

According to ASTM D 1203 - 67 (74), (ISO 176-1976), and ASTM D 2287 - 78.
Period of test = 240 hours at 105°C

After the above tests have been performed the P.V.C. compound shall show the following properties:

C - PROPERTIES AFTER AGING TESTS

C.1 - Appearance

The vinyl coating shall not crack, blister or split and shall not show any remarkable change in color.

C.2 - Specific Gravity

Shall not show change higher than 6% of its initial value.

C.3 - Durometer Hardness

Shall not show change higher than 10% of its initial value.

C.4 - Tensile Strength

Shall not show change higher than 25% of its initial value.

C.5 - Elongation

Shall not show change higher than 25% of its initial value.

C.6 - Modulus of Elasticity

Shall not show change higher than 25% of its initial value.

C.7 - Resistance to abrasion

Shall not show change higher than 10% of its initial value.

C.8 - Brittleness Temperature

Cold bend temperature = shall not be higher than - 20°C
Cold flex temperature = shall not be higher than + 18°C

MESH DEFORMATION

The wire mesh shall have deformability sufficient to permit a minimum mesh elongation equivalent to 10% of the unstretched length of the mesh test section without reducing the gauge or tensile strength of the individual wire strands to values less than those for similar wire, one gauge smaller in diameter.

GABION FILL. The material used for gabion fill shall be clean, hard stone with pieces ranging from three (3) to eight (8) inches in greatest dimension.

ASSEMBLING AND PLACING

a) Each gabion shall be assembled by tying all untied edges with binding wire. The binding wire shall be tightly looped around every other mesh opening along the seams in such a manner that single and double loops are alternated.

b) A line of empty gabions shall be placed into position according to the contract drawings and binding wire shall be used to securely tie each unit to the adjoining one along the vertical reinforced edges and the top selvedges. The base of the empty gabions placed on top of a filled line of gabions shall be tightly wired to the latter at front and back.

c) To achieve better alignment and finish in retaining walls, gabion stretching is recommended.

d) Connecting wires shall be inserted during the filling operation in the following manner:

36" Gabions

I) Gabions shall be filled to a depth of twelve (12) inches.

II) One connecting wire in each direction shall be tightly tied to opposite faces of each gabion cell at a height of twelve (12) inches above the base.

III) Gabions shall be filled with a further depth of twelve (12) inches, and two connecting wires shall similarly be tied at this level.

IV) Gabions shall be filled to the top.

All connecting wires shall be looped around two mesh openings and the ends of the wires shall be securely twisted to prevent their loosening.

18" and 12" Gabions

Connecting wires are not necessary unless the eighteen (18) inch size is used to build vertical structures; in this case, two wires, one in each direction, at nine (9) inches from the base, must be placed as above.

e) The gabions in any row shall be filled in stages so that local deformations may be avoided. That is, at no time shall any gabion be filled to a depth exceeding one foot more than the adjoining gabion.

f) When a gabion has been filled the lid shall be bent over by hand until it meets the front and ends. Then the lid shall be tightly bound to the rest of the basket with the lacing wire along all edges and internal cell diaphragms in the same manner described above for assembly.

FILLING

Gabions may be filled by hand or by mechanical means. Every effort shall be made to keep voids and bulges in the gabions to a minimum in order to ensure proper alignment and a neat, compact, square appearance.

.RA AQUA Inc.
A SUBSIDIARY OF
MACCAFERRI GABIONS INTERNATIONAL
5 Thomas Mellon Circle, Suite 248
San Francisco, CA 94134
(415) 468-5980

STREAM HYDRAULICS RELATED TO FISH HABITAT IMPROVEMENT

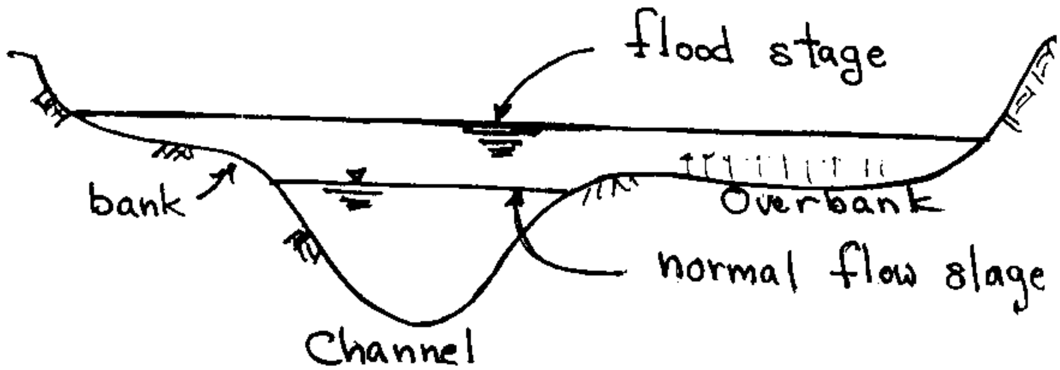
Joe DeVries
Water Resources Center
University of California, Davis

Distinction between "Hydraulics" and "Hydrology"

Hydrology -- General distribution and movement of water on the Earth

Hydraulics -- The detailed description of water flow (for example, in a channel)

Stream Channel Cross Section



Hydrology -- Volume of flow and how it changes with time (say due to storm rainfall)

Hydraulics
-- Area of the flow
-- Flow velocity
-- Sediment transport

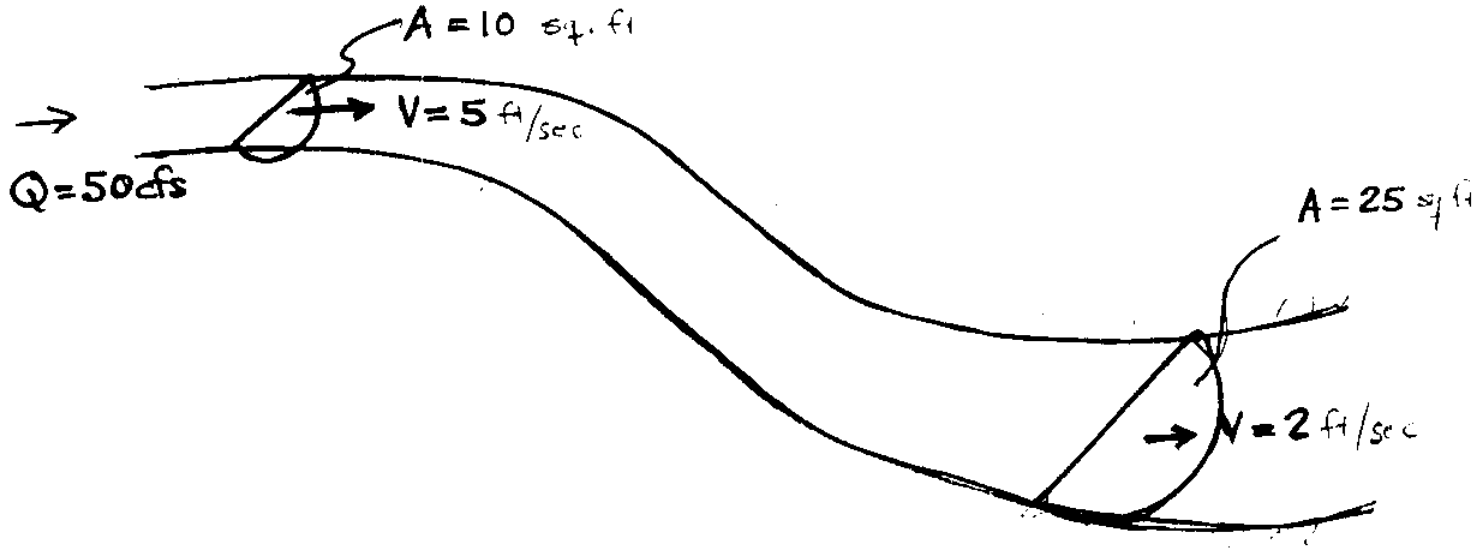
Q = flow in cubic feet per second (cfs or ft^3/sec)

V = velocity in feet/second (ft/sec or fps)

$$\text{Average Velocity} = V = Q/A = \frac{\text{Flow in } ft^3/sec}{\text{Area in } ft^2}$$

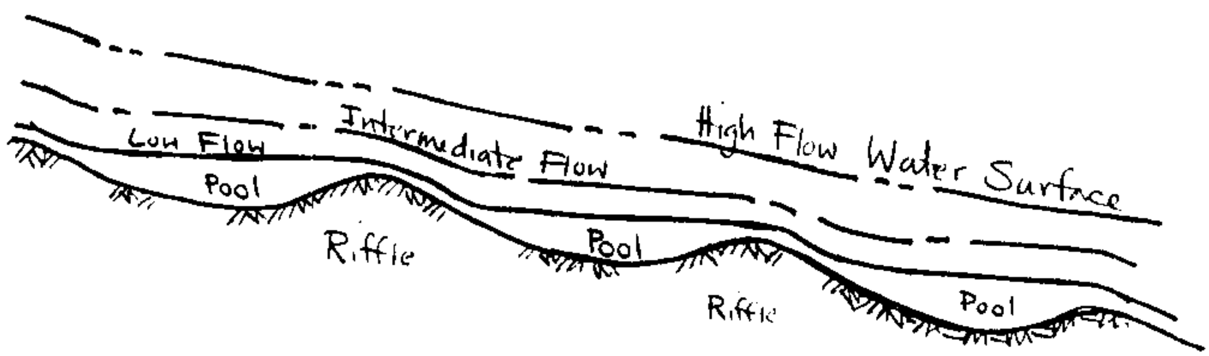
Third California Salmon and Steelhead Restoration Conference, Ukiah, CA, Feb. 23, 1985

Change in average velocity along a stream reach



- To decrease water velocity increase area;
- To increase water velocity decrease area.

Profile along a stream channel:



Water flows "downhill" (ie, the channel must have a slope).

The flow is resisted by drag on the boundaries and obstructions in the flow.

Resistance to flow is due to:

1) The size of the material which makes up the banks and bottom (boundary roughness).

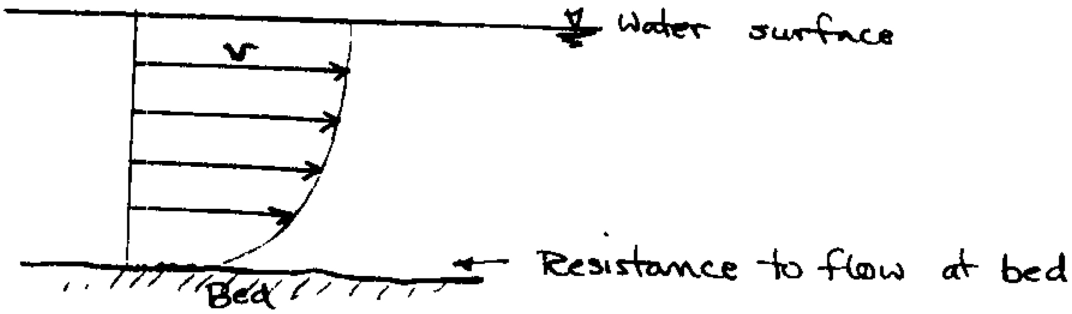
2) Amount and tyes of vegetation on the banks (boundary roughness).

3) Stream curvature; pool and riffle sequence effects.

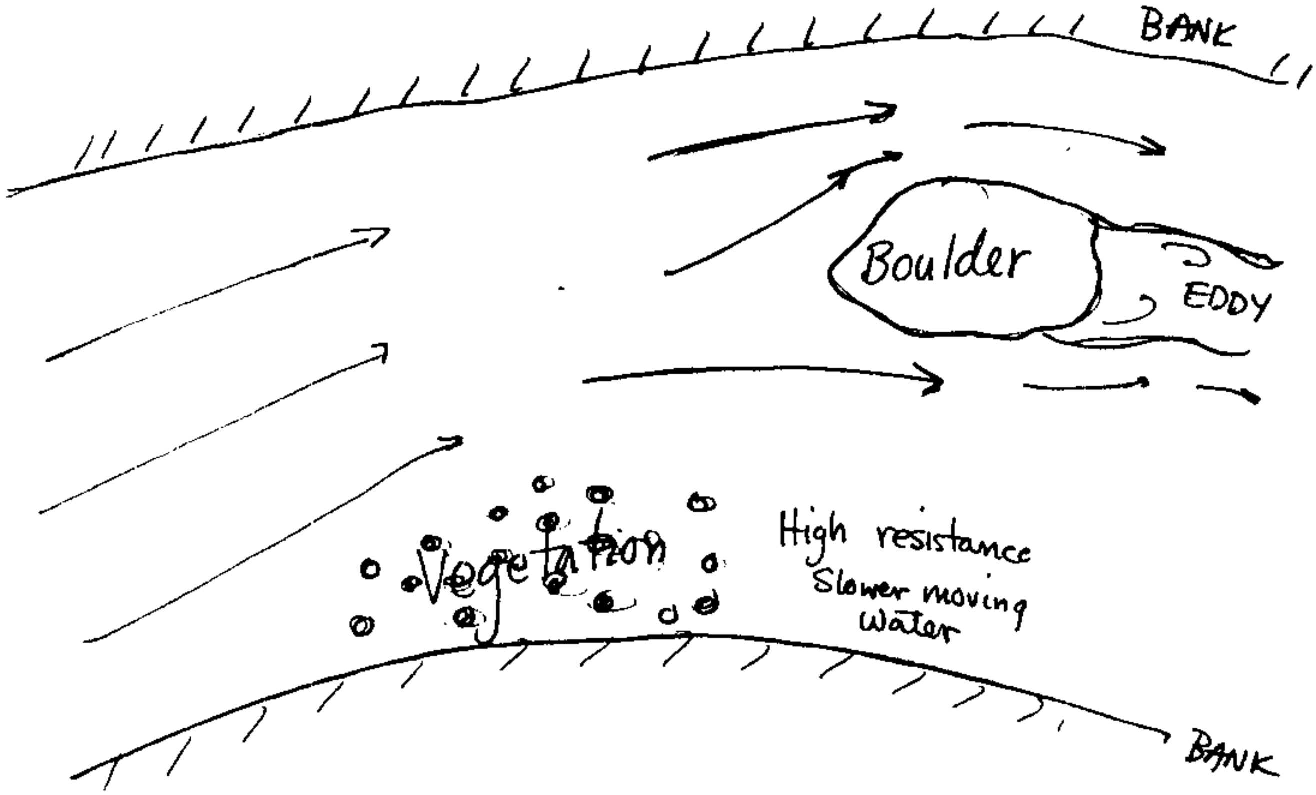
4) Obstructions to flow -- boulders, rock out crops, log jams

Variation of velocity in the stream

1) Vertical distribution

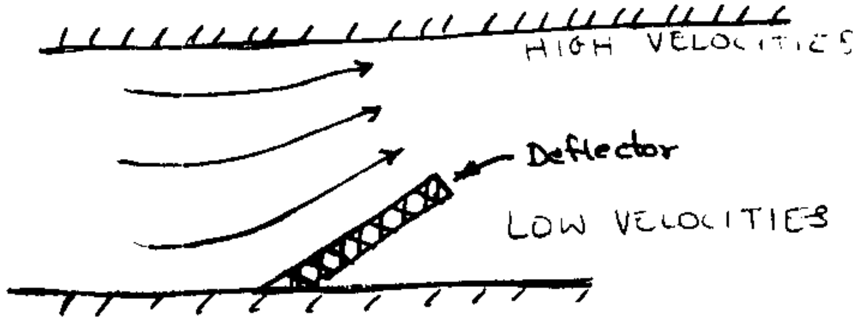


2) Variations across stream width

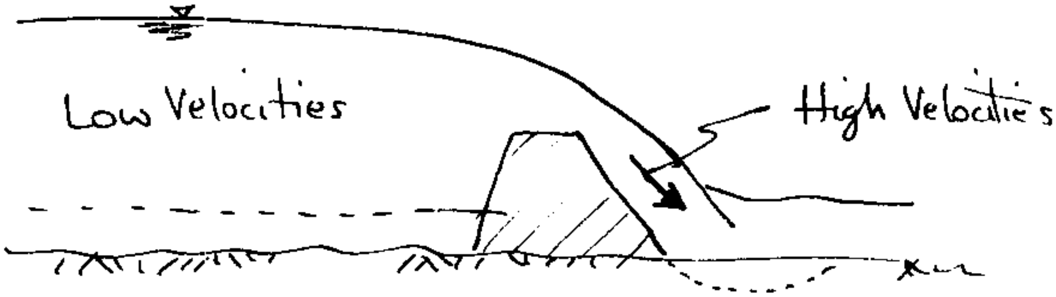


Modification of local velocities in a stream:

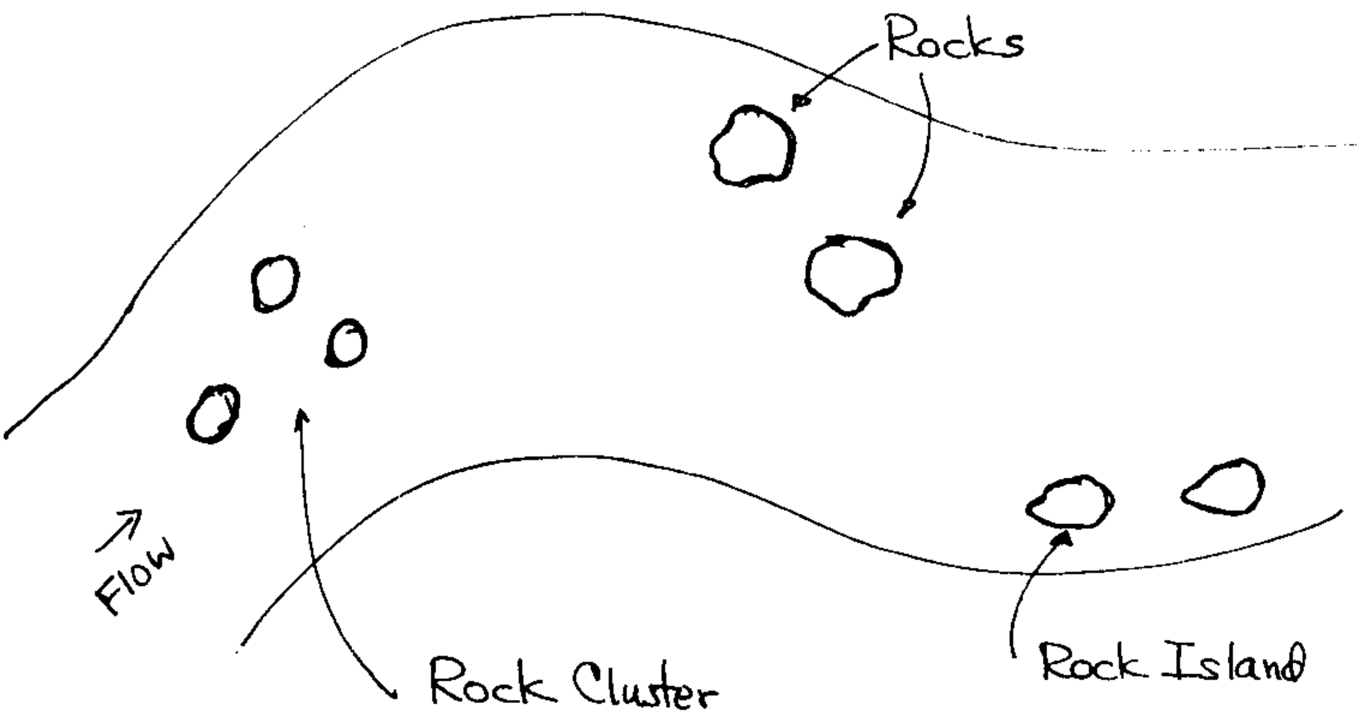
1) Deflector



2) Weir

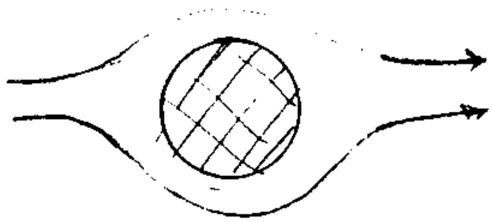


3) Obstructions to the flow



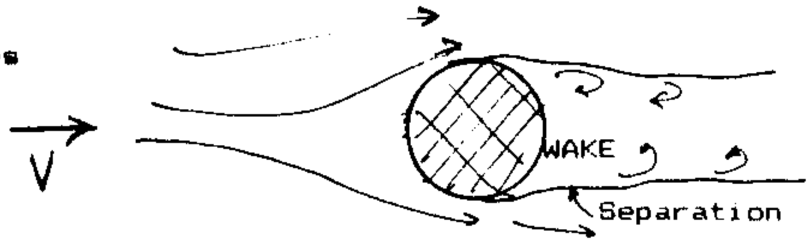
Drag on immersed bodies:

1) Very low velocities



Low Drag

2) High velocities



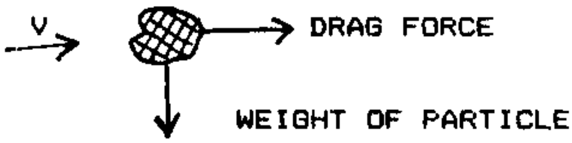
High Drag

Drag varies as the velocity squared -- if you double the velocity, the drag will be 4 times greater.

Example -- If a boulder is placed at a point in the stream where the velocities at high flows are high it may not stay in place.

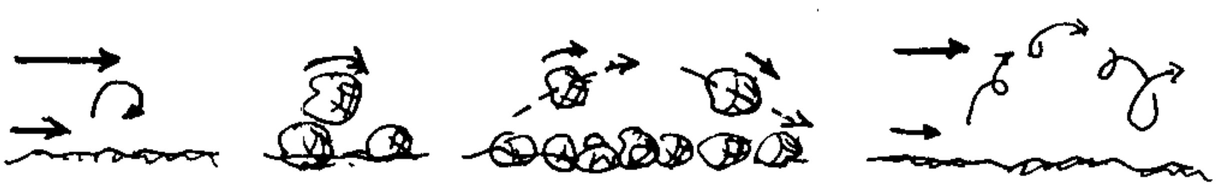
Movement of Sediment Particles

Drag of water on a particle:



For small particles, the relative effect of drag vs weight is much greater than for large particles.

Action of water on particles near stream bed:

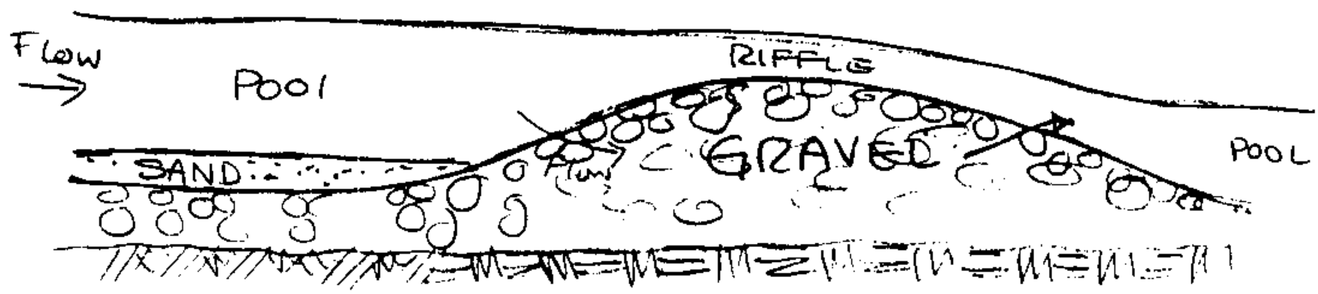


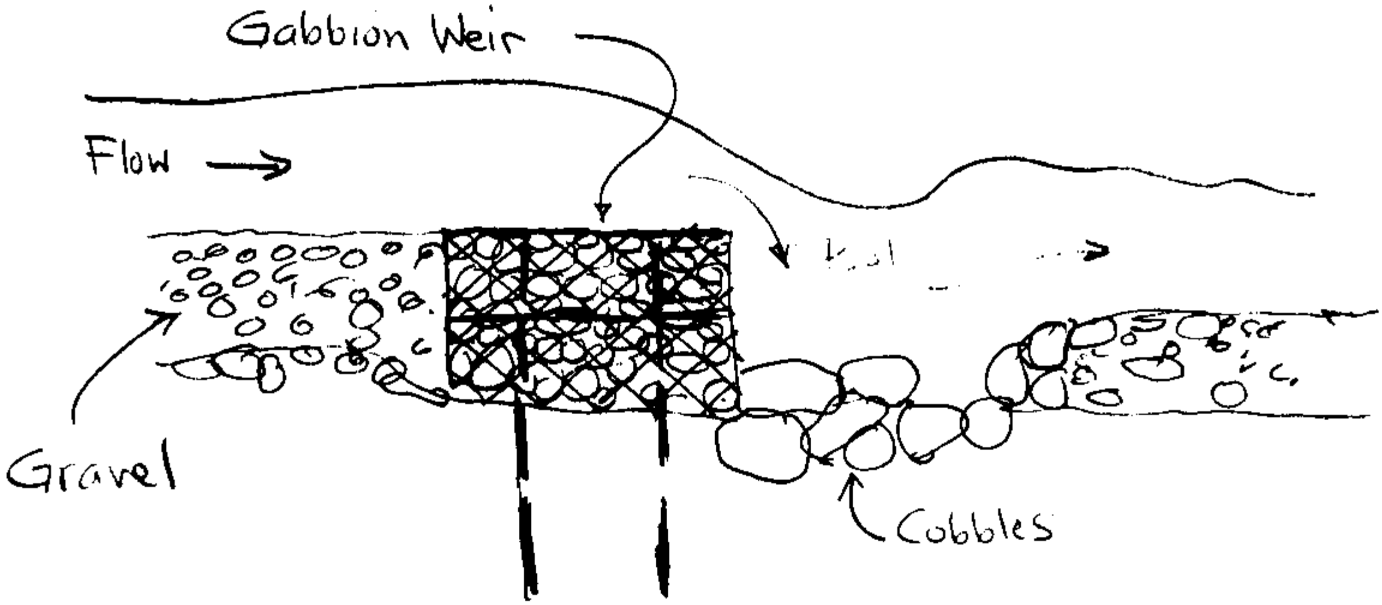
Velocities at Which Stream Bed Materials Will Move

Material	Diameter	Transport Velocity
Sands	0.01 to 0.1 in.	1 to 2 ft/sec
Gravels	0.2 to 0.6 in.	2.5 to 4 ft/sec
Fine to Coarse Stone	1 to 3 in.	5 to 8 ft/sec
Cobbles	4 to 8 in.	8 to 13 ft/sec

The size of material present in the stream bed is a guide to estimation of the velocities that usually occur in the stream. For example, a stream bed with only cobbles usually has velocities greater than 8 ft/sec.

Natural Spawning Riffle





HABITAT SESSION II

Evaluation and Monitoring

Facilitator: Forrest Reynolds
Calif. Dept. of Fish & Game
1416 Ninth Street
Sacramento, CA 95814

The purpose of this session was to discuss the importance of monitoring and evaluating restoration projects, to provide resources for doing this, and to discuss case studies in which projects have been successfully evaluated.

Forrest Reynolds of CDF&G presented a history of habitat rehabilitation and protection projects in California, reviewing efforts by the original CCC's (the Federal Civilian Conservation Corps of the 1930's), CDF&G log jam removal crews of the 1950's and 1960's, volunteer habitat protection by timber companies, and the current volunteer projects which have grown during the 1980's following passage of the Bosco-Keene bill. He stressed the Department's long-term commitment to habitat restoration, the need to be able to measure the success of restoration projects, and the need to build a monitoring and evaluation component into the Bosco-Keene projects.

Lynn Decker of the Forest Service's Redwood Science Laboratory in Arcata stressed the need for careful documentation of projects so that people working in the drainage in the future will have a history of what has been done previously. This will allow evaluation of which methods and structures worked over the long run and which ones didn't. She also stressed the importance of considering all species, rather than manipulating streams solely to increase salmon and steelhead production. Coastal cutthroat and resident trout populations are often adversely affected by activities performed in the name of enhancement such as barrier removal in the headwaters of coastal streams. She also pointed out the importance of woody debris for habitat structure (particularly pool creation) and invertebrate production. She cautioned against removing too much wood from streams and reminded participants that, historically, coastal streams were clogged with fallen logs when salmon production was at a maximum level.

Kerry Overton of the USFS described methods used to monitor habitat restoration projects in the Six Rivers National Forest. Detailed descriptions of on-the-ground surveys and methods for evaluating the performance of instream structures were given. Forms used by Six Rivers National Forest were handed out and are included as Attachment A.

Gordon Reeves of the USFS Pacific Northwest and Range Experiment Station discussed methods for evaluating projects from both a biological and economic perspective. He distributed copies of two Forest Service publications that describe evaluation methods in detail. Because of their length, only the covers, abstracts, and tables of contents are included as Attachment B. Free copies of these reports can be obtained from the addresses listed.

Melody Farrell of the Canadian Department of Fisheries and Oceans gave a slide show and presented information on an estuarine restoration project in the Campbell River estuary. This project was a cooperative effort between agencies, industry, and the public to develop a new log handling facility and rehabilitate a formerly industrialized area of 32 hectares. She described the planning activities, rehabilitation measures, and studies underway to evaluate the success of the project. Preliminary results of the post-restoration investigations indicate 1) the intertidal islands created during this project are stable; 2) 93% of the 23,322 marsh core transplants survived and are growing; 3) invertebrate recolonization is incomplete but encouraging; 4) juvenile wild chinook and chum salmon are using the islands; 5) catches are proportional to the number of wild salmon fry in the estuary; and 6) hatchery-reared salmon do not appear to be making extensive use of the islands. She stressed the importance of post-project evaluations, especially when novel restoration techniques are used, to document which things worked and which didn't and to make the results available to other projects. Copies of a report on this project are available from Melody Farrell at the Dept. of Fisheries and Oceans, Salmonid Enhancement Branch, 1090 W. Pender St., Vancouver, B.C. V6E 2P1.

CHINOOK SALMON MONITORING OBJECTIVES:

1. Estimate of the chinook salmon spawner escapement on historical fish producing streams.

2. Chinook salmon spawning habitat availability- quality and quantity.

3. Evaluation of chinook salmon spawning habitat restoration and enhancement techniques - project cost - effectiveness.

4. Evaluation of chinook salmon stock restoration techniques - egg box, yearling ponds, smolt enhancement projects.

CHINOOK SALMON SPAWNING GROUND COUNTS

- Identify Survey Reach

  1. Determine total stream area available for chinook salmon spawning.

  2. Select a representative section that can be surveyed in one easy day.

  3. Station surveyed reach for continued reference. Stationing will facilitate:

     - Tracking spawning habitat and activity from storm to storm, year to year or project to project.

     - Identify key habitat areas for intense studies or as a model for designing habitat improvement structure.

  4. Surveyors need to become intimately familiar with all potential spawning areas.

  5. Survey section at least every 7 to 10 days.

  6. Develop a Standard Form to keep data collection consistent from year to year (Blue Form).

  7. Basic Information to be collected during spawning ground count:

     - Count live adults, carcasses, number and size** of redds, survey conditions, and the channel features* responsible for gravel deposition. Such as:

     - Large logs or debris jams.

     - Meander bends.

     - Large rock or bedrock influencing gravel deposition.

     - Tails of pools.

* Channel features for modeling spawning habitat restoration.

** Measure from beginning of pit to end of the tailspill.

8. Need to survey 5 to 10 years to identify changes in spawner escapement.

9. Uses for this data are:

   - Timing of fish trapping.
   - Spot check adjacent streams during peak spawning.
   - Effectiveness of spawning habitat improvement projects.
   - Changes in spawner escapement.
   - Baseline data for management decisions.

10. Temperature, discharge and turbidity should be recorded on each trip.

11. "Consider Safety" - Work in teams and have appropriate gear.

12. Data should be summarized, copied and turned over to California Department of Fish and Game.

<u>PROJECT EVALUATION FORM - (Yellow)</u>

<u>Completed Project Evaluation Form - (Green)</u>

Good Examples of Spawning Reports

1. Jim Waldvogel; January, 1985; Fall chinook salmon spawning escapement estimate for a tributary of the Smith River, California; Interim Report; See Grant.

2. James Hopeland; December, 1984; Upper Klamath River chinook spawning survey 1984. California Department of Fish and Game.

FISH HABITAT PROJECT EVALUATION
SUMMARY

Monitoring Objectives:

1. Determine if the project achieved the intended results.

2. Evaluation of the different structure types, designs, construction procedures, and siting criteria; to identify the most cost effective techniques and procedures.

3. Will modification or maintenance be necessary to improve structures performance and longevity?

4. Produce a document for each project stream to track project performance (i.e. biological and physical changes), project procedures (i.e. studies, E.A., contracts, monitoring), identify costs (i.e. project costs, maintenance, monitoring, man-days), and display a photographic record.

Project Purpose: What the project is intended to achieve, and what salmonid species are involved.

Salmonid Habitat Limitations: Identification of those factors that are limiting anadromous fish production. Explain your reasons for your assessment.

Project Area:

Attach a map of the stream to the back of the evaluation forms.

The map to show the following items:

- Stream, major tributaries, access routes, length and width.
- Anadromous fish stream area and length.
- Barriers to migration and length of habitat above the barriers.
- Index stream section, and the start and end of stationing.
- Location of spawning areas.

ANADROMOUS FISH HABITAT
RESTORATION/ENHANCEMENT PROJECT
EVALUATION FORM

Project Name: ______________________________ Index Stream: __________

Name of Stream: ____________________________ Date Prepared: __________

Project Purpose: ____

____

Project Type: ____

____

SALMONID HABITAT LIMITATIONS

SPAWNING:

Salmon: King ______ Silver ______; Steelheads: Fall/Winter ______ Summer ______

Limiting Factors: Gravel Quantity _____ Gravel Quality _____ Holding Area _____

Explain/Comments: ____

JUVENILE REARING:

Salmon: King __________ Silver __________; Age Class: 0 ________ 1+ ________

Steelhead: Fall/Winter _______ Summer _______; Age Class: 0 _______ 1+ _______

Limiting Factors: Shelter: Instream ______ Bank ______; Pool ______ Run ______

Waterflow ______ Temp. ______ Substrate ______ Inverts. ______ Predators ______

Explain/Comments: ____

HOLDING HABITAT:

Salmon: King ______ Silver ______; Adult ______, Juveniles: 0 ______ 1+ ______

Steelhead: Fall/Winter ____ Summer ____; Adult ____ Juveniles: 0 ____ 1+ ____

Limiting Factors: Pool ______ Run ______ Shelter ______ Temp. ______ Flow _____

Explain/Comments: ____

ACCESS:

High Flow ________________ Low Flow ________________ Barrier

Salmon: King __________ Silver __________; Adult __________ Juvenile __________

Steelhead: Fall/Winter _______ Summer _______; Adult ________ Juvenile ________

Barrier Type: Bedrock ____________ Velocity ___________ Debris Jam ___________

Explain/Comments: ____

SPAWNING ESCAPEMENT:

Salmon: King ______ Silver ______; Steelhead: Fall/Winter ______ Summer ______

Explain/Comments: ____

MONITORING PROCEDURES

Project Name: _____________________________ Stream Name: ______________________

Index Stream: _____________________________ Stationed: ________________________

Type of Monitoring:*

Morphometric: Cross Sections _______ Topo Map. _______ Longit. Profile _______

Spawning Gravel: Composition-McNeil _____ Freeze-core _____ Pebble Count _____

Gravel-Area _______________ Redd-Area _______________ Photo-Reg. _______________

Adult Counts _________________________ Carcass Counts _________________________

Rearing Habitat: Juvenile Counts: Electro-Fish ________ Snorkel Trans.________

Instream Structures: Mapping __________ Photo Reg. __________

Access Problems: Photo-Reg. ________ Adult Counts: above ______ below ______

Juvenile Counts: above ______ below ______

Spawning Escape: Adult Counts ______ Redd Counts ______ Carcass Counts _______

Adults/Gravel Area ______________________

Annual Monitoring Costs: Dollars ________________ Man-Days ___________________

_____________________________ _____________
Preparer Date

*Mark blanks according to frequency of monitoring, utilizing the following codes: Ann. = Annual, Bian. = Bi-annual, FS = Full Survey, PS = Partial Survey; OT = One time.

FISH HABITAT STRUCTURE EVALUATION

STREAM NAME: ______________________ Page: __________

Structure Type	ID #	BIOLOGICAL				PHYSICAL			Modification	Remarks	Name Date
		Spawning	Rearing	Shelter	Pool	Design	Substrate	Site			

Structure Type:

Gabion/Rock/Log
Weir/Deflector/Cluster

Biological Performance:

Species: K.S.=King Salmon
S.S.=Silver Salmon
S.T.=Steelhead Trout

Rating: 0-5
0=Non-Utilization
5=Full-Utilization

Physical Performance:

Rating: 0-5
0=Poor
5=Excellent

Substrate: Coarse/Fine + Rating

STREAM NAME: ______________________ Page ________

PROJECT MONITORING INFORMATION

Project Type	ID# Station	Monitoring				Remarks	Name
		Type	Date	Cost	Man-Days		

STREAM NAME: ____________________ Page ____________

PROJECT COST INFORMATION

Project Type	ID# Station	Output Acres/Structures	Completion Date	Completion Cost	Completion Man-Days	How Completed	Maintenance Date	Maintenance Type	Maintenance Cost	Remarks/Name

SIX RIVERS N.F. SPAWNING GROUND INFORMATION

STREAM ____________________

LIVE FISH	CARCASS (SEX/F.L./TAG)	REDD(S)	REDD AREA	STATION	REASON FOR GRAVEL LOCATION	COMMENTS	OBSERVOR /DATE

United States
Department of
Agriculture

Forest Service

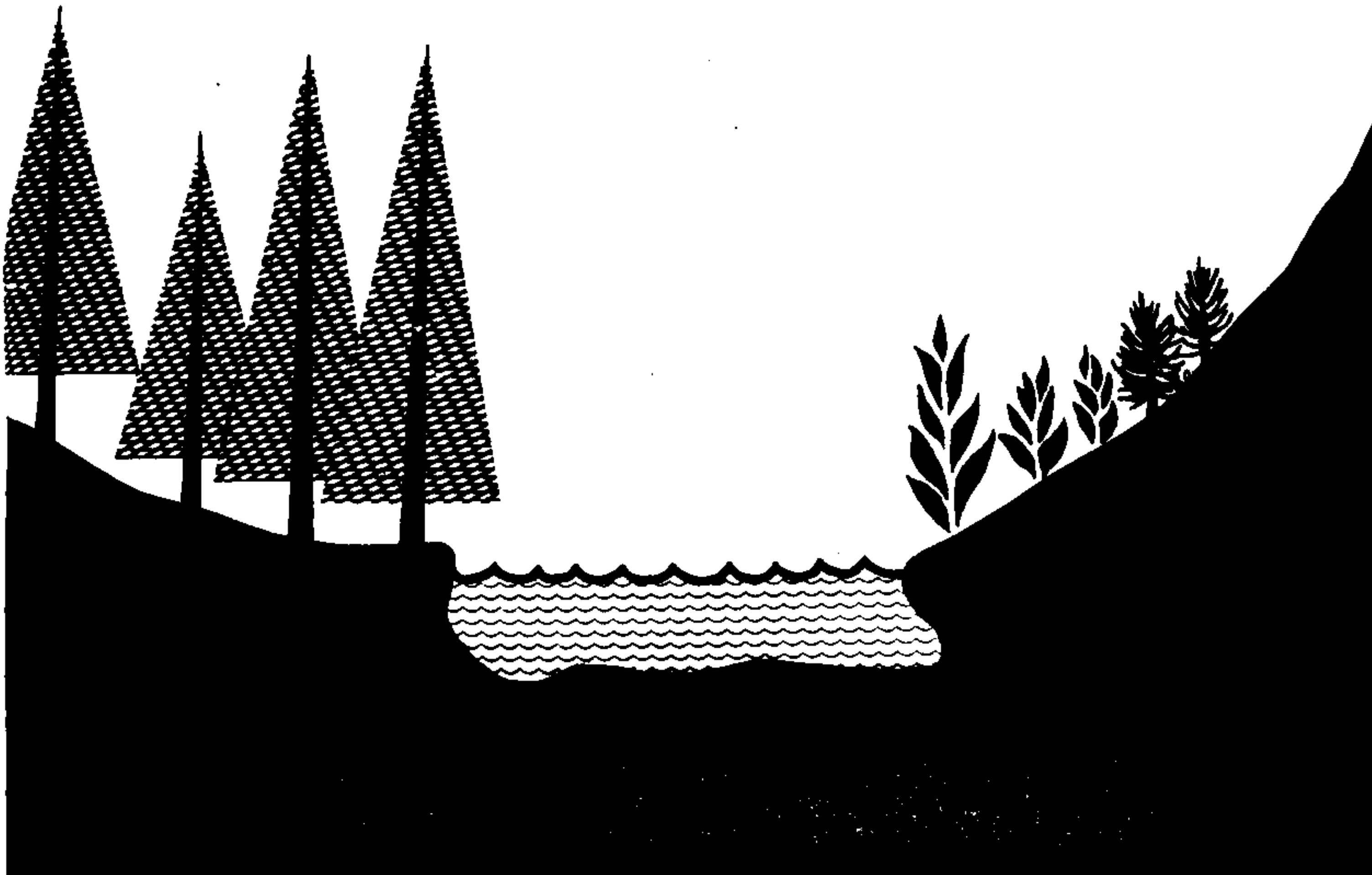
**Intermountain
Forest and Range
Experiment Station
Ogden, UT 84401**

General Technical
Report INT-138

May 1983

Methods For Evaluating Stream, Riparian, and Biotic Conditions

William S. Platts
Walter F. Megahan
G. Wayne Minshall



THE AUTHORS

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WALTER F. MEGAHAN is a Principal Research Hydrologist and Leader of the Intermountain Station's Nonpoint Source Pollution Research Work Unit in Boise, Idaho. He holds B.S. and M.S. degrees in forestry from the State University of New York, College of Forestry at Syracuse University, and a Ph.D. degree in watershed resources from Colorado State University. He served as Regional Hydrologist for the Intermountain Region of the Forest Service in Ogden, Utah, from 1960 to 1966 and has been in his present position since 1967.

G. WAYNE MINSHALL is Professor of Zoology at Idaho State University, Pocatello, Idaho. He received his B.S. degree in fisheries management in 1961 from Montana State University and his Ph.D. degree in zoology in 1965 from the University of Louisville. He was a North Atlantic Treaty Organization (NATO) postdoctoral fellow at Freshwater Biological Association Windemere Laboratory from 1965 through 1966. He joined the staff at Idaho State University in 1966 where he has pursued a teaching and research program in stream ecology.

RESEARCH SUMMARY

Most stream habitat evaluation techniques currently in use today have not been tested to determine their validity in describing conditions and have been designed to optimize time rather than accuracy. The purpose of this report is to further standardize the way physical and biological attributes are measured and quantified and to shed light on the strengths and weaknesses of those attributes. This report discusses some of the environmental parameters that best measure and describe conditions existing in aquatic ecosystems. The precision and an estimation of the accuracy that can be expected when measuring many of these conditions are given.

ACKNOWLEDGMENT

We are grateful to the Library Executor of the late Sir Ronald A. Fisher, to Dr. Frank Yates, and the Longman Group Ltd., London, for permission to reprint our table 19 from their book *Statistical Tables for Biological, Agriculture, and Medical Research* (6th ed., 1974) and to the American Society of Civil Engineers for permission to reprint our table 4 from their publication *Sedimentation Engineering* edited by Vito A. Vanomi.

CONTENTS

United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

General Technical
Report
PNW-146
November 1982

Evaluating Projects for Improving Fish and Wildlife Habitat on National Forests

Fred H. Everest and Daniel R. Talhelm

Abstract

Everest, Fred H.; Talhelm, Daniel R. Evaluating projects for improving fish and wildlife habitat on National Forests. Gen. Tech. Rep. PNW-146. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 12 p.

Recent legislation (P.L. 93-452; P.L. 94-588) has emphasized improvement of fish and wildlife habitat on lands of the National Forest System. A sequential procedure has been developed for screening potential projects to identify those producing the greatest fishery benefits. The procedure — which includes program planning, project planning, and intensive benefit/cost analysis — has nationwide application for both fish and wildlife projects. Fisheries and wildlife values are difficult to assess and available estimates are far from ideal, but better estimates are gradually becoming available.

Keywords: Habitat improvement, wildlife habitat, cost/benefit evaluation, program planning, salmonids.

Contents

Introduction

In the 1970's, Congress formally recognized the potential value of improving fish and wildlife habitat on the National Forests by requiring comprehensive planning for fish and wildlife on National Forest System lands (Sikes Act, P.L. 93-452, as extended in 1974). USDA Forest Service budgets for habitat improvement have grown steadily in recent years, and the National Forest Management Act of 1976 (P.L. 94-588) provided the option to use Knutson-Vandenberg funds for habitat rehabilitation and enhancement within designated timber sales. These recent actions have enabled forest managers to initiate a positive program to improve fish and wildlife habitat on the National Forests. But because more potential projects exist than can be completed annually with existing funds, projects that provide the greatest benefits must be selected.

Biologists, economists, and others who participate in the planning and selection process have difficulty comparing project alternatives objectively because the range of potential projects is so great, and little information has been available for estimating expected benefits from projects. Thus standard, objective evaluation tools, such as benefit/cost analyses, have been difficult to use. Ideally, projects can be compared by evaluating the benefits and costs of each alternative. Project benefits can be defined as the degree to which people are better off with the project than without it. This can be estimated in terms of the aggregate willingness of people to pay to have the project rather than to go without.

ORDER FROM: Pacific Northwest Forest and
Range Experiment Station
809 NE Sixth Avenue
Protland, OR 97232

HABITAT SESSION III

Erosion Control

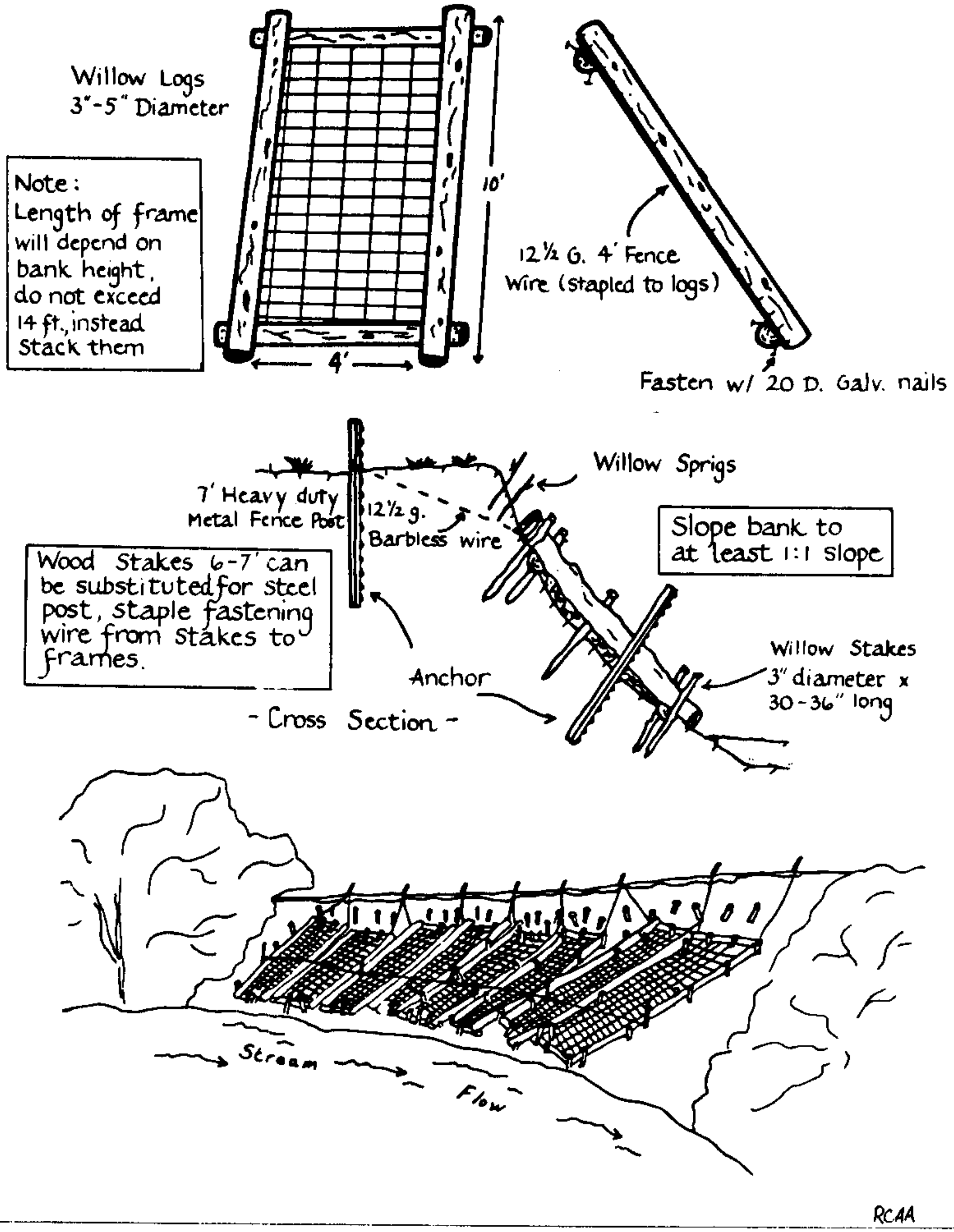
Facilitator: Nancy Reichard
Redwood Community Action Agency
904 G Street
Eureka, CA 95501

John Schwabe of Redwood Community Action Agency gave a talk on erosion control methods used on Prairie Creek. A variety of biotechnical streambank stabilization techniques were applied along a one-mile reach of Prairie Creek near Orick. The streambanks were fenced to exclude livestock, and mixed native riparian tree species were planted within the fenced corridor.

Many combinations of hardware and plant material can be used to protect streambanks, most effectively in conjunction with the use of rock rip-rap to protect the toe of the banks. The use of biotechnical methods can produce a more natural end-product than the use of 100% rip-rap and may often be more cost effective if plant materials are available on-site and rock is hard to come by.

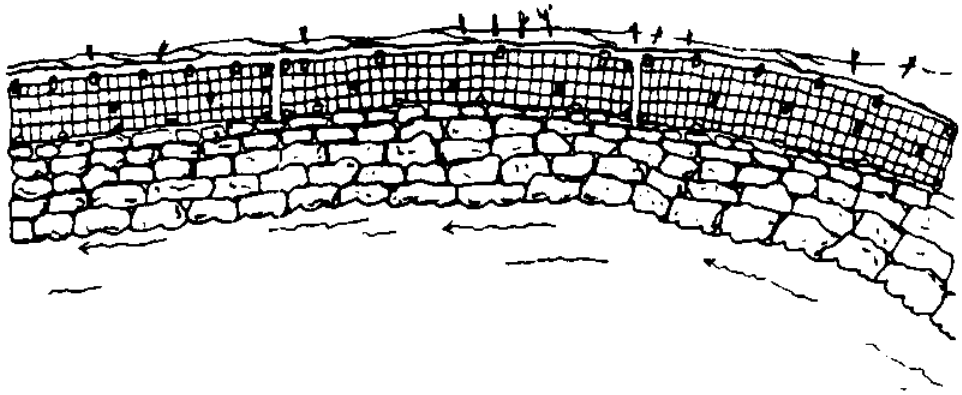
Techniques utilized on Prairie Creek are illustrated in Attachment A. Contact RCAA for further information.

Dave Patterson of the Soil Conservation Service gave a presentation on controlling erosion from a watershed perspective. He also addressed the problems inherent in getting private landowners to initiate projects on their land and the role the SCS can play in assisting them. A summary of his comments are included in Attachment B.

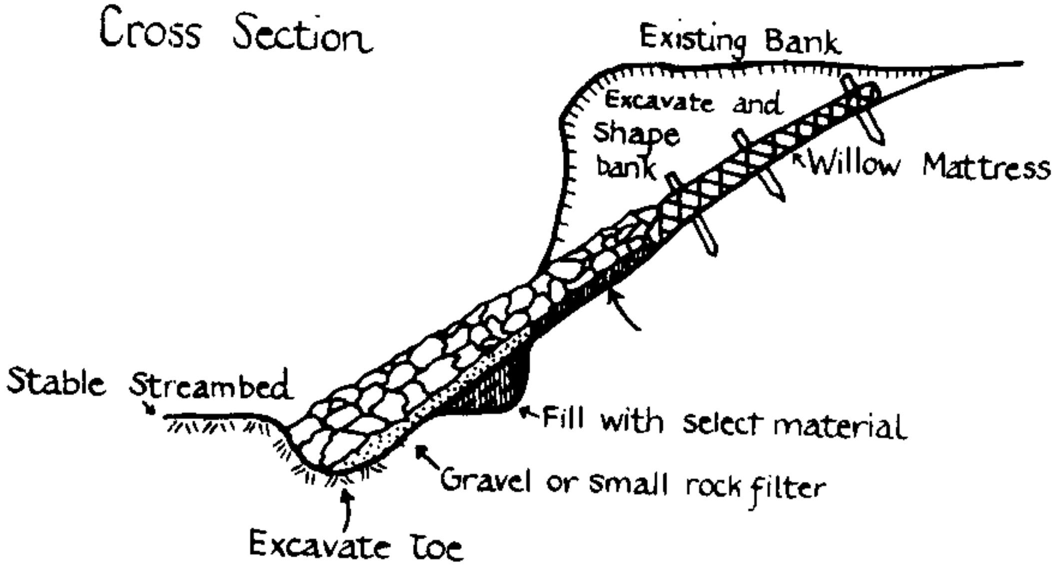


Willow Frames

Willow Mattress with Rock Rip-Rap

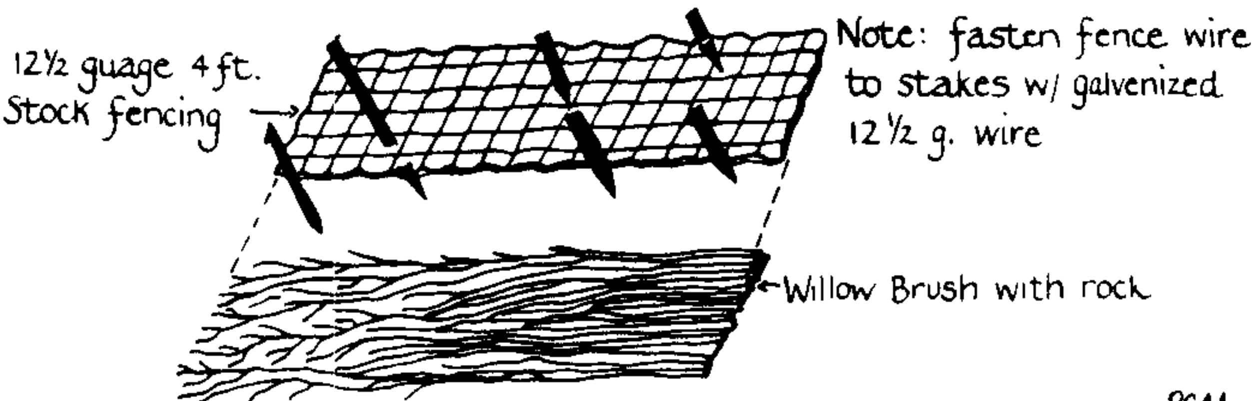


Cross Section

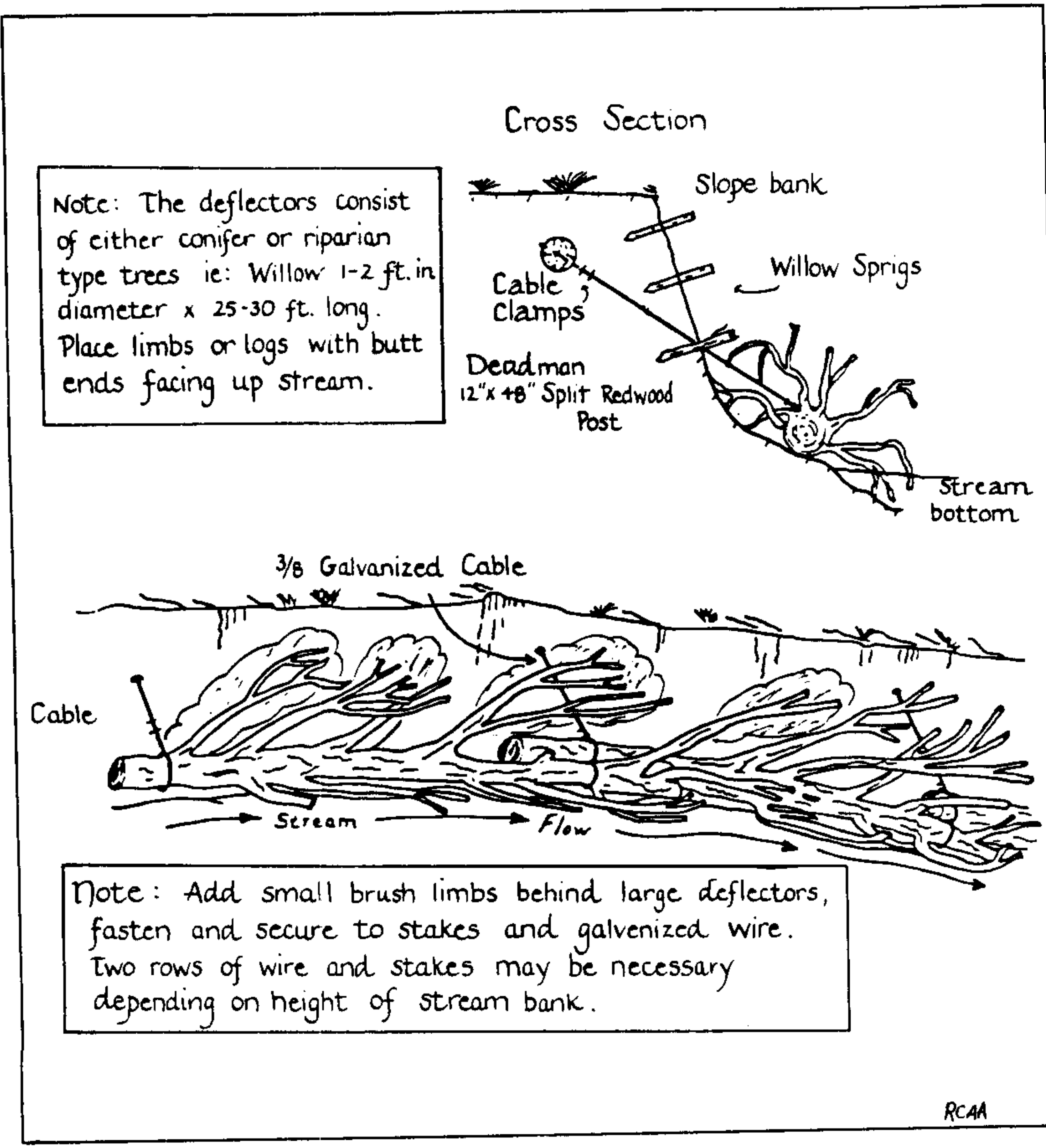


Note: Mattress secured to bank with willow and Redwood stakes 2-3" diameter x 30" long driven in at the corners and at 4' intervals

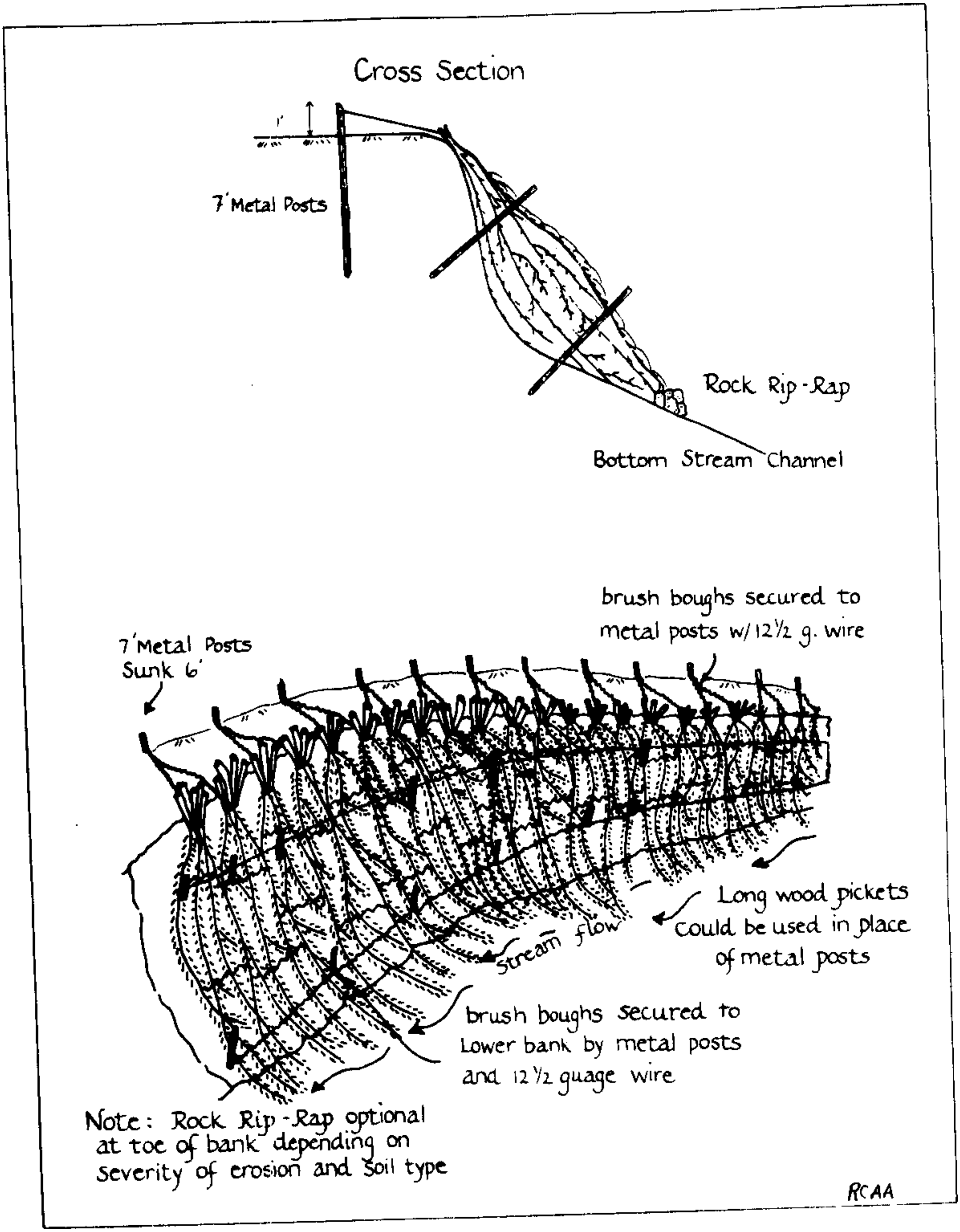
Willow Mattress Construction



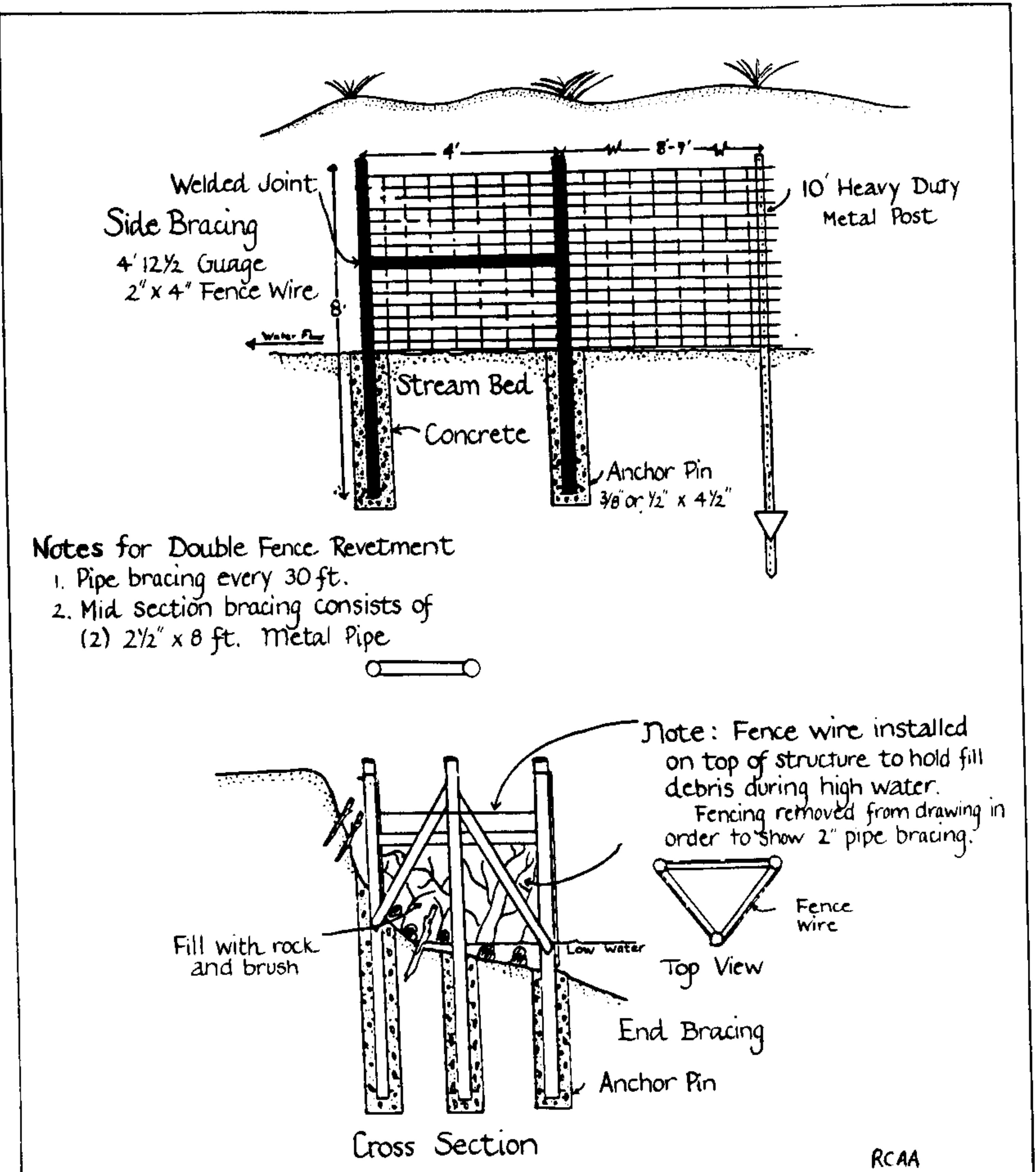
RCAA



Tree or Limb Deflectors

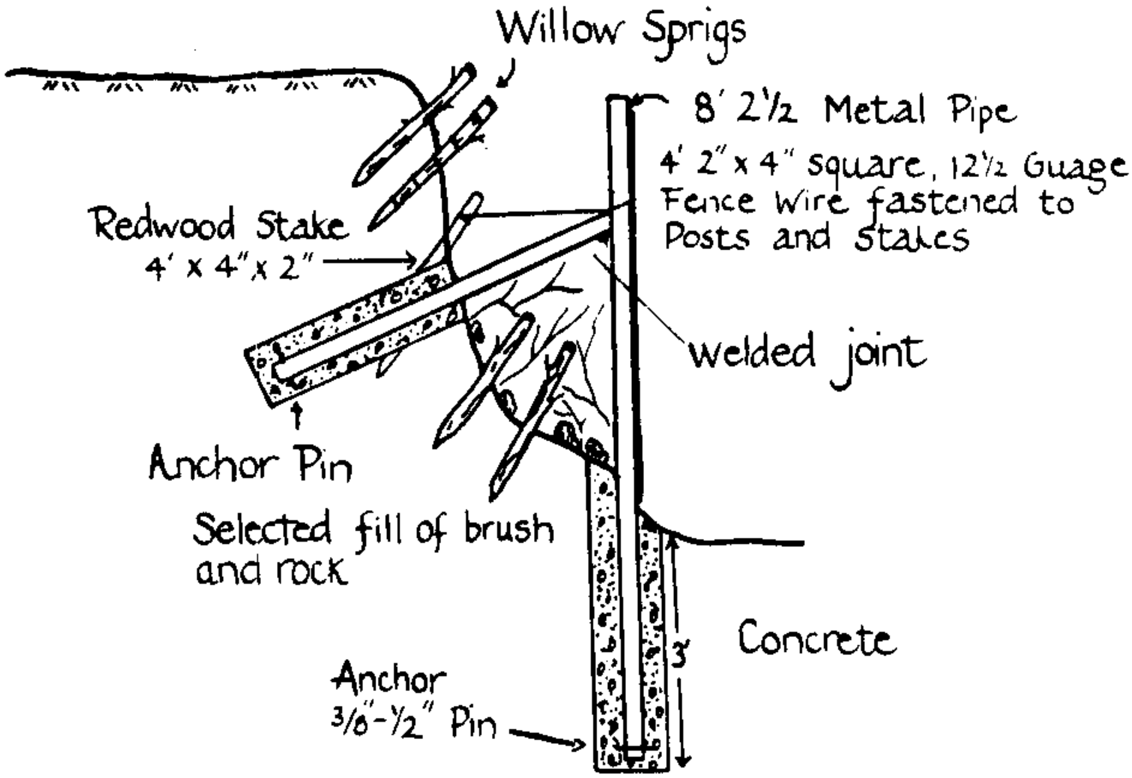


Bough Deflectors



Double Fence Revetment

Cross Section



Notes:

General:

1. 4 ft. fence wire connected to post w/ 12½ guage galvenized wire
2. Concrete can be poured into pipe posts for added support and weight.

Single Fence Revetment:

1. End anchor posts keyed in bank 2 ft.
2. Side bracing same as Double Revetment
3. Pipe bracing every 50 ft.

RCAA

Single Fence Revetment - End Brace

EROSION CONTROL ON PRIVATE LANDS

Dave Patterson
Soil Conservation Service
1350 N. Main Street, #1
Red Bluff, CA 96080

Managers of inland and anadromous fisheries, not unlike managers of other natural resources, are becoming aware of the need to consider entire watersheds in management programs rather than considering aquatic systems exclusively. The impacts of prevailing land uses such as timber harvesting, road building, mining, livestock grazing, and recreation have all too often resulted in reduced values for natural resources. Accelerated soil erosion, or erosion resulting from the activities of man, has reduced the productivity of upland sites, impacted riparian zones, and degraded fish habitat and water quality as well.

Preventing or mitigating the impact of man's activities on natural resources has been difficult at best, especially on private lands. Most landowners and operators have been either unwilling or unable to make the necessary investments to fully mitigate impacted resource values. Additional laws and ordinances regulating land use is one approach to improved land use practices on private land; however, public attitudes in opposition to additional land use controls and the prohibitive cost to local governments for enforcement precludes this approach.

Public education stressing land stewardship is a long-term effort, but over time it would result in improved land use practices. The cost of restoring damaged sites and habitat is often prohibitive for private landowners and improvements, no matter how desirable, will never be made. Public cost-shares or in-kind services can provide the needed incentive to encourage some landowners to apply needed improvements. Landowners must also be provided with practical, durable, and affordable designs for land treatment measures.

Resource planners and managers working on both public and private lands should be aware of treating the symptoms rather than the causes of apparent resource problems. Often the frenzied search for practical, durable, and affordable Band-Aids precludes attacking the overall cause of reduced resource values we have identified.

There are a large number of innovative approaches for healing various critical areas such as eroding upland gullies and streambanks. Both private and public agencies have fostered solutions ranging from the sublime to the ridiculous. Resource Conservation Districts offers technical assistance for both overall land use planning as well as on-site planning and design for treating critical areas. Hopefully, SCS planners and others will at least discuss with both public and private land users the need for proper land use and land use practices before getting down to the frenzied search for solving apparent problems.