

**Humboldt Bay Municipal Water District
Habitat Conservation Plan**

Appendix D

**Evaluation of the Conformity of Station 6 with
NMFS' 1997 Fish Screening Criteria For Anadromous Salmonids**

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1.0 INTRODUCTION

The Humboldt Bay Municipal Water District (District) pumps untreated surface water from the lower Mad River at its Hilfiker Pump Station 6. Station 6 was built in 1976, and was designed to provide up to 60 million gallons per day to its industrial customers. Station 6 contains a forebay, intake structure, and a fish bypass system; the latter is comprised of vertical traveling “Rex” screens and a fish return system.

In 1997, the Southwest Region of NMFS published Fish Screening Criteria for Anadromous Salmonids that are applicable for new facilities. In 1999, the District completed an evaluation which examined the extent to which Station 6 complies with NMFS’ 1997 guidelines for new facilities. Subsequently, the District updated portions of the evaluation based on the discussions which occurred with NMFS staff during the technical consultation phase of the District’s HCP process.

This report has been prepared in a question–answer format, addressing each criterion presented in NMFS’ 1997 guidelines. All calculations and Station 6 design details were provided by John Winzler, District Engineer, and also Professional Engineer of record for the 1975 facility design. Input provided by others are referenced herein.

2.0 BACKGROUND

A brief summary of Hilfiker Pumping Station 6 is provided below by John Winzler.

“Major considerations for design and selection of the type and site for a direct river diversion on the Mad River include:

- *The extreme variation in river flow and river elevation experienced during seasonal changes in runoff in the river basin.*
- *The copious silt and gravel suspensions transported by the river during high water and resultant extensive sediment depositions.*
- *Protection and preservation of the fishery as it applies to the anadromous fish runs and their spawning cycles.*

It is evident that any diversion facility on the Mad River will have to be constructed so as to allow for the continued mechanical removal of silt and gravel within the diversion channelization and structure itself; some type of pre sedimentation for the coarser sands and gravel is required.”

3.0 GENERAL CONSIDERATIONS

What is the swimming ability of fish present at the pumping facility?

Anadromous salmonid fry are present at Station 6. Fry will have the least developed swimming ability of any other salmonid life stage of present at Station 6. In studying the effects of culverts on the migration of salmonids, researchers have found that salmonid fry are capable of swimming against velocities up to 2.0 fps (personal communication, William Trush, 1999).

What time of year are fish present at the pumping facility?

For anadromous salmonid fry in the Mad River, the critical time period is March through July; for smolt outmigration, it is April through August. The critical adult migration occurs from October through February, and for spawning, the critical period is from December through March.

What has been the historic rate of diversion at the pumping facility?

Station 6 is designed to deliver is 60 MGD (93 cfs). Its actual achieved maximum diversion was in the 1980's, at 42 MGD (65 cfs); and for the last five years, the diversions have been reduced to approximately 18 MGD (30 cfs).

What are the behavioral responses of those fish present at the pumping facility?

The effect of Station 6 on the behavior of anadromous salmonid juveniles was investigated in comprehensive fish studies conducted in 1998 and 1977. (Refer to Appendices E-1 and E-2, respectively). The studies found that juvenile anadromous salmonids were free to enter and leave the forebay at all times during all flow conditions, and also that capture rates at Station 6 were extremely low.

4.0 STATION 6 EVALUATION vs. NMFS CRITERIA

Is Station 6 Pumping facility a functional design that reflects NMFS design criteria: define type, location, method of operation, and other important characteristics of the fish screen facility? Hydraulic information should include: hydraulic capacity, expected water surface elevations, and flows through various areas of the structures.

4.1 Direct Diversion Design Criteria

Station 6's pumping facilities was designed in 1975. It is comprised of a steel sheet pile forebay, which is directly adjacent to the Mad River and extends transverse to the direction of flow, and a concrete pumping structure with three pumps in each compartment. The concrete intake structure is basically divided into two equal pumping "cells", with both cells being protected with a composite inclined trash rack at the entrance to the structure. Each pumping cell has a vertical mechanically operated fish screen located approximately 12 feet in front of the pump impellers. The cells have sloping floors from the trash rack (which is approximately 12 feet in front of the fish screen) which creates 5 feet of additional depth of water at the screens and pumps.

Station 6 is designed to accommodate a maximum average daily pumping rate of 60 million gallons per day (MGD), or approximately 93 cubic feet per second (cfs).

4.2 Forebay

The forebay is trapezoidal in shape, varying in dimension from over 90 feet in width at the entrance (i.e., confluence with Mad River) to approximately 36 feet in width, in front of the trash racks at the concrete pumping structure. The forebay is approximately 90 feet long, at its center, from the river to the trash racks. The elevation of the forebay entrance was designed to be elevation 13'±, i.e., similar to the elevation of the thalweg of the Mad River, adjacent to the forebay.

A 30 ton crane is used to dredge the forebay. Dredging is required after high river events in which large amounts of silt and gravel settle out in front and within the forebay. The forebay is normally dredged to a depth of 10 to 12 feet.

Approach velocity into the forebay is controlled by a shear wall which has multiple movable concrete gate sections (4'x10'). These gate sections control the inlet area into the forebay, and, as a consequence, effect the inlet velocity. The District maintains sufficient openings in the shear wall to provide entrance velocities below 0.40 fps. The current delivery rate of 18 MGD creates velocities of only 0.04 fps at the forebay entrance with all gates open. At the maximum pumping rate of 60 MGD, and the lowest possible water stage height of 21.5 feet (given the grade control weir downstream), the

total “ungated” area of the forebay entrance would create an inflow velocity of 0.13 fps. To meet NMFS’ 0.4 fps entrance velocity criterion at the maximum pumping rate of 60 MGD, the District will maintain a minimum of 233 feet of gate opening (i.e., via removal of 6 concrete gates from the shear wall).

4.3 Fish Screens

The fish screens are two Rex “four post type” screens furnished by Envirex. The basic horizontal opening to accommodate each screen is 13’-4” clear, concrete sidewall to concrete sidewall. The fish screen, including the structural framing system completely fulfills the opening and is further “guarded” against unprotected vertical open space along both sides of the screen by redwood 2 x 4 sealing strips directly connected to the concrete sidewalls.

At the bottom of the screen, a steel bottom boot plate reduces any unprotected opening at the screen bottom to less than 3/8” and the direction of the rotating screen and fish bucket is toward the face of the screen creating, if anything, creating a movement of water away from the screen at this point.

Each of the two fish screens is basically 13’-2” wide (frame to frame) and articulated at 2’ vertical intervals. The screen material is Type 304 stainless steel wire cloth with 3/16” square opening. The screen material provides an excess of 37 percent open area.

NMFS has established 0.33 feet per second (fps) as the maximum approach velocity for fry-sized salmonids at a direct diversion facility located on a river, and 0.40 fps for a canal. Station 6 is akin to a canal so the more relevant criterion is 0.40 fps. Approach velocities at the Station 6 screens are below the new criteria established by NMFS. At the maximum design pumping rate of 60 MGD, and under the lowest historical water surface elevation ever experienced (20.7 feet), the approach velocity at the screens is only 0.30 fps. (It should be noted that the lowest possible water surface elevation is now approximately 21.5 feet given the addition of the grade control weir downstream.) The maximum approach velocity at the historical maximum delivery rate of 42 MGD is only 0.20 fps, and at the current pumping rate of 18 MGD, the maximum velocity is just 0.09 fps. Therefore, under all possible operating conditions, the approach velocities at the Station 6 screens are below the NMFS criteria for both a canal structure and an in-river structure .

The timing, frequency, and duration that the screens are run are dependent on water quality conditions. The normal run time of the screens is 20 minutes every 96 hours. During periods of high water discharge, particularly the first overbank flows of the season, high concentrations of sediment and organic debris are common, resulting in more frequent screen run times. Algae build-up on the screens in the summer may also trigger more frequent run times to reduce head loss.

4.4 Screen Criteria for Juvenile Salmonids

Where installation of fish screens at the diversion entrance is undesirable or impractical, the screens may be installed at a suitable location downstream of the canal [Forebay] entrance. (NMFS, 1997)

Do physical factors at the Station 6 Pumping facility preclude screen construction at the diversion entrance such as excess river gradient, potential for damage by large debris, and potential for heavy sedimentation?

It would be our opinion (i.e., Winzler & Kelly, Consulting Engineers) that a screen at the forebay entrance could not be maintained because of the heavy bed load of large gravel that is moved through the river system in the vicinity of the Diversion Facilities and the preponderance of large debris and heavy drift which accompany each high river occasion. The District, initially, attempted to operate the Diversion Facilities with only a log boom across the entrance to deter debris and drift from entering the forebay. This proved entirely impractical as the forebay became a depository of logs, stumps, limbs and other woody debris, as well as the fact that accelerated siltation occurred within the forebay as a result of extensive deposits of heavy gravel. Ultimately, to mitigate this problem, a removable concrete gating system was installed across the forebay entrance, which acts as a shear in terms of deflecting debris and gravel, and yet provides adequate open area for water entry into the forebay."

4.5 Structure Placement

For on-river screens, it is preferable to keep the fish in the main channel rather than put them through intermediate bypasses. (NMFS, 1997)

Does Station 6 pumping facility and its screen placement function the same as an "on-river" screen, to keep the fish in the main channel rather than put them through intermediate bypasses?

Station 6 does not divert the Mad River into a "canal" like structure. Rather, the position of Station 6 in relation to the Mad River is analogous to a "backwater" or "lateral pool" habitat. The District's facility is built into the left bank (looking downriver) of the Mad River. Fish that enter the forebay are not physically removed from the main channel, nor are they prevented from freely swimming out of the facility into the main flow of the river. The screen placement does not put fish through any intermediate bypass. The screens function as the interior third wall to the backwater environment created by the forebay walls. When the screens are not in motion, fish can either continue to occupy the forebay, or can swim back out into the Mad River.

4.6 Approach Velocity

Approach Velocity is the water velocity vector component perpendicular to the screen face. Approach velocity shall be measured approximately three inches in front of the screen surface. If a biological justification cannot demonstrate the absence of fry-sized (less than 2.36" (60 mm) in length) salmonids in the vicinity of the screen, fry will be assumed present and the following criteria apply: (NMFS, 1997)

4.6.1 Fry Criteria

Design approach velocity shall not exceed:

Streams and Rivers: -----0.33 feet per second

Canals: -----0.40 feet per second

4.6.2 Fingerling Criteria-2.36" (60 mm) and longer

Design approach velocity shall not exceed:

All locations: -----0.8 feet per second

Does the approach velocity at Station 6's fish screen, measured approximately three inches in front of the screen surface exceed 0.40 feet per second?

An important factor in calculating the approach velocity is the water surface elevation at the screen face. The initial design criteria for Station 6 assumed that the low water surface elevation in the forebay and at the fish screens would be maintained at or above 21.0 feet mean sea level (msl). Actual operational experience has shown that the lowest historical water surface elevation ever encountered was 20.7 feet. The velocity calculations at the fish screens have been computed on the basis of this lowest historical water surface elevation of 20.7 feet. It should be noted that installation of the grade control weir downstream of Station 6 allows the District to control the water surface elevation at approximately 21.5 feet now. Therefore, using the 20.7' surface elevation to compute velocities at the screen face is a very conservative assumption.

The calculated approach velocity, 3-inches in front of the screen face, under existing conditions (i.e., delivery of 18 MGD) is 0.09 feet per second, significantly below the allowed criterion of 0.40 for canals, which Station 6 is akin to. At the maximum design pumping capacity of 60 MGD, the calculated approach velocity 3-inches from the screen face is 0.30 fps, again well below the allowed criterion of 0.40 fps for canals, and also below the 0.33 fps criterion for rivers.

What is the total submerged screen area (excluding area of structural components) calculated by dividing the maximum diverted flow by the allowable approach velocity?

The total submerged unencumbered screen area at the current controlled low water surface elevation of 21.5 feet msl is 240.4 square feet. The *required* submerged screen area under the maximum design pumping rate of 60 MGD, at the allowed approach velocity of 0.40 fps and 3-inches in front of the screen face, would be 232.1 square feet. Thus, the available submerged screen area meets NMFS requirements under all possible flow conditions.

Does the screen design provide for uniform flow distribution over the surface of the screen, thereby minimizing approach velocity?

“In-situ velocity tests have never been performed, however, it is our opinion (i.e., Winzler & Kelly, Consulting Engineers) that the uniformity of the approach chambers would create a laminar or uniform flow condition approaching the screens, and this uniform flow would be distributed equally over the screen surface, precluding the occurrence of localized accelerated approach velocities.”

4.7 Sweeping Velocity

Sweeping Velocity is the water velocity vector component parallel and adjacent to the screen face. Sweeping Velocity shall be greater than approach velocity. (NMFS, 1997)

Is the sweeping velocity greater than approach velocity?

The District’s intake structure does not create sweeping velocities. Since the screens are installed at right angles to the direction of flow, sweeping velocities do not exist at the screen or within the diversion chambers.

4.8 Screen Face Material

Does the woven wire: screen openings exceed 3/32 inches (2.38 mm), measured diagonally (e.g.: 6-14 mesh)?

Openings currently measure 8/32” diagonally. (See addendum, page 17. The District will be retrofitting Station 6 to meet NMFS’ 3/32-inch criterion).

Does the screen material provide a minimum of 27% open area?

The screen material is Type 304 stainless steel wire screen cloth with 3/16” clear square openings, providing an open area of 37 % of the total screen surface area.

Is Station # 6's fish screen material corrosion resistant and sufficiently durable to maintain a smooth and uniform surface with long term use?

As noted herein before, the screen material is stainless steel and consequently is corrosion resistant and thus provides a long-term smooth and durable surface.

4.9 Civil Works and Structural Features**Is the face of the screen surface flush with any adjacent screen bay, pier noses, and walls, allowing fish unimpeded movement parallel to the screen face and ready access to bypass routes?**

The basic horizontal opening to accommodate each screen is 13'-4" clear, concrete sidewall to concrete sidewall. The fish screen, including the structural framing system completely fulfills the opening and is further "guarded" against unprotected vertical open space along both sides of the screen by redwood 2 x 4 sealing strips directly connected to the concrete sidewalls.

At the bottom of the screen, a steel bottom boot plate reduces any unprotected opening at the screen bottom to less than 3/8" and the direction of the rotating screen and fish bucket is toward the face of the screen creating, if anything, a movement of water away from the screen at this point.

Does Station 6 pumping facility provide structural features to protect the integrity of the fish screens from large debris? Trash racks, log booms, sediment sluices, or other measures may be needed.

The District's Pump Station 6 facility has the following structure in front of the vertical traveling Rex screens; forebay gates, trash racks, and the gated rear wall of the forebay. The Forebay gates are 126 feet, the trash racks 36 feet, and gated rear forebay wall is 12 feet in front of the vertical traveling Rex screens.

Does the civil works design eliminate undesirable hydraulic effects (e.g.- eddies, stagnant flows zones) that may delay or injure fish, or provide predator opportunities?

There are no identifiable undesirable hydraulic effects within the forebay and approach chambers to the fish screens (i.e., eddies or stagnant flow zones) which would delay, confine or injure fish. The very fact that the forebay provides a deeper, slow moving water area for fish to enter and rest before moving on down or up stream, may encourage the presence of predators, however, the visual presence of such predators (i.e., kingfishers and river otter) seems no more prevalent in the forebay than in the adjacent river.

4.10 Juvenile Bypass System Layout

Juvenile bypass systems are water channels which transport juvenile fish from the face of a screen to a relatively safe location in the main migratory route of the river or stream. Juvenile bypass systems are necessary for screens located in canals because anadromous fish must be routed back to their main migratory route. For other screen locations and configurations, NMFS accepts the option which, in its judgment, provides the highest degree of fish protection given existing site and project constraints. (NMFS, 1997)

Does the fish bypass system transport juvenile fish from the face of a screen to a relatively safe location in the main migratory route of the river or stream?

The District's Pump Station 6 facility is not located or configured as a "canal", but more as a backwater pool or off-channel slough habitat. Fish are never segregated from their main migratory route or prevented from swimming freely in or out of the pumping facility. The pumping facility provides a slack water environment for settling of suspended sediment, and a low velocity deep water habitat for migrating salmonids.

The fish bypass system begins with the troughs attached to the vertical traveling screens. Juvenile fish are transported, through a series of flumes and conduits back to the Mad River, where they exit below a rock weir into a flatwater habitat.

Does the screen and bypass system work in tandem to move out-migrating salmonids to the bypass outfall with minimum injury or delay?

When the screens are in motion the bypass system is also functioning. Water continues to flow through the bypass system for twenty minutes after the screens have been shut off. The District has modified its fish bypass facility, to reduce the rate of fish mortality in response to findings from the 1998 Fishery Study at Station 6.

Are all components of the bypass system, from entrance to outfall, of sufficient hydraulic capacity to minimize the potential for debris blockage?

Yes. Debris is dislodged from the vertical traveling Rex water screens by low and high pressure Rex spray nozzles. The screens, debris is washed into a refuse trough and conveyed by water through a steel debris grate and into to a concrete containment basin. Water from the refuse troughs joins the water in the fish bypass in the concrete basin. Water and fish in the bypass system join surface runoff in a 48 inch steel corrugated culvert that empties into a 30 inch culvert to exit at the outfall. While debris is effectively removed from the fish bypass system, debris could be re-introduced into the bypass system from surface runoff flowing into the 48 inch culvert and then to the 30 inch culvert.

Is access provided at locations in the bypass system where debris accumulation may occur?

Yes. Regular inspections occur at debris rack at the exit of the refuse trough located in the concrete containment basin, and at the clean-out basin. A trash bin is always in place to collect debris from the refuse trough. Access is provided at the clean-out basin for personnel and equipment as needed.

The screen civil works floor shall allow fish to be routed to the river safely in the event the canal is dewatered.

The screen civil works are not located in a canal, but within the intake structure behind the rear wall of the Forebay. The rear wall has a full length opening of 13'4"; it is gated and capable of being sealed off. Two parallel intake chambers operate separately from each other. One chamber can be dewatered while the other continues to function. The floor of the chamber is at 8 feet msl, which is below the Mad River's thalweg bed elevation. These chambers are dewatered once a year to allow for an inspection of the screens and their maintenance.

4.10.1 Bypass Entrance**Is the bypass entrance provided with an independent flow control, acceptable to NMFS?**

Flow control in the fish troughs and therefore through out the bypass system is programmed for 60 GPM, and is capable of manual control.

Is the bypass entrance velocity equal or exceed the maximum velocity vector resultant along the screen, upstream of the entrance?

The maximum approach velocity of 0.30 fps, 3 inches in front of the screens, is achieved during maximum pumping rates of 60 MGD. The velocity in the fish trough is up to 10 fps.

4.10.2 Bypass Conduit Design**Does the bypass facility provide smooth interior pipe surfaces and conduit joints to minimize turbulence, debris accumulation, and the risk of injury to juvenile fish?**

No, the interiors of some of the conduit pipes are corrugated, and there are 90 degree turns in the bypass system. During the 1998 fish study, biologists observed that the 30 inch x 220 foot steel corrugated culvert did not convey all of its water to the outfall. The biologists observed a loss of fish, specifically when fish were placed into the entrance of

the 220 foot culvert. Opening(s) in the culvert may have allowed fish to be lost in transport through the culvert. In response, the District has repaired this culvert to prevent any further loss of water or fish.

Does the bypass system cause fish to free-fall?

Yes, fish can free-fall 2' from the face of the screens into either the fish or refuse troughs. One other point with a free-fall of 8 inches is located at the outlets of the two troughs into the concrete containment basin. Depending on river stage, the outfall from the 30" culvert discharges directly into the river through a flexible 12 inch conduit.

Does the bypass system pump fish within the system?

No.

Is the pressure in the bypass pipe equal to or above atmospheric pressure?

As the various segments of pipe in the fish bypass system are always exposed to the atmosphere in terms of entry characteristics, manhole junctions and ultimate termination of flow, the pressure in the piping system is always equal to atmospheric pressure.

Does the bypass system contain extreme bends in the pipe layout that may cause, excessive physical contact between small fish and hard surfaces and result in debris clogging. Is the bypass pipe centerline radius of curvature (R/D) 5 or greater? Greater R/D may be required if supercritical velocities exist.

The bypass piping involves several varying types of hydraulic structures, including a segment of half-round flume which collects any fish brought to the pump deck level by the screen buckets; the fish are conveyed by the flume to a containment structure; thence through varying piping systems to the river. The pipe layout should not cause excessive physical contact between small fish and hard surfaces, nor would the layout create issues of debris clogging.

Is Station # 6 bypass system designed for bypass pipes or open channels to minimize debris clogging and sediment deposition and to facilitate cleaning?

The bypass piping system was designed and constructed in a manner to facilitate easy access for purposes of debris and sediment removal and/or other cleaning and maintenance issues.

Are the bypass system conduit pipes 24 inches (0.610m) or greater in diameter?

No, approximately 21% of the conduit length in the bypass system is less than 24” in diameter.

BYPASS SEGMENT	LENGTH	DEPTH	WIDTH
Fish Trough	56 feet	1 foot	2 feet
Refuse Trough	56 feet	1 foot	2 feet
Settling Basin	8 feet	3 feet	4 feet
Steel Trough	11 feet	1 foot	1.75 feet
Steel Pipe	73 feet	N/A	0.75 foot-diameter
Steel Culvert	46 feet	N/A	4 feet-diameter
Steel Trough	8 feet	1.3 feet	4 feet tapering to 2.5 feet
Steel Culvert	220 feet	N/A	2.5 feet-diameter
Flex Pipe	30 feet	N/A	1 foot-diameter

Does the bypass system conduit pipes achieve a velocity of 2.0 fps (0610 mps) or greater?

Yes, up to 10.0 fps. Field tests performed in various reaches of the bypass conduit piping system illustrate that the velocity of flow within the system exceeds 2.0 fps.

Does the bypass system contain any closure valves?

Yes, one 8” valve.

Is the depth of flow in the bypass conduit at least 0.75 ft. (0.23m) or greater?

No, the flow depth varies, although it averages 2 inches to 3 inches through most of the conduits in the bypass system. During periods of high surface runoff, the 48” and 30” culverts may have greater flow depths because they convey both runoff and bypass flow.

Are there any hydraulic jumps within the bypass system?

There are no instances or circumstances that create hydraulic jumps within the bypass system.

4.10.3 Bypass Outfall

Are ambient river velocities at the bypass outfall greater than 4.0 fps(1.2 mps)?

No, velocities of 4.0 fps should only occur during flood flows.

Is the bypass outfall located and designed to minimize avian and aquatic predation in an area free of eddies, reverse flow, or known predator habitat?

The outfall is located below the District's grade control weir, beyond its bubble cover where larger fish could be holding, in an area characterized as flatwater run habitat.

Is there sufficient depth at the bypass outfall(depending on the impact velocity and quantity of bypass flow) to avoid fish injuries at all river and bypass flows?

During low flow conditions, water depth would average 1.5 feet to 2.5 feet. During normal high water events the depth would increase to 3 feet to 5 feet.

Does impact velocity (including vertical and horizontal components) exceed 25.0 fps (7.6 mps)?

The manner in which the exit flow to the river is controlled is such that in no instances does the impact velocity of bypass water entering the river approach or exceed 25.0 fps.

Is the bypass outfall designed to avoid adult fish attraction or injuries to jumping fish?

No, deep water habitat is created where adult anadromous salmonids will hold at the outfall location. The outfall does not create a situation that would attract jumping fish.

4.11 Operation and Maintenance

Can the fish screens be automatically cleaned as frequently as necessary to prevent accumulation of debris?

Yes, the screens can be triggered to run at any specified head loss.

The Rex Traveling Screens are checked on a daily basis by operators. A monthly inspection is made on chains, running gear, fish buckets and rotating parts. An annual dewatering is done to inspect total screen assembly and frames.

Does the open channel intake include a trash rack in the screen facility design which can be kept free of debris?

Dual trash racks are present at the entry to the intake structure's concrete floor (elevation 13') up to the concrete pump deck (elevation 55'); and are sloped in the direction of flow.

A mechanical, motor-driven trash rake provides a means of rack cleaning, which is activated manually. A headloss alarm will alert operators of abnormal debris buildup. The trash rake brings all trash and debris to the pump deck surface for disposal.

Is the head differential to trigger screen cleaning for intermittent type system a maximum of 0.1 feet (0.03m)?

No, the current setting for head loss trigger of the screens is set at 0.5 feet.

The timing, frequency, and duration that the screens are run are dependent on water quality conditions. During periods of high water discharge particularly the first overbank flows of the season high concentrations of organic debris are common, as well as a high suspended sediment load. Conversely, during low flow conditions in the summer, algae build-up on the screens may trigger the running of the screens, to reduce head loss.

"The following is a basic criteria for setting the screen run times. These criteria may vary due to the conditions of several variables in the river. A brief explanation is that if the river rises and drops quickly within a few days no change in the run time may be necessary or if the turbidity does the same again, no change would be needed. The normal run time on the screens is set for every 96 hours. A change of time may occur when the river is over 23.0 feet. The time that is set may vary from every 4 hours, above the normal of every 96 hours. Also it should be mentioned that the screens run on a headloss situation when they occur." (H. Shamps, HBMWD, personal communications 1997)

"The Rex Traveling screens are programmed to run 20 minutes with a 20 minute delay between screen #1 and #2. The screens will also activate automatically on a headloss programmed at 6 inches. The frequency of screen runs is programmed by operations and is generally determined by the debris present in the water. During abnormally high river events it could be programmed for every 2 hours. The screens can be run manually from the pump station bypassing the automatic control." (HBMWD, Pump Station 6 Fish Bypass System, Correspondence D. Stoveland, 9/30/97)

Screen and bypass facilities shall be evaluated for biological effectiveness and to verify that hydraulic design objectives are achieved.

In 1977, the District cooperated in a fish study, and in 1998, the District conducted a comprehensive fishery studies at Station 6. The results from both studies were very favorable and confirm that the hydraulic and biological objectives at this facility have been met. (Refer to Appendices E-1 and E-2)

5.0 CONCLUSIONS

In 1998, the District's fish study found that a negligible number of salmonid juveniles were caught in its screens. While the District's screens exceed NMFS's guideline of a maximum diagonal screen opening of 3/32 inch, the results of the 1998 study indicate that operation of the fish screens at Station 6 on an annual basis capture, just 4 coho salmon fry, 18 chinook fry, 15 steelhead smolts, and zero coastal cutthroat. During the 1998 study there was also an opportunity to conduct a "mark-recapture" study of hatchery released (247,000) steelhead, with just 14 fish (0.006%) being captured in the District's screens. (Refer to Appendix E-1)

Anadromous salmonids, particularly adults migrating, can be attracted to the forebay of Station 6. The forebay is contiguous with the main migratory route of these fish, and functions similarly to natural backwater pool habitats. Adult salmonids as well as juveniles are free to swim in or out of the forebay and intake structure. The presence of the forebay, like a natural holding pool, does not cause anadromous salmonids to delay their migration. Avian and aquatic predators can access the forebay as they can access any backwater pool habitat; it is not known if the predation frequency is greater than in other similar habitat in the lower Mad River. Adult anadromous salmonids cannot gain access beyond the trash racks. Juvenile salmonids can, but whether they are drawn to the screens during normal foraging activities is unknown. The conclusion of the 1977 fish study was that they were not. Under the maximum pumping capacity at the screen face the approach velocity is a fraction of the swimming ability of even juvenile salmonids.

6.0 Addendum

During the technical consultation with NMFS on the District's HCP, the District agreed to make Station 6 "fish tight" by complying with NMFS' 3/32-inch screen size opening criterion. The District also agreed to remove the existing buckets on the fish screens and replace them with rakes, thereby eliminating the possibility of lifting fish out of the water. This in turn eliminates the need for the fish return system, which does not meet current standards. Additionally, the District agreed to conduct a comprehensive monitoring program after the Station 6 retrofit project is complete. The Station 6 retrofit project plus the monitoring program are outlined in greater detail in the main body of the District's HCP.

Humboldt Bay Municipal Water District Habitat Conservation Plan

Appendix E Contains three Fish Study Reports as follows:

- Appendix E-1:** **Fishery Study at Humboldt Bay Municipal Water District's
Hilfiker Pump Station 6 Fish Screen & Bypass System (Trinity
Associates, March 1999)**
- Appendix E-2:** **1977 Fishery Study at Station 6 (synopsis of R. Barnhart's
1977 study prepared by Trinity Associates, 2002)**
- Appendix E-3:** **A Fishery Study of the Lower Mad River: Fish Habitat
Mapping, Direct Observation, and Migration Barrier
Evaluation (Trinity Associates, May 1995)**

**Humboldt Bay Municipal Water District
Habitat Conservation Plan**

Appendix E-1

**Fishery Study at Humboldt Bay Municipal Water District's
Hilfiker Pump Station 6 Fish Screen & Bypass System**

Prepared for
Humboldt Bay Municipal Water District
Prepared by
Trinity Associates
March 1999

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1.0 INTRODUCTION

In 1998, Trinity Associates conducted a three-phase fishery study at the Hilfiker Pump Station 6, a direct diversion facility. The purpose of phase one (a pilot fishery study) was to determine if the vertical traveling “Rex” fish screens were capturing anadromous salmonids. The second phase of the fishery study quantified the number of juvenile anadromous salmonids entrained by the fish bypass system. The purpose of third phase was to quantify the survival rate of juvenile anadromous salmonids in the fish bypass system.

The fishery study was conducted by Aldaron Laird, Environmental Planner/Project Manager from Trinity Associates; Dr. Bill Trush, senior fish biologist of McBain and Trush; Ross Taylor, fish biologist; and Dennis Halligan, fish biologist of Natural Resources Management (NRM) Corporation. Dennis Halligan, the Federal Section 10(b) permit holder, and field technicians from NRM CORP, conducted daily fish trapping at Station 6 daily.

2.0 PHASE 1 PILOT STUDY (March 13 to March 27, 1998)

The primary objective of the pilot study was to determine if two vertical traveling Rex screens at Station 6 were in fact capturing wild anadromous salmonids, during natural spring flows. The pilot study involved running a McBain ramp trap twice a day, for ten consecutive days. The length of each sampling period was consistent with the Station 6’s normal operating procedures. Sampling was conducted during five sampling periods to determine if more fish were trapped in the pumps and screens, during different times of the day.

Trapping also allowed the fish biologist to identify the fish species captured, and to determine whether certain times of day and/or flow conditions influenced the fish capture rate. The pilot study results would be used to develop recommendations on sampling frequency and timing, for the subsequent second phase fishery study.

Fortuitously, the start of the pilot study occurred three days prior to the first release of marked fish from CDFG’s Mad River Hatchery. On March 15th, 77,000 yearling steelhead, all with clipped adipose fins were released from the hatchery, approximately five miles upstream of Station 6’s forebay. These marked fish facilitated a “mark-recapture” study, with a known number of fish moving down river, under natural spring flow conditions, past Station 6’s forebay.

The sampling period for the pilot study was extended to March 27th, in order to run the screens during a moderately sized storm event. Between March 22nd and 25th, approximately 3.5 inches of rain fell in the Eureka area. There was considerable snowmelt at higher elevations, which contributed to a stage height increase in the Mad River. Sampling occurred once per day during the storm, and continued as the Mad River’s stage height dropped.

2.1 Results

The pilot study sampling confirmed that a negligible number of anadromous fish were being captured by the vertical traveling "Rex" screens and transported through the bypass system (Table 1).

Table 1. Anadromous Salmonids Caught during the Pilot Study at the District's Direct Diversion Station 6, March 13-27, 1998.

SPECIES	Number Caught in Pilot Study	Between Midnight and 7 AM	Between 7 AM and Noon	Between Noon and 6 PM	Between 6 PM and Midnight
Coho salmon	0	0	0	0	0
Chinook salmon	21	1	10	1	9
Steelhead trout	3	0	1	2	0
Cutthroat trout	0	0	0	0	0

No coho salmon or coastal cutthroat trout were captured during the pilot study phase, even though they are common in the lower Mad River during the period of spring out-migration. Capture rates were calculated by dividing the measured capture (numbers of fish captured in bypass troughs) by the measured effort (time that screens were run). Thus, the units to describe the capture rate were "number of fish per hour". There were 24 sampling periods during the pilot phase of the fish study, resulting in the following capture rates:

- Coho salmon----- 0.00 fish per hour
- Chinook salmon----- 1.31 fish per hour
- Steelhead trout----- 0.06 fish per hour

During the March 22nd to March 25th storm, there were 5 sampling periods. Stage height had no effect on the capture rates of coho salmon or steelhead, but stage height did appear to influence the capture rate of chinook salmon.

- Coho salmon----- 0.0 fish per hour
- Chinook salmon----- 4.5 fish per hour
- Steelhead trout----- 0.0 fish per hour

During the pilot study, only two marked steelhead were captured in the vertical traveling “Rex” screens, after the CDFG released 77,000 steelhead from the Mad River Hatchery. The pilot study confirmed several important factors to consider while conducting the second phase of the fishery study:

- The vertical traveling screens capture fish, including juvenile salmonids.
- Capture rates were fairly similar between sampling periods.
- The March 22nd-25th storm sampling period between 7 AM and 12 noon had the highest “salmonid per sample” at 1.0 salmonids/sample.
- Capture rates of all fish species were greater during the March 22nd – 25th storm, especially during the rising limb of the storm hydrograph.
- The results of the pilot study established early morning, after 7 AM, as the most productive time to sample the screens. The results also indicated that some sampling should occur at night, as flow drops and turbidity decreases. Further, sampling should occur during any future storm events that cause an increase in stage height.

3.0 PHASE II FISH STUDY (March 28 to September 30, 1998)

The second phase of the fish study ran from March 28th to September 30th, 1998. The objectives of the phase II study expanded on those of the pilot study, to include:

- Identify and enumerate the different species of fish captured by the revolving Rex traveling screens.
- Document the number of fish captured per sampling effort during the study period of March through September.
- Determine the extent of mortality of fish captured.

Monthly capture rates (number of fish/hour) for the various species of anadromous fish caught were calculated by dividing the number of fish caught by the amount of time the screens operated. These capture rates will facilitate quantifying the level of incidental take from the operation of the vertical traveling “Rex” screens at Station 6.

The two vertical traveling “Rex” screens were run daily, starting March 13, 1998 in Phase I, and ending with Phase II in September 30, 1998. Typically, each screen was operated for 20 minutes, for a total of 40 minutes of trapping effort per visit. From March through September, the total time that the screens were operated for the trapping project ranged from a high of 22 hours per month in the spring to 18 hours per month by fall. The normal run time duration is 5 hours per month.

Out-migrating juvenile anadromous salmonids comprised a minority of the total fish captured during the study: 74 of 1,176 fish, or 6.3%. Most of the salmonids were captured in March and April: 56 out of 74, or 76% (Table 2). Twenty-two of the 42 chinook salmon handled (52.4%) were captured during the moderate storm event between March 22nd to 25th. The juvenile chinook captured ranged from 29 to 61 mm in fork length (with a mean of 41.6 mm), suggesting that they were smaller, early out-migrants (and weaker swimmers). The literature reports mean fork lengths of out-migrant fall chinook juveniles averaging 52 to 72 mm (Healey 1991).

Fifty percent of the 28 steelhead trapped were marked fish released from CDFG's Mad River Hatchery. Of these 14 clipped fish, 11 were captured in April. During spring 1998, the hatchery released a total of 247,000 marked steelhead, including the initially released 77,000 marked fish, three days after the pilot study began (March 15, 1998). The remaining marked steelhead were released on March 24th (74,000 fish) and April 2nd (96,000 fish). The capture rate of marked steelhead in the vertical traveling "Rex" screens at Station 6 was minimal ($14 \div 247,000 = 0.000057$ or less than 0.006%), which assumes all marked fish passed the Station 6 facilities. Because of the high number of avian predators observed along the lower Mad River after the steelhead releases, fewer than 247,000 marked steelhead are likely to have passed the forebay. However, even assuming an unlikely mortality of 50% of the hatchery steelhead prior to reaching the forebay, the vertical traveling "Rex" screens capture rate would still be minor ($14 \div 123,500 = 0.00011$ or less than 1/100%).

No coho salmon smolts or coastal cutthroat trout (any age class) were captured during the trapping project, even though the forebay at Station 6 is located directly downstream from Lindsay Creek, a major producer of coho salmon and coastal cutthroat trout in the Mad River basin. The eight coho salmon captured were young-of-the-year, ranging from 49 to 74 mm in fork length.

Table 2. Monthly capture (numbers of fish), by species of anadromous salmonids at the vertical traveling "Rex" screens at Station 6, March 13 – September 30, 1998.

Month	Screen Time (hours)	Chinook Salmon	Coho Salmon	Steelhead Trout	Cutthroat Trout
March	22.00	27	0	4	0
April	20.00	13	1	17	0
May	20.66	2	3	1	0
June	19.66	1	2	0	0
July	18.33	1	2	2	0
August	19.33	0	0	3	0
September	17.65	0	0	1	0
Total	137.63	44	8	28	0

Capture rates were calculated by dividing the measured capture (numbers of fish captured in bypass troughs) by the measured effort (time that screens were run). Thus, the units to describe the capture rate were “number of fish per hour” (Table 3). Because juvenile salmonids migrate seasonally, capture rates were calculated for each month. March and April were the peak months of capture chinook salmon (90.9%) and steelhead (75.0%). The peak months of capture for coho salmon was May, June and July (87.5%).

Chinook salmon had the highest monthly capture rate of 1.23 fish/hour in March, steelhead’s highest monthly capture rate was 0.85 fish/hour in April however the majority of these fish were hatchery releases, and coho’s highest capture rate was 0.15 fish/hour in May (Table 3).

Table 3. Capture Rate (# of fish per hour of screen run time), by anadromous salmonid species and month, in the vertical traveling “Rex” screens at Station 6, March 13 – September 30, 1998)

Month	Chinook Salmon	Coho Salmon	Steelhead Trout	Cutthroat Trout
March	1.23	0	0.18	0
April	0.65	0.05	0.85	0
May	0.10	0.15	0.05	0
June	0.05	0.10	0	0
July	0.05	0.11	0.11	0
August	0	0	0.16	0
September	0	0	0.06	0
Total Catch	44	8	28	0
Average Capture Rate	0.32	0.06	0.20	0

One major change in stage height occurred, between March 22nd and 25th when 3.5 inches of rain fell in Eureka, during the trapping project. Higher elevation areas experienced more rain, in addition to snowmelt (4.5 inches of rain was recorded at Ruth Reservoir). Stage height increased from 21.9 feet at 10:00 PM on March 21st to 28.7 feet at 11:30 PM on March 22nd. By April 2nd, the stage height decreased to 23.1 feet, dropping at a slow, steady rate.

During the entire fish study, 44 juvenile chinook salmon were captured. The mortality rate for juvenile chinook salmon during the fish study was 35.7%. The mortality rate for young-of-the-year coho salmon was similar to chinook salmon (three mortalities out of eight fish, or 37.5%). The mortality rate for steelhead trout was 7 out of 28 fish (25%).

Despite running the screens 3.5 to 4.5 times longer than is normal, only 80 fish were captured during the total duration of the seven-month study. At Station 6 the location and backwater configuration of the forebay probably reduces the number of juvenile salmonids

entering the forebay. In larger rivers, juvenile chinook salmon tend to migrate along the rivers' slower, shallower edges (Healey and Jordan 1982). Station 6's forebay is located on the outside of a river bend; the shallower, low velocity margin is located on the inside of the river bend (opposite the forebay location).

The configuration of the forebay creates a backwater area, which is most likely not utilized heavily by out-migrating salmonids. The low velocities through the screens created by the pumps, and the slow movement of the vertical traveling Rex screens, allow juvenile salmonids ample opportunity to avoid the troughs at the base of each screen section.

The extremely low numbers of salmonids trapped are apparent when one considers that only 14 marked hatchery steelhead out of 247,000 were collected in the bypass troughs. Also, one can assume that many chinook migrated past Station 6's forebay between March and June of 1998, yet only 44 were caught in the bypass system. The lack of trapped coho salmon smolts is another indication that out-migrating salmonids either avoid the screens, or fail to enter the forebay.

4.0 PHASE III FISH STUDY (September 2, 1998)

The purpose of this study was to observe the passage of "young of the year" steelhead through the fish bypass system at Station 6. In order to return to the Mad River, all fish captured in the vertical traveling "Rex" screens must travel through the fish bypass system. Hatchery reared "young of the year" steelhead are assumed to behave the same as wild fish entering the system from the lower Mad River. On September 2, 1998, Station 6 fish bypass system was tested. Dennis Halligan, fish biologist, and Andrew Jensen of NRM Corporation conducted the test, with assistance from Aldaron Laird, from Trinity Associates.

To test the ability of the fish bypass system to transport fish safely to the Mad River, a three-stage study was conducted. In each stage, a fish net was put in place at the outlet of whatever reach was to be tested. The screens at Station 6 would then be turned on, thus releasing the normal volume of water through the fish bypass system. Ten fish were then placed into each of the three stages of the fish bypass system. After approximately 5 minutes, the screens were turned off, reducing the volume of water by roughly half. All fish were inspected for scale and fin damage, and then released into the Station 6 forebay.

Sixty healthy "young of the year" steelhead were obtained from the Mad River Hatchery. The healthy fish were transported to Station 6 and exhibited vigorous swimming behavior before the tests. The fish used in the study ranged in length from 65 to 100 mm. Of the thirty fish released, sixteen were recaptured in the three stages; and fourteen were not (Table 4).

Table 4 Fish bypass system, fish transport mortality study

STAGE NUMBER	SEGMENT NUMBER	FISH RELEASED	FISH RECOVERED	FISH NOT-RECOVERED
STAGE 1	1 TO 8	10	7	30%
STAGE 1	10	10	4	60%
STAGE 3	1 TO 10	10	5	50%
SUBTOTAL		30	16	47%
FLUSHING	1 TO 10	0	2	N/A
TOTAL		30	18	40%

The fish bypass system was separated into 10 segments. At stage 1, a net was placed after segment 8; at stage 2, a net was placed after segment 10; and, at stage 3, a net was placed after segment 10. After checking all nets, fourteen fish were missing. By increasing flow, attempts were made to recover the fourteen fish. Two more fish were recaptured in nets. Six more fish were netted in the open-air clean-out basin. Six fish were unaccounted for and may have escaped in Segment 10, a 220-foot culvert, which was observed to leak.

“Young of the year” steelhead entering the fish bypass system appear to move in greater numbers after the fish screens stop, during the declining limb of a water release. “Young of the year” steelhead became stranded in Segment 3, the concrete basin. At the base of the hydraulic trash grate lift a depression in the Concrete Basin, creates an area of lower velocities during normal water release. The basin’s depression holds sufficient water so that a few fish can remain, once the basin becomes dry.

A significant leak was observed in Segment 10 a 220 foot x 30-inch culvert. When the screens are turned off, water volume is reduced by approximately half. When the shut-off valve stops all water from entering the fish bypass system, water ceases to flow in Segment 10, the 220 foot x 30 inch Culvert; however, water continues to exit from the rip rap below the Segment 10, 220 foot x 30 inch Culvert outlet, for a few more minutes.

Six fish recaptured had suffered scale damage during passage through the Fish Bypass System covering approximately 20% of their body. The remaining eighteen fish recaptured were observed to not exhibit any scale or fin damage.

“Young of the year” Steelhead Trout moving through the Fish Bypass system were detained in two locations Segment 3, Concrete Basin, and Segment 9, Open Air Clean-out Basin. Mortality of “young of the year” Steelhead Trout could occur at these two locations.

The District in response to the findings of this study, has modified the fish bypass system to eliminate impacts to fish at; the concrete basin that had a depression which could trap fish, the open-air clean-out basin which also could trap fish has been removed from the bypass system, and the openings in the bottom of the 220 foot culvert have been sealed.

5.0 CALCULATION OF ANTICIPATED TAKE LEVELS

Vertical Traveling Rex Screens

The 1998 fish study at Hilfiker Pump Station 6 documented monthly capture rates for chinook salmon, coho salmon and steelhead, by dividing the number of fish caught by the amount of time the screens operated (number of fish/hour). During the fish study, from March through September, the screens were run more frequently, every 24 hours instead of every 96 hours. Most (76%) of the salmonids were captured in March and April, during a moderate storm event. Because juvenile salmonids out-migrate seasonally, capture rates were calculated for each month. March and April were the peak months of capture for chinook salmon (90.9%) and steelhead (75%); and coho salmon capture peaked in May, June and July (87.5%). The highest capture rate for chinook salmon was 1.23 fish/hour in March, for coho salmon, it was 0.15 fish/hour in May, and for steelhead the highest capture rate was 0.85 fish/hour in April. No coastal cutthroat trout were captured during the fish study.

The 1998 fish study found that 50% of the 28 trapped steelhead were marked fish released from CDFG's Mad River Hatchery. The capture rate of marked yearling steelhead in the Station 6 screens was low ($14 \div 247,000 = 0.000057$ or less than 0.006%), assuming all marked fish passed the Station 6 facilities. Because a high number of avian predators were observed along the lower Mad River after the steelhead releases fewer than 247,000 marked steelhead passed the forebay. However, even assuming an unlikely mortality of 50% of the hatchery steelhead prior to reaching the forebay, the screens capture rate would still be low ($14 \div 123,500 = 0.011$ or less than 1/100%).

The District normally runs its screens every 96 hours, 20 minutes for each screen, for a total run time of just 5 hours/month. During the 1998 study the normal run time for the screens was increased (Table 2) from 5 hours to 17-22 hours per month. At the highest monthly capture rate measured for each species, the District's normal operation of its screens (approximately 5 hours run time per month) would amount to a yearly incidental take of just 134 individual animals (9 coho salmon, 74 chinook salmon, and 51 steelhead) (Table 5).

Table 5. Comparison of actual monthly capture rates versus maximum monthly capture rates. The maximum was calculated by taking the maximum monthly capture which actually occurred and assuming that maximum rate occurred each month between October and February (based on normal screen run time of 5 hours per month).

Capture Rate	Coho Salmon	Chinook Salmon	Steelhead Trout	Cutthroat Trout
Maximum Capture Rate	9	74	51	0
Monthly Capture Rate	4	18	15	0

Calculating incidental take under normal screen run time of 5 hours, and using actual monthly capture rates scientist measured (extrapolating for the months of October through February) the yearly take is reduced from 134 to just 37 individuals (4 Coho salmon, 18 Chinook salmon, and 15 Steelhead).

Table 6. Capture Rate Measured (# of Fish Per Hour of Screen Run Time), Times Normal Monthly Screen Run Time of Five Hours, Based on 1998 Hilfiker Pump Station Fish Study

Month	Coho Salmon	Chinook Salmon	Steelhead Trout
January	0	0	<i>0.06 yields 0.3 fish</i>
February	0	<i>0.65 yields 3.25 fish</i>	<i>0.06 yields 0.3 fish</i>
March	0	1.23 yields 6.15 fish	0.18 yields 0.9 fish
April	<i>0.05 yields 0.25 fish</i>	0.65 yields 3.25 fish	0.85 yields 4.25 fish
May	<i>0.15 yields 0.75 fish</i>	0.10 yields 0.5 fish	0.05 yields 0.25 fish
June	<i>0.10 yields 0.5 fish</i>	0.05 yields 0.25 fish	0
July	<i>0.11 yields 0.55 fish</i>	0.05 yields 0.25 fish	0.11 yields 0.55 fish
August	0	0	0.16 yields 0.8 fish
September	0	0	0.06 yields 0.3 fish
October	0	0	<i>0.06 yields 0.3 fish</i>
November	0	0	<i>0.06 yields 0.3 fish</i>
December	0	0	<i>0.06 yields 0.3 fish</i>
Total	4 fish	18 fish	15 fish

The levels of incidental take per year, calculated for the District's Hilfiker Pump Station 6 screens, ranges from; 4 to maximum of 9 coho salmon, 18 to maximum of 74 chinook salmon, and 15 to maximum of 51 steelhead. In the case of steelhead based on the 1998 study, 7 to 25 taken would be of hatchery origin.

**Humboldt Bay Municipal Water District
Habitat Conservation Plan**

Appendix E-2

1977 Fishery Study at Station 6

**(synopsis of R. Barnhart's 1977 study
prepared by Trinity Associates, 2002)**

The United States Fish & Wildlife California Cooperative Fishery Research Unit, at Humboldt State University, conducted a fish behavior study on June 1, 1977, to evaluate HBMWD's two new fish return systems. The two fish return systems were: 1) a screen bypass, and 2) a pump bypass. The pump bypass system is no longer used or operable at this time, and will not be discussed further. The fish study used 6,000 Mad River hatchery reared chinook salmon smolts, 3-5 inches in length. In 1977, the District was diverting 43.7% (89 cfs) of the flow in the lower Mad River; water stage in the forebay was 21.4', and the flow at the USGS Arcata stream gauge was 98.8 cfs.

The first test run consisted of introducing 2,000 fish into the forebay and running the screens for 30 minutes. "At the end of the 30 minute test no fish had gone through the screen By-Pass system. We then observed most of the fish swimming in a school in the forebay area apparently without regard for the small attraction current towards the diversion pumps" (Barnhart, 1977).

Because fish were not attracted to the screens or pumps in the first test run a decision was made to run a second test run and introduce another 2,000 fish 15' in front of the pumps (approximately 2 feet in front of the running screens), by dropping them 40' down the "well" (the intake Structure chamber behind rear gated wall of the forebay). The screens were run for 30 minutes. Fish entering the bypass system were netted at the outlet. One hundred and eighty eight live and 30 dead fish were recovered.

The 1977 study concluded that most of the mortality measured resulted from handling during transit from the hatchery to Pump Station 6. "Many mortalities were observed in the water-filled holding channels on the vertical traveling screens shortly after the screens had emerged from the water. These fish began appearing in the screen channels about 10 minutes after they had been dropped down the well. Dead fish exhibited no evidence of body damage due to impingement on the screens"(USFWS, 1977). Of 2,000 fish introduced in the second test run when the bypass screens were running, 218 fish (5.5%) went through the screen bypass system, 30 were dead (13.8%).

In the 1977 study, fish in the "fish baskets/troughs" did not always get washed into the fish trough but ended up in the "refuse" trough. The author concluded..."it is also apparent that the pulling or attracting power of the current from the forebay to the diversion pump area is negligible. Healthy fish should be able to maintain their position in the forebay area without difficulty. At low flow conditions (less than 100 cfs) when most of the river flow would be diverted through the pumps the situation would be changed and most fish might be forced to travel through the fish by-pass systems. During average run-off years, however, low flow conditions occur after the peak of downstream fish migration"(USFWS, 1977).

Reference

California Cooperative Fishery Research Unit "Test Of Fish By-Pass Facilities, Essex Pump Station, Mad River, Ca., Research Report 77-1, USFWS, R. Barnhart, 1977

Appendix E – 3

A Fishery Study of the Lower Mad River: Fish Habitat Mapping, Direct Observation, and Migration Barrier Evaluation

Prepared for
Humboldt Bay Municipal Water District

Prepared by
Trinity Associates

May 1995

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1.0 INTRODUCTION

The Mad River, Humboldt County, supports as many as four runs of steelhead (*Oncorhynchus mykiss*), several runs of chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), and coastal cutthroat (*Salmo clarkii*). All are anadromous, migrating between freshwater spawning areas and the Pacific Ocean during their life cycle. The lower portion of the Mad River functions thus mostly as a migration route for the adults on their upstream spawning runs and for smolting juveniles downstream on the way from their freshwater rearing areas to the ocean.

The Humboldt Bay Municipal Water District (HBMWD) operates and maintains five Ranney wells and a surface water collector on the Mad River between the Highway 299 Bridge and the Arcata and Mad River Railroad (A&MR) bridge. HBMWD and the US Geological Survey (USGS) have both installed grade control structures, which affect water surface elevation, velocity and depth, which in turn affect fish migration. In order to assess fish usage and habitat conditions of this reach, HBMWD secured the services of Trinity Associates (TA) to: 1) conduct an inventory of the physical fish habitat; 2) determine habitat use by salmonids during the fall, 1994 by direct observation with mask and snorkel, and; 3) analyze two boulder grade control weirs to determine whether they were migration barriers (see Habitat Map).

2.0 LIFE HISTORY

Habitat use by anadromous salmonids is characterized by constant change throughout their complex life cycles. As a result, population estimates for a particular section of stream offer only a temporary snapshot of a fishery during one stage of its life. For the Mad River, four salmonid species each have their own habitat requirements and survival rates for their different life stages. This complexity demands that fishery manager's focus on managing physical habitat rather than numbers of fish.

General descriptions of freshwater habitat use by anadromous salmonids must include: upstream spawning migration, adult holding and spawning, juvenile (summer and winter) rearing, and downstream migration to the ocean (smolting). All Mad River adult salmonids require adequate water flow to negotiate potential barriers during upstream migration from the ocean. Most adults move upstream during the fall, after the first rains, and through the winter. They look to hold in pools and runs with good cover or depth, which adjoin good spawning habitat. The latter is usually characterized by shallow, swift glide areas between a pool and a riffle, with a substrate of large gravel and small cobble in which eggs are buried, and preferably devoid of large amounts of sand, which can suffocate the incubating eggs. An exception, the native summer steelhead migrate in the spring to holding pools high in the system, taking advantage of areas which the fall/winter fish can't reach for lack of time. After spawning, chinook and coho adults die, but steelhead and cutthroat adults may head back to the ocean to return the following season to spawn again.

All salmonids hatch from eggs buried under gravel and emerge through the gravel to rear for a time in freshwater. During this early stage, salmonid fry use the slow velocity margins of pools where small food items drift slowly past and where the small fish aren't swept downstream. Overhanging vegetation or clean gravel substrate provides protection from bird predation. Chinook salmon juveniles spend only a few months in freshwater before moving downstream in the early summer of their first year to the lower sections of rivers and estuaries to rear before entering the ocean. On the other hand, coho salmon generally spend one year and steelhead and

coastal cutthroat trout spend at least one or more years rearing in freshwater before they smolt. As such, quality freshwater rearing habitat takes on more importance for these species, both during the summer and winter seasons. Coho juveniles prefer deep pools with large woody debris while rearing steelhead tend towards pools and runs (even riffles) characterized by boulders and bedrock and use clean cobble substrate to dive into for protection from high winter flows.

Once the juveniles reach a particular size, different for each species, they go through gradual external and internal changes to a form better suited to life in a saltwater environment. During this smolting process, the fish migrate downstream usually during the spring and early summer before flows are too reduced. Habitat requirements during this migration are adequate flow and shelter from predation.

3.0 METHODS

3.1 Habitat Typing

The above discussion illustrates how a population estimate for a stream reach can reveal only a small and temporary picture of the salmonid use. Fisheries managers, recognizing the complex task to monitor salmonids, have opted to focus on physical fish habitat, which is not as temporal as fish populations. Fish habitat typing provides a cost-effective framework for fish management and as such has become an important fisheries tool.

The habitat survey method used here is consistent with the methods adopted by the California Department of Fish and Game (CDFG) (CDFG 1995) and the U.S. Forest Service for managing anadromous salmonids. The method produces a 100% description of a stream's physical fish habitat at one of three levels: micro, meso or macro-habitat. Micro-habitat typing usually targets a particular life stage (such as summer rearing) and flow (summer base flow) and separates the stream into small habitat units. Micro-habitat typing is useful for project level stream restoration design and monitoring. Macro-habitat typing, used in this project, takes a broader perspective separating the river into habitat types, which are maintained regardless of discharge, often lumping several small pools at low flow into one large pool as it would function at a higher winter flow.

On October 3, 1994, beginning at the downstream end of the study reach, the Highway 299 Bridge, Trinity Associates characterized each habitat unit within the flowing, wetted channel as one of five types: pool, riffle, run/glide, cascade or backwater. For each unit, we measured the length and width in feet with a 200' reel tape and the average and maximum depth in tenths of feet with a stadia rod. We also identified the amount and quality of fish shelter useful to adult and juvenile salmonids. For pools and runs, we also measured the maximum depth at the crest of the pool tail (downstream end). This is subtracted from the maximum or average pool depth to determine the residual pool depth, either of which are useful to monitor bed changes independent of discharge (Lisle 1987).

3.2 Direct Observation

During the habitat inventory on October 3 and 4, direct observations for the presence or absence of salmonids were made with mask and snorkel in each of the pools and runs. The species and the approximate size and number of the observed fish were recorded. Trinity Associates planned to continue direct observation throughout the fall to determine usage of the reach as a migration route. Instead, we found that a fish ecology class at Humboldt State University under the direction of Dr. William Trush was diving several reaches of the lower Mad River each week. Rather than duplicating their effort, we met and worked with the students covering the HBMWD reach to verify their fish identification and diving skills. We present their preliminary results here, recognizing that the students for a future report are synthesizing the overall class results.

3.3 Migration Barrier Analysis

Two grade control structures (boulder weirs) within the reach were analyzed to determine whether they were fish migration barriers at low summer flows. One is a high gradient boulder riffle just upstream of the Highway 299 bridge apparently placed by the US Geological Survey (USGS) as a datum control for their gauging station (Trinity Associates 1994). The second is a boulder weir further upstream and constructed by HBMWD to back-flood the forebay on Pump Station 6. For each grade control structure, the main thread of attractant flow was first identified and then measured for water depths and velocities. Where a jump appeared necessary for upstream fish migration, vertical distance and maximum depths of the starting and ending pools were measured. Measurements were then compared to velocity criteria reported by Orsborne (1985) for sustained swimming, prolonged, and burst speeds of the different fish species to determine whether or not they were barriers.

4.0 RESULTS

4.1 Habitat Typing

The results of the habitat inventory are presented in Table 1 and on Figure 1 habitat map. This reach of the Mad River was typical of the lower reach of rivers with a low gradient, dominated by pools with an abundance of fine sediment and few riffles. The area of each habitat unit was calculated by multiplying the average width by the average length and for the area surveyed, 64% were pools, 11% riffles, and 22% runs or glides and 3% backwater pools (Figure 1). Most of the pools were lateral scour pools along bedrock or boulders with very little shelter for adults or juveniles. The exceptions to this were the two pools under the bridges (units # 1 and 34), where small boulders and the bridge footings themselves provided some shelter. Residual pool depths are reported on the habitat map (Residual Average Depth) and on Table 1 (Residual Average and Residual Maximum Depths) for future monitoring purposes.

The substrate throughout the reach was characterized by sand and small gravel. This dominance of fine sediment is consistent with: poor production of food organisms for juvenile salmonids; poor spawning due to low egg survival rates; and poor over wintering cobble habitat for juveniles.

There was a notable lack of large woody debris (LWD) in this section of the Mad River. Downriver of Highway 299, LWD is fairly common as shelter and as a structural element for pools, and in upriver areas there is frequently after large storms a great deal of LWD left on the river bars. Large wood is an important shelter element for coho salmon juveniles and the lack of it reduces the quality of available habitat.

4.2 Direct Observation

On October 3 and 4, 1994, we observed very few salmonids in the study reach. The only adults we observed were in the two bridge pools (units #1 and #34). No attempt to count the fish was made but each contained more than 10 steelhead half-pounders. These fish have spent less than one year in the ocean when they enter the river as immature adults. They do not spawn but remain in the lower part of the river a few months before they return downstream to the ocean to spend another year before their actual spawning run. The scarcity of shelter resulted in very few juveniles found- a few young-of-the-year (0+) and one year old (1+) steelhead in the pool below the weir and in some backwater areas.

Table 1. Habitat inventory for the Mad River between Highway 299 and the A&MR Railroad trestle on October 3, 1994

UNIT #	HABITAT TYPE	AVERAGE			MAX DEPTH	RES.AVG. DEPTH	RES.MAX DEPTH	SHELTER	NOTES
		LENGTH	WIDTH	DEPTH					
1	POOL	275	75	2	3.3	1.3	2.6	Boulders	Hwy.299 pool. Observed ~20 SH half-pounders, otter on right bank (RB)
2	HI GRADE RIFFLE	50	44	1.3	2.3			Boulders	Good, deep channel for upstream passage. Max. velocities 2.0, 2.7 fps
3	RIFFLE	167	40	0.8				Gravel	Staff gage @ 2.98'. Top of riffle very shallow, .5' with velocity 1.8 fps
4	BACKWATER	200	50	2.4	3.5			Boulders	
5	POOL	575	72	1.4	1.8	0.4	0.8	None	
6	RIFFLE	52	60	0.7	0.7			None	
7	POOL	194	46	1.6	1.6	0.2	0.2	None	
8	RIFFLE	171	42	0.6	0.6			None	Top of riffle shallow, .45'
9	POOL	250	60	4.5	13	3.6	12.1	Depth	Deep but not very good cover,
10	POOL	490	70	2.2	3.5	1.3	2.6	Bdrk, bldrs	Some 0+, 1+ SH near weir
11	WEIR	20	43	0.5				Boulders	2.5-3' drop, Velocities in chute: 1.6, 2.9, 1.5, 2.9, 5.3, 5.6 fps. Passable
12	BACKWATER	161	49	2.5	5.8			Boulders	
13	POOL	220	190	2.3	4.5	1.3	3.5	Forebay	Dam pool behind weir
14	GLIDE	253	100	0.6				None	
15	POOL	775	76	3	10	1.8	8.8	Bdrk, depth	
16	GLIDE	315	151	0.5				None	
17	POOL	870	105	2.4	4.7	1.4	3.7	Boulders	No fish or cover
18	RUN	640	35	1.5				Bdrk, bldrs	#15-18 one corner pool at high flows with very little shelter
19	RIFFLE	110	60	0.4				Boulders	
20	POOL	324	58	2.3	3.7	1.5	2.9	Boulders	
21	RIFFLE	70	50	0.7				None	
22	POOL	570	60	2.9	4.8	1.9	3.8	Bedrock	Big bedrock pool with some shelter near LB but no fish
23	RIFFLE	135	70	0.7				None	
24	POOL	200	56	1.6	3.5	0.6	2.5	Boulder weir	
25	RIFFLE	268	40	0.7				Boulders	Secondary backwater channel adjacent but barely flowing
26	BACKWATER	122	42	2.7	4.7	1.7	3.7	Boulders	
27	BACKWATER	79	93	4.9	6.8	3.9	5.8	Depth	Mouth of Warren Creek, some 0+ salmonids
28	GLIDE	662	150	1.3				None	
29	POOL	862	90	3	6	1.6	4.6	Bedrock	
30	RIFFLE	170	100	0.6				None	
31	POOL	940	100	2.1	3.5	1.1	2.5	Bedrock	
32	RIFFLE	357	48	0.7				None	
33	POOL	360	70	2.6	6	1.6	5	Footing	Foot of RR trestle good shelter under footing, ~20 half-pounder SH
34	RIFFLE	185	65	0.7				None	

We compiled the diving results from the HSU student project to show changes in the usage of habitat between September 23 and November 3, 1994 (Table 2). Water temperatures ranged from 60-67 degrees Fahrenheit, suitable for salmonid rearing. Four age classes were distinguished for steelhead in the student counts: 0+ and 1+ juveniles, half-pounders (HP) and adults (AD) and for chinook salmon (KS) just adults (AD) were observed. The students typed and numbered habitat units differently than we, but since Trinity Associates supplied them with the aerial photos they used, we were able to correspond their field observations to our habitat units. One student group reported the steelhead juveniles as 0+/1+ for the youngest and 2+ for the next size class. We took the liberty of reporting them as 0+ and 1+ respectively in Table 2. Numbers in Table 2 are not population estimates but are indicators of presence and general abundance.

Table 2. Direct observation of salmonids on the Mad River between Highway 299 and the A&MR Railroad trestle.

		9/23/94 (HSU)				9/30/94 (HSU)				10/3/94 (TA)				10/7/94 (HSU)				10/15/94 (HSU)				10/22/94 (HSU)				10/31/94 (HSU)				11/3/94 (HSU)			
		STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS	STEELHEAD	KS
		0+	1+	HP	AD	0+	1+	HP	AD	0+	1+	HP	AD	0+	1+	HP	AD	0+	1+	HP	AD	0+	1+	HP	AD	0+	1+	HP	AD	0+	1+	HP	AD
1	POOL									~20				58	7	34		42	12	1	1	38	14	25		32	13	15		1			(1 Chum salmon)
2	HG RIFFLE																																
3	RIFFLE												23																				
4	BACKWATER																																
5	POOL												4				6				1												
6	RIFFLE											3					1																
7	POOL																																
8	RIFFLE																																
9	POOL																				1										1		
10	POOL					13				>10	>3			36	4			28	2			15				18	1						
11	WEIR																																
12	BACKWATER																																
13	POOL												3				2																
14	GLIDE												1																				
15	POOL					30							37	1			33	3				35	2			28							
16	GLIDE																																
17	POOL																																
18	RUN					35	1						78	2							36	1											
19	RIFFLE																																
20	POOL					2							15	2							3												
21	RIFFLE																																
22	POOL												2																				
23	RIFFLE					2							4																				
24	POOL																																
25	RIFFLE																																
26	BACKWATER																																
27	BACKWATER																																
28	GLIDE																																
29	POOL																																
30	RIFFLE																																
31	POOL																																
32	RIFFLE																																
33	POOL					24				~20			10	32	2		20	1												1	2	4	17
34	RIFFLE																																

The habitat throughout this reach appears to get little summer use by rearing salmonid juveniles. According to these data, steelhead juveniles predominantly used Units # 1, 10, 15, 18, and 34, most of which are pools with medium to good shelter. Steelhead half-pounders were holding in the two bridge pools (# 1 and 34) through most of October. Besides occasional sightings, adult steelhead and chinook salmon were not using the reach until early November, after the first of the fall rains. Once the rains started, the river became turbid making further direct observation impractical.

In the reach downstream of the Highway 299 bridge, another of the HSU student groups observed many more steelhead half-pounders and adults and chinook adults than those observed in the HBMWD reach. The lower reach is more confined and the pools are deeper and contain much more shelter than the HBMWD's middle reach.

4.3 Migration Barrier Analysis

Physical barriers to upstream fish migration can consist of either velocity chutes, differential elevations, shallow water depths or combinations of these. If an adult salmonid is forced to jump an obstacle, they generally need to jump from a pool at least 1.25 times deeper than the height of the obstacle.

A high grade boulder riffle formed by the USGS gauging station grade control weir just upstream of the Highway 299 bridge (unit #2) was assessed to determine if it posed a migration barrier to adult or juvenile fish at minimum summer discharge. The riffle drops 3-4 feet over its 50' length at a slope >4% and has several main flow channels. We measured depths and velocities through the main channels to determine whether adult salmonids could successfully negotiate their way upstream at this discharge. Average depths were 1.5'-2' and velocities were all less than 3 feet per second (fps), both parameters well within the capabilities of migrating adults (Figure 2 and Orsborn 1985).

The boulder weir built by HBMWD to back-flood the forebay was also analyzed for fish passage at this discharge. The weir was built of small to medium boulders and at low flow, water dropped 2.5'-3' over the weir's 20' length. The pool below averaged <2' deep with no deep spots near the weir from which to jump. The depth over the weir averaged <1' deep through the boulders except in a few deeper channels. Velocity measurements in the most likely access channel ranged from a low of 1.5 fps to a maximum of 5.6 fps with average depths >1'. Although fast, these upper velocities are below the "burst" speed and the "prolonged" speed of anadromous salmonids (Figure 2 and Orsborn 1985).

5.0 CONCLUSIONS

The middle section of the lower Mad River between the two bridges provides little summer rearing habitat for juvenile salmonids. Shelter is limited to boulders and bedrock in a few areas with much of the substrate embedded with fine gravel and sand. The lack of large woody debris or clean cobble in the reach limits rearing by coho salmon or steelhead juveniles during the summer and probably the winter.

Adult salmonids find little holding or spawning habitat within the reach because of the lack of shelter and clean gravels. Holding habitat for adult salmonids is limited to the pools under the two bridges. Observation of the pools downstream of Highway 299 indicate that by early October, salmonid adults are in the lower river awaiting higher discharges associated with the fall rains for their spawning migrations. By contrast, the HBMWD reach held only steelhead half-pounders during the same period.

The habitat value for the middle reach for juveniles and adults could be increased with addition of large woody debris, particularly for coho salmon. We suspect that one reason for the lack of wood is that after high flows leave material perched on upstream river bars out of the low flow channel, local citizens salvage this material for firewood, etc. without realizing the value it might have as future downstream fish shelter and structure for pools. We would recommend that efforts be made to prevent salvage of this LWD material.

Neither the USGS boulder area near Highway 299 or the HBMWD weir appear to function as upstream or downstream migration barriers at low flows. Riffles between the two boulder areas may be more limiting to migration due to their shallow depth. But once the first fall rains occur, the discharge increases which triggers the spawning migration instincts in the salmonids at the same time it increases the water depth.

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**Humboldt Bay Municipal Water District
Habitat Conservation Plan**

**Appendix F
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