FINAL REPORT: HUMBOLDT COUNTY CULVERT INVENTORY AND FISH PASSAGE EVALUATION

By

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INTRODUCTION

The inventory and fish passage evaluation of culverts within the Humboldt County road system was conducted between October, 1998 and December, 1999 under contract with the California Department of Fish and Game (CDFG) (contract # **FG-7068 IF**). The objective was to assess passage of juvenile and adult salmonids and develop a project-scheduling document to prioritize corrective treatments to provide unimpeded fish passage. The inventory was limited to county-maintained crossings within anadromous stream reaches known to historically and/or currently support runs of coho salmon (*Oncorhynchus kisutch*) and steelhead (*O. mykiss irideus*).

The inventory process included:

1. locating and counting all culverted stream crossings which may inhibit fish passage;
2. visiting each culvert location during both late-summer/early fall low flow and during the first few storm events;
3. collecting information regarding culvert specifications;
4. assessing fish passage using culvert specifications and passage criteria for juvenile and adult salmonids (from scientific literature and Fish Xing computer software);
5. assessing quality and quantity of stream habitat above and below each culvert; and
6. assessing fish passage during storm events.

Final Product of Culvert Inventory:

As the final product, each of the following agencies and departments will receive a hard copy and a diskette of a detailed project-scheduling document: Humboldt County Public Works Natural Resources and Engineering Divisions, and CDFG- Inland Fisheries Division and Region 1 Office. The three copies of the final report include the following information:

1. A count and location of all culverted stream crossings. Locations were identified by stream name; road name; watershed name; mile marker or distance to nearest crossroad; Humboldt county road map #; Township, Range and Section coordinates; and lat/long coordinates. All location information was entered into a spreadsheet for potential database uses.

2. For each site, culvert specifications including: length, diameter, type, position relative to flow and stream gradient, amount of fill material, depth of jump pool below culvert, height of jump required to enter culvert, previous modifications (if any) to improve fish passage, and evaluate effectiveness of previous modifications.

   Information regarding culvert age, wear, and performance will also be collected, including: overall condition of the pipe, height of the rust line, and ability to pass flows (and debris) during the past two winters of moderately large storm events. Presence or absence and condition of trash racks will be assessed. All culvert specifications will be entered into a spreadsheet for potential database uses.

3. An evaluation of fish passage at each culvert location. Fish passage will be evaluated by two methods. First, the information collected on culvert specifications will be used to calculate the hydraulic characteristics of each culvert. These values will be compared to values cited in current scientific literature regarding the jumping and swimming abilities of juvenile coho salmon and steelhead. Secondly, fish passage will be assessed by on-site observations of fish movement.

4. Photo documentation of each culvert to provide visual information regarding inlet and outlet configurations.

5. An evaluation of quantity and quality of fish habitat above and below each culvert location. Most information will be obtained from habitat typing surveys previously conducted by CDFG, watershed groups, and/or timber companies. Where feasible, a first-hand inspection and evaluation of stream habitat will occur. Length of potential anadromous habitat will also be estimated from USGS topographic maps. In situations where formal habitat typing surveys were not conducted and/or access to stream reaches was not permitted, professional judgement of biologists familiar with watershed conditions will be utilized. Habitat information will be vital in prioritizing which culverts should be modified and/or replaced as funding becomes available. For example, a culvert would be a low-priority site if additional migration barriers existed downstream which prevented or inhibited adult and juvenile salmonids from reaching the culvert location. Quality and amount of potential spawning and over-wintering habitat above inaccessible culverts will be a major factor in identifying high-priority treatment locations.

6. A prioritized list of culverts that require treatment to provide unimpeded fish passage to spawning and rearing habitat. Criteria for priority ranking were based on methods previously developed in Oregon and Washington. On a site-by-site basis, recommendations for providing unimpeded fish passage will be made. For example, some stream crossings may require a bridge or properly-sized culvert set below stream grade to accommodate fish passage, whereas other locations may just require building up the jump pool with rip rap to backflood the culvert inlet and/or baffles to reduce velocities within the culvert.

Project Justification

Fish passage through culverts is an important factor in the recovery of depleted salmonid populations along the Pacific Northwest. Although most fish-bearing streams with culverts tend to be relatively small in size with only a couple of miles or less of upstream habitat, thousands of these exist and the cumulative effect of blocked habitat is probably quite significant. Culverts often create temporary, partial or complete barriers for anadromous salmonids on their spawning migrations (Table 1)(Robinson et al. 1999).

Typical passage problems created by culverts are:

- Excessive drop at outlet (too high of entry jump required);
- Excessive velocities within culvert;
- Lack of depth within culvert;
- Excessive velocity and/or turbulence at culvert inlet; and
- Debris accumulation at culvert inlet and/or within culvert.

Table 1. Definitions of barrier types and their potential impacts.

Barrier Category	Definition	Potential Impacts
Temporary	Impassable to all fish some of the time	Delay in movement beyond the barrier for some period of time
Partial	Impassable to some fish at all times	Exclusion of certain species and lifestages from portions of a watershed
Total	Impassable to all fish at all times	Exclusion of all species from portions of a watershed

Even if culverts are eventually negotiated, excess energy expended by fish may result in their death prior to spawning. Migrating fish concentrated in pools and stream reaches below culverts are also more vulnerable to predation by birds, otters, and humans. Culverts which impede adult passage limit the distribution of spawning, often resulting in underseeded headwaters and superimposition of redds in lower stream reaches.

Current CDFG guidelines for culvert installation (Flosi et al. 1998) are intended to provide unimpeded passage for both adult and juvenile salmonids. However many culverts on federal, state, county, and private roads are actually barriers to anadromous adults, and more so to resident salmonids and juveniles. The smaller body sizes of resident coastal cutthroat trout (*O. clarki clarki*), coastal rainbow trout (*O. mykiss irideus*), and juvenile coho and steelhead limits their jumping and swimming abilities to negotiate culverts.

Juvenile coho salmon spend approximately one year in freshwater before migrating to the ocean, and juvenile steelhead may rear in freshwater for up to four years (one to two years is most common in California). Thus, juveniles of both species are highly dependent on stream habitat. Many studies indicate that a common strategy for over-wintering juvenile coho is to migrate out of larger river systems into smaller streams during late-fall and early-winter storms to seek refuge from possibly higher flows and potentially higher turbidity levels in mainstem channels (Skeesick 1970; Cederholm and Scarlett 1981; Tripp and McCart 1983; Tschaplinski and Hartman 1983; Scarlett and Cederholm 1984; Nickelson et al. 1992). Recent research conducted in Prairie Creek tributaries suggests that juvenile salmonids migrate into smaller tributaries in the fall and winter to feed on eggs deposited by spawning adults as well as flesh of spawned-out adults (Roelofs, per. comm).

Coastal cutthroat trout are present in many smaller tributaries in the northern portion of Humboldt county. Numerous lower Eel River tributaries historically supported large runs of sea-run and resident populations. These runs have mostly been extirpated by over a century of multiple, landuse practices that have degraded once complex and productive estuary habitat. Most Humboldt Bay and lower Mad River tributaries still support runs of coastal cutthroat trout. The species is known for a wide variety of life-history strategies that encompass headwater resident populations, resident fish that migrate to and from mainstem channels for foraging and small tributaries for spawning, and sea/estuary-run fish. Their migration into tributaries for spawning often occurs into the upper reaches of a watershed's smallest tributaries, often the tributaries where culverts are located.

The variable life history of resident coastal rainbow trout (steelhead are sea-run coastal rainbow trout) is similar to coastal cutthroat trout, exhibited by seasonal movements in and out of one or more tributaries within a watershed. Again, smaller tributaries are where most culverts are still located since larger channels tend to be spanned with bridges.

In response to the federal listing of coho salmon as threatened in northern California, five counties (Humboldt, Del Norte, Trinity, Mendocino, and Siskiyou) formed the Five-County Salmon Group to examine various land-use activities conducted or permitted under county jurisdiction that may impact coho salmon habitat. Initial meetings identified causative factors of potential impacts, information gaps, and priority tasks required to obtain missing information. A priority task identified included culvert inventories on county roads to evaluate fish passage and prioritize treatments.

Anadromous salmonids will benefit from this planning effort because the final document will provide Humboldt County's Natural Resources and Engineering Divisions with a prioritized list of culvert locations to fix that will provide unimpeded passage for all species (and life stages) of salmonids. The inventory will also provide the County with a comprehensive status evaluation of the overall condition and sizing of culverts within fish-bearing stream reaches.

METHODS AND MATERIALS

The methods for conducting the culvert inventory and fish passage evaluation were divided into seven tasks in the following order:

1. Location of culverts.
2. Initial site visits.
3. Data entry and passage analyses.
4. Site visits for migration observations during fall/winter migration flows.
5. Collection and interpretation of existing habitat information.
6. Prioritization of sites for corrective treatment.
7. Site-specific recommendations for unimpeded passage of both juvenile and adults salmonids.

Location of Culverts

Preliminary project scoping included examination of Humboldt County road system maps and counting culverted crossings on known coho-bearing streams. The National Marine Fisheries Service (NMFS) coho salmon stock questionnaire list was used to identify and locate coho streams on the Humboldt County road maps. NMFS's list of current and historic coho streams was based heavily on a compilation of field and survey reports produced by Brown and Moyle (1989). Seventy-four county culverts were initially identified on coho-bearing reaches of streams, primarily within four major watersheds: Humboldt Bay, Mad River, Eel River, and the Mattole River. The remaining culverts were located on smaller coastal streams that drain directly into the Pacific ocean.

Because the use of maps was considered a rough, first-cut at locating potential culvert locations, additional sites were also investigated once the project started. Most of these sites were identified by fisheries biologists, restoration groups, or watershed groups with intimate knowledge regarding their local streams.

Initial Site Visits

The objective of the initial site visits was to collect physical measurements at each crossing to utilize with the fish passage evaluation computer software (Fish Xing). Notes describing the type and condition of each culvert, as well as qualitative comments describing the stream habitat immediately above and below each culvert were also included. Photographs of the outlet and inlet were taken at each site.

Culvert Location

The location of each culvert was described by: Humboldt County road system map # ; road name; stream name; watershed name; Township, Range, and Section; latitude and longitude; and mile marker or distance to nearest cross-road. If more than one county road culvert crossed single stream, a number was assigned to the stream name with the #1 culvert located farthest downstream (numbering then proceeded in an upstream direction). Lat/long coordinates were determined using Terrain Navigator (Version 3.01 by MapTech), a geo-referenced mapping software program.

Longitudinal Survey

A longitudinal survey was shot at each culvert to provide accurate elevation data for computer analyses. We utilized an auto-level (Topcon AT-G7) with an accuracy of ± 2.5 mm, a domed-head surveyor's tripod, and a 25' leveling rod in feet/10ths/100ths. All data and information were written into a bound, water-proof, field notebook with a pencil. On a weekly basis, the field notebook was photocopied to provide a back-up in case of loss or destruction of the notebook.

Once a site was located in the field by the two-person survey crew, bright orange safety cones with signs marked "Survey Party" were placed to warn oncoming traffic from both directions. Bright orange vests were also worn by the survey crew. Vests increased one's visibility to traffic, and decreased suspicions of nearby property owners to our unannounced presence in the roadside stream channel.

To start the survey, a 300-foot tape (in feet and 10ths) was placed down the approximate center of the stream channel. The tape was started on the upstream side of the culvert, usually in the riffle crest of the first pool or run habitat unit above the culvert. This pool or run would be considered the first available resting habitat for fish negotiating the culvert. The tape was set to reflect any major changes in channel direction. The tape was set through the culvert and continued downstream to at least the riffle crest (or control) of the pool immediately downstream of the culvert outlet. If several "stair-stepped" pools led up to the culvert inlet, then the tape was set to the riffle crest of the lower-most pool. Extreme caution was used when wading through culverts. A hardhat and flashlight were standard items used during the surveys.

The tripod with the mounted auto-level were set in a location to eliminate or minimize the number of turning points required to complete the survey. If possible, a location on the road surface was optimal, allowing a complete survey to be shot from one location. The leveling rod was placed at the thalweg at various stations along the center tape, generally capturing visually noticeable breaks in slope along the stream channel. At minimum, four vital elevations were measured: the culvert inlet, culvert outlet, maximum pool depth within five feet of the outlet, and the outlet pool control. If a culvert had apparent breaks in slope within the crossing, these were surveyed as well. Each surveyed point was entered with a station location (distance along tape) to the nearest 1/10 of a foot. If the channel slope was steep above the culvert inlet, an elevation was measured at the riffle crest of the upstream holding habitat.

Active channel widths (approximate base winter flow) were measured above and below the culvert, away from any apparent influence the crossing had on channel geometry. A cross-section survey of at least the bankfull channel width at the outlet pool control is recommended for some of the Fish X-ing analyses. In other instances the elevation of the active channel margin was taken. The active channel margin (or ordinary high-water mark) is often distinguished by changes substrate size, moss line on rocks, and/or margin of annual vegetation.

Fill Estimate

At each culvert, the amount of fill was estimated by calculating the volume of the fill prism between the road surface and the culvert (Figure 1) (from Flannigan et al 1997). The purpose of estimating fill volume was to assist in development of cost estimates for barrier removal by estimating equipment time required for fill removal and disposal site space needed.

The fill prism was calculated from the following measurements:

1. Upstream and downstream fill slope measurements (L_d and L_u).
2. Slope (%) of upstream and downstream fill slopes.
3. Width of road prism (W_r).
4. Length of road prism (W_u).
5. Channel width (flood prone width) (W_c).

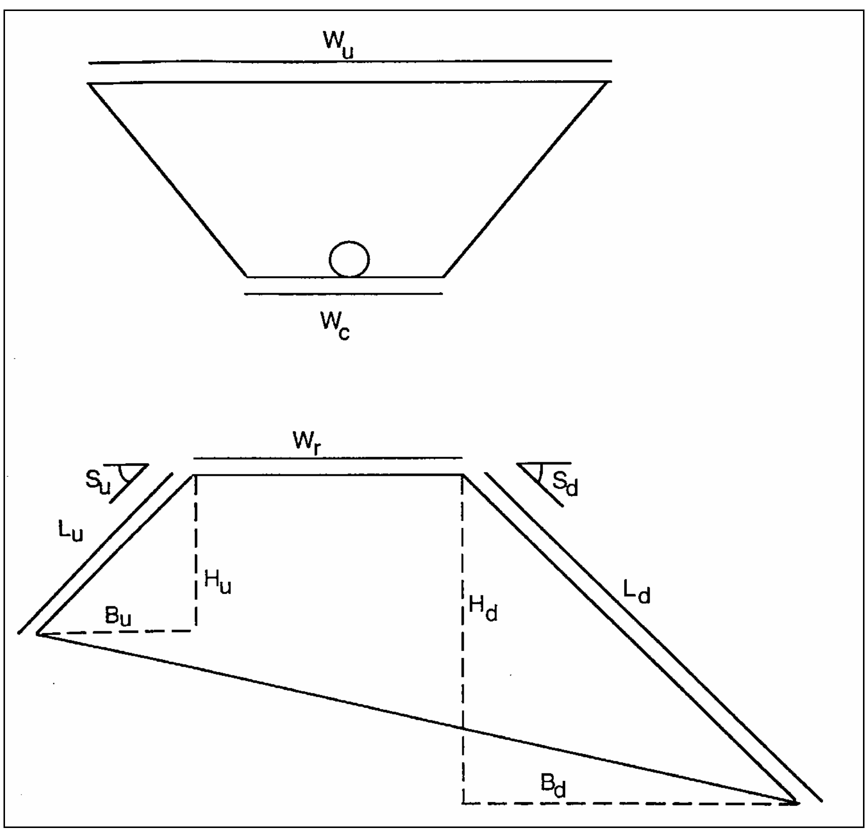

Figure 1. Fill measurements – solid lines were measured values, dashed lines were calculated.

Other Site-specific Measurements

For each site, the following culvert specifications were collected:
1. Length (to nearest 1/10 of foot);
2. Dimensions: diameter (circular), or height and width (box culverts), or span and rise (pipe arches);
3. Type: corrugated metal pipe (CSP), structural steel plate (SSP), concrete pipe, concrete box, bottomless pipe arch, squashed pipe-arch, or a composite of materials;
4. Overall condition of the pipe;
5. Height and width of the rust line (if present);
6. Position relative to flow and stream gradient;
7. Depth of jump pool below culvert;
8. Height of jump required to enter culvert;
9. Previous modifications (if any) to improve fish passage; and
10. Condition of previous modifications.

Qualitative notes describing stream habitat immediately upstream and downstream of each culvert were taken. Where feasible, at least five measurements of the active channel width were taken above and below the culvert (visually beyond any influence the crossing may have on channel width). Active channel was defined as the portion of channel commonly wetted during winter base flows and was identified by a break in rooted vegetation or moss growth on rocks along stream margins. Recent culvert design guidelines utilize active channel widths in determining the appropriate widths of new culvert installations (Robison et al 1999; Bates et al. 1999).

Data Entry and Passage Analyses

All survey and site visit data were written into a bound, waterproof, field notebook. Then data for each culvert were entered into a spreadsheet (Excel 97). A macro was created to calculate thalweg elevations of the longitudinal profile and compute culvert slopes.

Fish Xing Overview

Fish Xing is a computer software program developed by Six Rivers National Forest's Watershed Interactions Team - a group of scientists with diverse backgrounds in engineering, hydrology, geomorphology, geology and fisheries biology. Mike Furniss, a Forest Service hydrologist for Six Rivers, managed program development. Test versions of Fish Xing were used during the Humboldt County culvert inventory, which provided an excellent testing ground for evaluating fish passage though a wide variety of culvert configurations, as well as catching glitches and bugs in the software. A final version of Fish Xing was available in March, 2000. In-depth information regarding Fish Xing (or a copy) may be obtained at the Fish Crossing homepage on the internet (www.stream.fs.fed.us/fishxing/).

Fish Xing analyzes fish passage through culverts by using site-specific data that is entered by the user. The user also provides site-specific hydrologic information and range of expected migration flows. Jumping and swimming speeds for a multitude of fish species were programmed into the software. For salmonids, data were provided for both juveniles and adults. These values were obtained through extensive literature reviews and the software is amenable to updates. Fish Xing runs the range of flows "through" the culvert and compares estimated depths and velocities to the abilities of the fish species and lifestage of interest and predicts if and when a culvert is a barrier. Fish Xing also defines what is causing the barrier, such as: lack of depth in culvert, excessive velocities, too high of entry jump, lack of depth in outlet pool.

The elevation data, along with culvert specifications were used in the Fish Xing software program to evaluate passage for all species and lifestages of salmonids known to currently or historically reside in the streams of interest.

Hydrology and Design Flow

In order to estimate the range of expected migration flows (a Fish Xing input) and to determine the sizing (flow conveyance) of existing culverts, information was needed on stream hydrology above each culvert location. Since all culverts were located on small ungauged streams, site-specific hydrology was estimated using methods described by Waananen and Crippen (1977). This method estimates the recurrence interval of storm flows using data collected on basin drainage area, regional rainfall estimates, and basin elevation. Drainage areas above culverts were calculated using Terrain Navigator (Version 3.01 by MapTech).

Because salmonids do not migrate upstream on all storm flows, it was not necessary to evaluate passage at flood stage or greater flows. The upper range of expected migration flows through a culvert were calculated as the 10% exceedence flow ($Q_{10\%}$), that is a culvert must be passable to fish during 90% of the passage season for the target fish species. This standard is utilized by current fish passage methodologies in Oregon and Washington (Robison et al. 1999; Bates et al. 1999). For cases where the 2-year storm flow (Q_2) was estimated as greater than 44 cubic feet per second (cfs), the following equation was used to approximate the 10% exceedence flow:

$$Q_{10\%} = 0.18 \times Q_2 + 36$$

For cases where Q_2 was less than 44 cfs, the 10% exceedence flow was approximated as the Q_2 discharge.

Determining flow capacity of existing culverts is vital in identifying undersized culverts. These culverts are often fish barriers due to excessive velocities which are influenced by the constricting nature of small culvert dimensions (relative to channel dimensions). Undersized pipes also have a higher potential for catastrophic failure which may impact downstream habitat, other stream crossings, and personal property. Culvert sizing is thus a vital factor in the priority ranking of culvert locations. Pending NMFS culvert design guidelines for fish passage are recommending that culverts pass a 100-year storm flow at a depth less than 100% of the culvert's inlet height (to accommodate for passage of woody debris and bedload transport). Most Humboldt county culverts are older than 20 years and were probably designed for a 25 or 50-year storm with substantial ponding above the culvert inlet expected.

Site Visits for Fish Migration Observations

During late-fall and winter storms, some culverts were visited in order to observe salmonids attempting to migrate through culverts. These visits were limited to culverts with perched outlets because turbid conditions of most streams during winter migration flows allowed only observation of jump attempts.

The purpose of these visits was to:
1. confirm upstream migration of adult and/or juvenile salmonids;
2. record numbers of successful and failed attempts at specific culverts;
3. observe behavior of jump attempts;
4. identify locations with high levels of migration;
5. better understand the timing of fish migration as related to storm hydrographs; and
6. measure velocities through culverts and jump heights during migration flows.

The migration observation data was not intended for use in the priority ranking matrix for several reasons:
1. observations were made at a subset of culvert locations;
2. observations were conducted sporadically at various locations and flow levels; and
3. total observation time (in minutes) accounted for a small fraction of total migration period.

However, this information provided valuable insight of fish behavior at culverts and served as an important component of professional judgement in the final ranking of priority locations. The following is the protocol developed and used for conducting observations at perched culverts.

<u>Fish Observation Protocol at Perched Culverts:</u>

1. First, measure present water depth inside the culvert at a location where the flow is relatively uniform (such as inlet invert or a specific location within the culvert). Record the location where the depth was measured. Also, if you're at a site with a stage plate record stage level.

2. Observe for jump attempts at culvert outlet for 20 minutes. Station yourself so that the entire outlet area is in view. If using a video camera, position it on a tripod so that the entire outlet is in view (record during the entire observation period). Stay focused

on the outlet – jumps often occur quickly (best to have preliminary information entered and a tally table sketched in your field book prior to starting the first 20 minute observation period).

3. If no jump attempts are observed, remeasure the water depth (to determine if flow is rising, steady, or dropping), and then proceed to the next culvert location. Also record location, date, time, and weather conditions.

4. If jump attempts are observed within the first 20 minutes, stay for an additional 20 minute increment. If jump attempts are observed within the second 20 minute increment, stay for a third 20 minute period. Observe and record the following information outlined in steps 5-14. Also record location, date, time, and weather conditions.

5. Count jump attempts, tally as either "successful" or "failed" by juvenile and adult. For adults, note if they enter pipe, but are unable to swim through (see #7 below). Observe and note location of jump attempts.

6. When fish successfully enter the culvert, time how long they are in the pipe. Watch the outlet to see if fish is swept back. If there are two observers, one person should move to the upstream end of the culvert to watch for the fish exiting the culvert inlet.

7. For adult fish, if possible, identify to species. Often the jump (or swim-up) will occur too quickly. However, look for large, irregular-shaped spots on the back to ID chinook (also any fish greater than 20lbs is most likely a chinook). Coho will have small, round spots and may have a drab, olive-colored head and a red body. Steelhead will be more likely seen later in the spawning season (December – March); however look for distinctive red slash along sides and on gill plates. For adults, also break-out jacks (> 50 cm or 22") from larger fish. For adults, also estimate the condition of the fish (bright, dark, fungus on body, cuts or open wounds, "sore tails"). For juveniles, estimate size class as either 3"-5" or 5"-8" or > 8".

8. If possible, examine fish and determine if you can identify individual fish. If so, note time of each jump attempt, and the quality of the attempt (just rolled, ½ way to inlet, almost into inlet, etc.).

9. For failed attempts, what is the probable cause? Too high a jump (fish never enter outlet invert)? Confused outlet flow (baffles or low flow notches may create turbulence at outlet)? Too much velocity (fish enter pipe, but are swept out)? Are fish swept out immediately, or after a period of time (at Sullivan Gulch we noticed some adults would get in pipe, but could not swim to inlet and after several minutes were swept out).

10. A rough velocity estimate can be made by floating an object (stick, orange peel, fern frond, etc.) through culvert and timing with a stopwatch. Repeat at least three times and average all trials.

11. Always measure water depth at the start and end of all observation periods (to determine if flow is rising, steady, or dropping). This is especially important if you’re on a re-visit to a location where no jumps were initially observed. If a stage plate is present (at NMFS study sites), record the water level at time of arrival and when you leave.

12. Measure the height of the jump into the culvert from the water surface to the culvert outlet invert. Make this measurement as soon as you see jump attempts and remeasure at the time you leave the culvert site. Also measure depth(s) of jump pool from location(s) of observed jumps.

13. Also visually note the flow and turbidity of the tributary of the culvert site versus the main stream/river channel…….are there differences that may induce the juveniles to seek the tributary habitat?

14. Any sign of predation (avian or other) at jump pools below culverts? This can include observing birds, raccoons, or otters; but also look for and record any sign of fresh tracks or scat on the banks or adjacent riparian vegetation.

15. Sites with high numbers of failed juvenile attempts will be prime candidates for sampling with nets to determine species and numbers of juveniles. Although “high” is subjective, use your best professional judgement and make recommendations for sampling at areas you think are important.

16. Note and record any other observations of interest – are fish being injured at culvert or jumping to exhaustion and moving back downstream? For example, at Sullivan Gulch adult salmon were observed ramming directly into culvert edges and receiving visible gashes (some then swept out of jump pool). Several other adults have missed the culvert inlet and landed on the rip-rap; one dead chinook was found head-first in the mud to the right of the culvert outlet.

17. Note any signs of poaching at pools below culverts, record what you observe and contact Fish and Game Cal-Tip ASAP (1-888-334-2258).

18. Sample Tally Sheet to Sketch into field notebook:

ADULTS			JUVENILES		
Species	Success	Fail	Size Class	Success	Fail
Chinook			3”–5”		
Coho					
Steelhead			5”-8”		
Unknown			>8”		

Habitat Information

Because this project addressed fish passage in a multitude of watersheds, plan development was based both on prior assessment and evaluation and on conducting habitat assessment and evaluation as part of the proposed project. Habitat conditions upstream and downstream of culvert locations relied on previously conducted habitat typing or fisheries surveys. These surveys also provided information on past, present, and future land uses within watersheds that flow through culverts on the Humboldt County road system.

Communication with agency and private-sector biologists, watershed groups, coordinators, restorationists, and large landowners assisted in acquiring additional information on watershed assessment and evaluation. Habitat information was used from reports on file at CDFG offices in Eureka and Fortuna, as well as reports located at Humboldt State University library. The Mattole Salmon Group provided habitat information and assisted in ranking the biological importance of 17 Mattole River tributaries crossed by Humboldt County culverts (Peterson, per. comm.). Professional judgment from on-site inspection of culverts and stream habitat also aided habitat assessment and evaluation. In some cases, with landowner permission, longer reaches of stream were walked to better assess the quality of habitat above and below county culverts.

Length of potential salmonid habitat upstream of each county culvert was also estimated off of digitized USGS 7.5 Minute Series topographic maps (Terrain Navigator, Version 3.01 by MapTech). The upper limit of anadromous habitat was considered when the channel exceeded an eight degree slope.

When available, summer water temperature data collected with data loggers (such as a HOBO or Stowaway) were reviewed to determine which tributaries provided potential coolwater thermal refugia. During summer months the mainstems of the Eel and Mattole Rivers regularly exceed stressful limits of juvenile coho salmon, steelhead, and coastal cutthroat which are present year-round. For example, along the lower and upper Mattole River, Humboldt County roads run along the river valley intersecting all tributaries at their mouths, 17 of these crossings are culverts. If these culverts are barriers to juveniles at low flows, those with cool summer water temperature will rank higher than those with warmer temperature profiles.

Priority Ranking of Culverts for Treatment

Methods for priority ranking of culvert locations were developed after carefully reviewing criteria used in Oregon (Robinson et at. 1999) and Washington (SSHEAR 1998). The two protocols are fairly similar except for how stream habitat information was utilized. Robison et al. (1999) relied mostly on potential species diversity of the fishbearing channel above a culvert site and did not factor in a "score" for habitat quality.

The Oregon method segregated culverts into five priority types, based on:

- Degree of barrier – partial or complete.
- Risk of failure – flow capacity.
- Species diversity of upstream habitat (in descending order) – coho salmon and others, steelhead and cutthroat, any gamefish, non-fish-bearing but flows into fish-bearing reach.

Once a cursory ranking of culverts was completed, the Oregon method used the input of fisheries professionals with knowledge of the stream's biological significance. The Oregon method also acknowledged numerous social, economic, and technical aspects often influences the ultimate order of treatment locations (and options).

The Washington method used a complex equation which takes the quadratic root of numerous factors, including discrete values assigned to habitat parameters (both physically measured and visually estimated). The equation analyzed passage for each species and lifestage of salmonid which may be present and sums the results for a "score". Thus for each culvert a specific number (or rank) was generated. Initially, the method appears quite objective in nature, yet many of the habitat parameters assigned a discrete value were actually generated from subjective (unrepeatable) estimates. The method also attempted to quantify (and rank) gains in spawning and rearing habitat by assuming all pooltails and riffles are viable spawning habitat. The Washington method has merit, but seemed too complex for the task of determining a first-cut of high, medium, and low priority culvert locations.

The need for extensive habitat information collected in a consistent manner is also time consuming and expensive to generate. This information was not available for many northern California watersheds and conducting surveys was beyond the scope (and budget) of this project. The ranking objective was to arrange the sites in an order from high to low priority using a suite of site-specific information. However, the "scores" generated were not intended to be absolute in deciding the exact order of scheduling treatments. Once the first-cut ranking was completed, professional judgement played an important part in deciding the order of treatment. As noted by Robinson et al. (1999), numerous social and economic factors influenced the exact order of treated sites.

Because Humboldt county intends on treating culvert sites identified as "high-priority" by submitting proposals to various fisheries restoration funding sources, additional opportunities for re-evaluating the biological merit of potential projects will occur through proposal review committees composed of biologists from CDFG and other agencies. The methods for ranking culvert locations is a developing process and will undoubtedly require refinement as additional information is obtained. This report also acknowledges (but makes no attempt to quantify or prioritize) that other potentially high-priority restoration projects exist throughout California, and these must all be considered when deciding where and how to best spend limited funds.

Priority Ranking Criteria

The method developed and utilized, assigned a score or value for the following parameters at each culvert location:

1. **Species diversity:** number of salmonid species known to occur (or historically occurred) within the stream reach at the culvert location. **Score:** Because of Federal listing status, coho and chinook salmon = 2 points each. Steelhead and coastal cutthroat trout = 1 point each.

2. **Extent of barrier:** for each species and lifestage known to occur, over the range of estimated migration flows, assign one of the following values. **Score:** 0 = 80-100% passable; 1 = 60-80% passable; 2 = 40-60% passable; 3 = 20-40% passable; 4 = less than 20% passable. For culverts not evaluated with Fish Xing, scores assigned by examining culvert slope, length, corrugation, height of entry jump, and depth of jump pool.

3. **Sizing (risk of failure):** for each culvert, assign one of the following values as related to flow capacity. **Score:** 1 = sized for at least a 50-year flow, low risk. 2 = sized for at least a 25-year flow, moderate risk. 3 = sized for less than a 25-year flow, high risk of failure.

4. **Current condition:** for each culvert, assign one of the following values. **Score:** 1 = good condition. 2 = fair, showing signs of wear. 3 = poor, floor rusting through, crushed by roadbase, etc. 4 = extremely poor, floor rotted-out, severely crushed, damaged inlets, collapsing wingwalls, slumping roadbase, etc.

5. **Habitat quantity:** above each culvert, length in feet to sustained 8% gradient. **Score:** Starting at a 1,000’ minimum; 1 point for each 5,000’ size class (**example**: 0 points for <1,000’; 1 point for 1,000’-5,000’; 2 points for 5,000-10,000’; 3 points for 10,000-15,000’; and so on).

6. **Habitat quality:** for each stream, assign a “multiplier” of quality (relative to other streams in inventory) after reviewing available information. **Score: 1.0 = Good** (dense riparian zones, frequent pools, cool summer water temperatures, complex inchannel habitat, channel floodplain relatively intact). **0.5 = Fair** (riparian zone present but lack of conifers, infrequent pools, summer water temperatures periodically exceed stressful levels for salmonids, sparse inchannel complex habitat, floodplain intact or slightly modified). **0.25 = Poor** (riparian zones absent or severely degraded, little or no pool formations, stressful to lethal summer water

temperatures common, lack of inchannel habitat, floodplain severely modified with levees, riprap, etc.

7. **Total habitat score:** Multiply #5 by #6 for habitat "score". The following example is provided to show why a habitat quality "multiplier" influences ranking of quality over sheer quantity. Top example assigns habitat quality a number (poor-1; fair-2; good-3), and the total score is additive. The following example uses the multiplier and results in a closer total score between the two creeks (Table 2).

Table 2. Effect of "habitat quality multiplier" on "Total Score".

Stream Name	Habitat Quantity	Habitat Quality	Total Score
Reas Creek	22,000' = 5pts	Poor = 1 pt	6 points
Sullivan Gulch	<5,000' = 1 pt	Good = 3 pts	4 points
Reas Creek	5 points	0.25	1.25
Sullivan Gulch	1 point	1.0	1.00

For each culvert location, the above criteria were entered into a spreadsheet and total scores computed. Then the list was sorted twice to determine ranking. The first sort was by "Habitat Quality Multiplier" in a descending order. Then the sites with Habitat Quality values of 1.0 and 0.5 were sorted by total score.

Sites with poor habitat (Habitat Quality value of 0.25) were ranked separately, focusing mainly on condition and sizing of the existing culvert. These sites should not be considered candidates for treatment via restoration funding sources. However, this information will provide Humboldt County Public Works with a list of sites in need of future replacement with county road maintenance funds. When these replacements are implemented, this report should provide guidance on treatments with properly-sized crossings conducive to adequate flow conveyance and unimpeded fish passage.

RESULTS

Initial Site Visits

Initial site visits were conducted at a total of 104 stream crossings on roads in Humboldt county (Table 3). However, only 67 of 104 culverts were surveyed (designated by **X**) and included in the fish passage evaluation and prioritization. The reasons for excluding 38 sites in the evaluation varied and are listed in the right-hand column of Table 3. Most site visits and surveys were conducted during fall or spring low flows, which provided safer wading conditions in streams and through culverts. A table of the 67 culvert sites inventoried and their locational information is provided in Appendix A.

Site-specific characteristics and photographs are provided in a "Catalog of Humboldt County Culverts" (Appendix B). The following list is an overview of the culvert inventory:

1. A wide variety of culvert configurations and materials were discovered.

2. Many culverts were in poor condition (19 sites or 28%) and are due for replacement. Another 28 culverts (42%) were described as in "fair" condition, and starting to deteriorate.

3. Most culverts were undersized, (37 sites or 55%) sized for less than a 50-year storm flow. However, based on recently released NMFS guidelines (pass a 100-year flow at less than 100% of inlet height) nearly all culverts inventoried should be considered undersized.

Passage Analyses

Of the 67 culverts included in the inventory, 49 were evaluated for passage with Fish Xing. Due to limitations inherent with the software package, only certain types of culvert configurations were readily analyzed. The following circumstances prevented passage analyses with Fish Xing at 18 culvert locations:

1. Crossings with multiple pipes set at varying elevations and slopes.

2. Culverts modified with baffles – Fish Xing was unable to accurately model velocities in baffled situations.

Fish Xing proved a useful tool in identifying where passage problems occurred and probable causes. However, like most models which attempt to predict complex physical and biological processes with mathematics, there were limitations (and assumptions) that must be acknowledged. For example, the water velocities predicted through a culvert and compared to a fish species' swimming abilities were averages. Fish Xing assumes all fish swim against this "average velocity flow". In reality, within every culvert there are slow-velocity areas to the sides that fish often take advantage of. Extensive field observations have confirmed fish movement along the inner edge of culverts.

Conversely, a localized, high-velocity area can exist within a pipe and act as the limiting factor to fish passage, but is "masked" within the average values estimated by Fish Xing.

Table 3. List of stream-crossing locations visited in Humboldt county. ("X" denotes crossing was included in fish passage evaluation and prioritization).

BASIN NAME	STREAM NAME	ROAD NAME	COUNTY MAP #	STATUS OF 1ST SURVEY
COASTAL (north of MAD RIVER)				
	Luffenholtz Creek #1	Trinidad Scenic Drive	1C34	X
	Luffenholtz Creek #2	Westhaven Drive	1C34	X
	Strawberry Creek #1	Central Avenue	1C44	X
	Strawberry Creek #2	Dows Prairie Road	1C44	X
MAD RIVER				
	Warren Creek	West End Road	1C55	X
	Hall Creek	Glendale Road	1C55	X
	Hall Creek	Unnamed	1C55	Private Road
	Noisy Creek	Glendale Road	1C55	X
	Mill Creek	Unnamed	1C55	Private Road
	Lindsay Creek	Murray Road	1C45	X
	Mather Creek	Murray Road	1C45	X
	South Anker Creek #1	Fieldbrook Road	1C45	X
	South Anker Creek #2	Anker Road	1C45	X
	North Anker Creek	Fieldbrook Road	1C45	X
	Grassy Creek	Fieldbrook Road	1C45	X
	Widow White Creek #1	Murray Road	1C44	X
	Widow White Creek #2	McKinleyville Ave.	1C44	X
	Widow White Creek #3	Central Ave.	1C45	X
	Norton Creek	McKinleyville Ave.	1C45	X
	Mill Creek #1	Turner Road	1C45	X
	Mill Creek #2	Central Ave.	1C45	X
	Mill Creek #3	Bartows Road	1C45	X
	Mill Creek #4	Azalea Road	1C45	X
	Mill (Watek) Creek	Riverside Drive	2C51	X
	Sullivan Gulch	Riverside Drive	2C51	X
HUMBOLDT BAY				
	Bieth Creek	Old Arcata Highway	1D15	Arcata City Limit
	Washington Gulch	Old Arcata Highway	1D15	X
	Rocky Gulch	Old Arcata Highway	1D15	X
	Golf Course Creek	Jacoby Creek Road	1D15	X
	Morrison Gulch	Quarry Road	1D15	X
	Wood Creek	Myrtle Ave	1D15	No channel
	McCready Gulch	Kneeland Road	1D15	X
	Cloney Gulch	Kneeland Road	1D15	X
	Graham Gulch	PALCO Camp Road	1D15	X
	Eureka Slough	Old Arcata Highway	1D15	X
	Cochran Creek	Ole Hanson Road	1D15	X
	Ryan Creek	Mitchell Road	1D14	X

Table 3 (continued). List of stream-crossing locations visited in Humboldt county.

BASIN NAME	STREAM NAME	ROAD NAME	COUNTY MAP #	STATUS OF 1ST SURVEY
HUMBOLDT BAY	Martin Slough #1	HerrickRoad	1D14	**X**
	Martin Slough #2	Campton Road	1D14	**X**
	Shaw Gulch	Zane's Road	1D24	Private road
	Shaw Gulch	Zane's Road	1D24	Private road
EEL RIVER	Salt River	Coffee Creek Road	1D33	No channel
	Reas Creek #1	Port Kenyon road	1D33	**X**
	Reas Creek	Meridian Road	1D33	Bridged
	Reas Creek #2	Centerville Road	1D43	**X**
	Reas Creek #3	Deschger Road	1D43	**X**
	Russ Creek	Grizzly Bluff/Centerville Rd	1D34	**X**
	Francis Creek	Grizzly Bluff/Centerville Rd	1D34	**X**
	Francis Creek	Port Kenyon Road	1D33	**X**
	Francis Creek	Vanston Avenue	1D34	Ferndale city limit
	Francis Creek	Fern Avenue	1D34	Ferndale city limit
	Francis Creek	Shaw Avenue	1D34	Ferndale city limit
	Francis Creek	Fourth Street	1D34	Ferndale city limit
	Francis Creek	Ocean Avenue	1D34	Ferndale city limit
	Francis Creek	Francis Street	1D34	Ferndale city limit
	Francis Creek	Berding Street	1D34	Ferndale city limit
	Francis Creek	Van Ness Road	1D33	Ferndale city limit
	Francis Creek	Arlington Road	1D33	Ferndale city limit
	Barber Creek #1	Grizzly Bluff Road	1D44	**X**
	Barber Creek #2	Price Creek School Road	1D44	**X**
	Price Creek	Price Creek Road	1D44	Bridged
	Wolverton Gulch #1	River Bar Road	1D44	**X**
	Wolverton Gulch #2	River Bar Road	1D44	**X**
	Wolverton Gulch #3	Rohnerville Road	1D44	**X**
	Barber Creek (Van Duzen)	Fisher Road	1D45	Private Road
	Copper Creek	Fisher Road	1D45	Concrete Ditch
	Howe Creek	Howe Creek Road	1D54	Private
	Howe Creek	Howe Creek Road	1D54	Private
	Jordan Creek	Elinor Road	1D55	Bridged
	Jordan Creek	Jordan Road	1D55	Private Road
	Newman Creek	Vinnum Road	2E 11	Bridged
	Chadd Creek	Sorensen Road	2E 11	CALTRANS

Table 3 (continued). List of stream-crossing locations visited in Humboldt county.

BASIN NAME	STREAM NAME	ROAD NAME	COUNTY MAP #	STATUS OF 1ST SURVEY
	Chadd Creek	Holmes Flat Road	2E 11	Bridged
	Bull Creek	Tanbark Road	2E 21	State Park Road
	Jewett Creek	Jewett Road	2E	X
	Perington Creek	Harris Road	2E	X
	Frenchman Creek	Harris Road	2E	X
	Bear Canyon Creek	Wallen Road	2E 43	Too high gradient
COASTAL	McNutt Gulch	Mattole Road	1E	Bridged
	McNutt Gulch #1	Mattole Road	1E	X
	McNutt Gulch #2	Mattole Road	1E	X
	McNutt Gulch	Old Mattole Road	1E	Bridged
MATTOLE RIVER	Bear Creek	Lighthouse Road	1E	X
	Stansberry Creek	Lighthouse Road	1E	X
	Mill Creek	Lighthouse Road	1E	X
	Titus Creek	Lighthouse Road	1E	X
	Lower North Fork Mattole River	Mattole Road	1E 1	Bridged
	East Mill Creek #1	Conklin Creek Road	1E 1	X
	East Mill Creek #2	Chambers Road	1E 1	X
	Clear Creek	Mattole Road	1E 1	X
	Indian Creek	Mattole Road	1E	X
	Granny Creek	Mattole Road	1E	X
	Saunders Creek	Mattole Road	1E	X
	High Prairie Ck	Wilder Ridge Road	1E	X
	Painter Creek	Shelter Cove Road	1E	X
	East Anderson Creek	Whitethorn Road	1E	X
	Harris Creek	Whitethorn Road	1E	X
	Gibson Creek	Whitethorn Road	1E	X
	Stanley Creek	Whitethorn Road	1E	X
	Baker Creek	Whitethorn Road	1E	Bottomless Arch
TRINITY RIVER				
	Hostler Creek	Hostler Creek Road	2C34	Bridged
	Horse Linto Creek	Horse Linto Road	2C34	Bridged
	Scottish Creek	Pine Creek Road	2C34	Bridged
	Mill Creek		2C34	Bridged
	Supply Creek	Bair Road	2C34	Bridged

Field surveys to numerous culverts during migration flows revealed other confounding results generated by Fish Xing:

1. Adult salmon having great difficulties entering culverts which Fish Xing suggested were easily within the species' jumping capabilities.

2. Adult salmonids successfully moving through water depths considered "too shallow" for migration.

3. The behavior and abilities of fish are too varied and complex to be summed up with an equation or number taken from a published article. Even a single fishes' jumping and swimming abilities at a culvert may change as numerous attempts are made. We observed individual fish become fatigued over repetitive attempts, and conversely documented other fish gaining access to culverts after numerous failed attempts.

Due to these factors, passage evaluation results generated by Fish Xing were used conservatively in the priority ranking matrix by lumping "percent passable" into large (20%) categories. Most culverts, 51 of 67 (76%), inventoried were temporary or partial barriers to adults salmonids, especially coastal cutthroat trout because of their smaller body size and limited jumping and swimming capabilities. Fifteen of the 67 culverts were considered total barriers to all adult and juvenile salmonids.

By species, 43 of 57 sites within stream reaches presumed to support coho salmon were estimated to be adult barriers (not passable on >60% of estimated migration flows) which blocked migration to 49.7 miles of upstream habitat. For steelhead, 29 of 64 sites were estimated to be adult barriers (>60% of expected migration flows) which blocked migration to 33.5 miles of upstream habitat

Nearly all surveyed culverts were some form of barrier to juvenile salmonids. Forty of 67 (60%) culverts were total barriers to juveniles, and 22 more culverts (33%) were classified as temporary barriers. Only five culverts allowed for unimpeded juvenile upstream migration on the entire range of estimated migration flows. Their extremely small size renders juvenile salmonids most vulnerable to perched culverts or those with velocities during migration flows exceeding two to four feet per second. Passage evaluation scores are provided in the Culvert Ranking Matrix (Appendix C).

Fish Observations

Fish observations were conducted at 21 culverts during the winter of 1998-1999, for a total of 3,880 minutes (64.6 hours) (Table 4). Data sheets with species and lifestage-specific information are located in Appendix D.

Observations provided insight into salmonid migration, including:

1. Most upstream migration occurred during the falling limb of storm hydrographs.

2. Regardless of jumping abilities cited in literature, most perched culverts were migration problems for adult salmonids. Site-specific hydraulics at culvert outlets appeared to create confusing flow patterns to migrating salmonids.

3. When individual fish made repeated jump attempts, these often occurred at regular intervals spaced about five to 12 minutes apart and often occurred at the same location. Fish were rarely observed attempting leaps from a variety of locations at an outlet. However, fish often appeared to make tentative jumps or "surface rolls" prior to successfully leaping into a culvert.

4. At Sullivan Gulch and Morrison Gulch, extremely high levels of fish activity occurred and these culverts are detrimental to salmonids. Prior to this project, four seasons of observations made at Sullivan Gulch documented extensive predation of juvenile salmonids by kingfishers, mergansers, and blue herons. During the peak of adult coho migration at Morrison Gulch (1/16-20/99) an otter was observed at the culvert on the 20^{th}. After the otter's appearance, no adult fish were observed, even though adequate migration flow conditions persisted for another week.

5. Avian predators may key-in on culverts with concentrations of juveniles in outlet pools. During a February 1999 trip to the Mattole River, kingfishers were observed when we arrived at the only two sites we observed juvenile steelhead (out of 14 sites visited) making unsuccessful jump attempts.

6. Although most literature on fall, upstream movement of juvenile salmonids concerned only coho salmon, we observed (and sampled with a dipnet) upstream movement of three year-classes of juvenile steelhead (young-of-year, 1+, and 2+) at numerous culverts. At Sullivan Gulch, juveniles jumping at the inlet were sampled twice with dipnets. A total of 21 fish were caught, 19 young-of-year and 1+ steelhead (from 68 to 140 mm in length) and two young-of-year coho (75 and 78 mm).

Fish observations assisted in final ranking of priority culvert locations. Sites such as Sullivan Gulch and Morrison Gulch were given top-priority rankings because of the level of migration activity (and avian predation) observed over five seasons. Conversely, sites such as Grassy Creek were lowered after the initial ranking because of the lack of migration activity observed over four winters of site visits.

Table 4. Observations of salmonid migration from 21 culverts on the Humboldt County road system, November 1998 – February 1999.

Stream Name	Total Obs. (minutes)	Adult Successful Attempts	Adult Failed Attempts	Juvenile Successful Attempts	Juvenile Failed Attempts
Sullivan Gulch	680	1	18	5	530
Morrison Gulch	1000	1	493	65	0
Ryan Creek Tributary	360	0	0	3	20
Graham Gulch	220	0	0	0	2
Cloney Gulch	300	2	1	0	11
Grassy Creek	260	0	0	0	16
South Fork Anker Ck #1	160	0	0	0	0
North Fork Anker Creek	140	0	0	0	0
Lindsay Creek	140	0	0	0	0
Mather Creek	80	0	0	0	0
Warren Creek	100	0	0	0	27
McNutt Gulch #1	40	0	0	0	0
McNutt Gulch #2	40	0	0	0	0
Stansberry Creek	40	0	0	0	0
Mill Creek	40	0	0	0	0
East Mill Creek #1	40	0	0	0	0
Clear Creek	40	0	0	0	0
Indian Creek	60	0	0	0	15
Saunders Creek	60	0	0	0	12
High Prairie Creek	40	0	0	0	0
Painter Creek	40	0	0	0	0

Priority Ranking Matrix

The 67 Humboldt County culvert locations first sorted by "Habitat Quality Multiplier" and then sites with habitat quality of 1.0 and 0.5 were ranked by "Total Score" (Appendix C). Sites with poor habitat (habitat quality value of 0.25), were ranked separately by examining "Condition" and "Sizing" scores (Appendix C).

The final priority list of the Humboldt County culverts located on streams with Habitat Quality scores of 1.0 or 0.5, reflects changes made due to professional judgement calls (Table 5).

Table 5. Final priority ranking matrix of top 45 culvert locations on the Humboldt County road system.

Final Rank	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
1	Morrison Gulch	Quarry Road	4	Very high level of fish activity – juveniles, adult coho, steelhead and cutthroat. Important Jacoby Creek tributary for spawning. Have observed avian predation on juveniles and otters at culvert when adult coho were present.
2	Sullivan Gulch	Riverside Drive	32	For five seasons, highest level of juvenile activity observed (and heavy avian predation). Adults appear to have more problems than Fish Xing indicates. Best tributary habitat for salmon within North Fork Mad River watershed (50 $mi.^2$).
3	Lindsay Creek	Murray Road	6	Storm damage in 11/98 worsened passage problems after survey was done. One of six county culverts in a major coho sub-basin of the Mad River watershed. Lindsay Creek watershed group should evaluate passage of private culverts off of Railroad Grade.
4	Ryan Creek tributary	Mitchell Road	2	Not only a fish barrier, undersized, falling apart, and a road hazard to traffic – must replace. Several miles of upstream habitat. 1+ and 2+ juveniles observed at outlet.
5	Stansberry Creek	Lighthouse Road	16	Prior to 1997, there was passage until large storm washed out jump pools. Should restore passage before last year-class of adult steelhead returns. Potential coolwater refugia.
6	North Fork Anker Creek	Fieldbrook Road	3	Undersized, in terrible condition, and floods road. No fish observed at culvert during migration flows. Part of Lindsay Creek network, known coho-bearing tributary.
7	Clear Creek	Mattole Road	19	Total barrier with highest measured velocities (25 ft/sec) during winter migration flows. Good habitat with potential coolwater refugia for over-summering juveniles. Past records suggest culvert has slumped and > slope. A 1983 survey confirmed coho and steelhead above site. No recent sittings above culvert.
8	South Fork Anker Creek #1	Fieldbrook Road	9	Poor condition, a barrier to most fish. Treating all county culverts in Lindsay Creek should be a priority because of the potential coho production. Must address treatment of South Fork Anker #2 simultaneously.
9	South Fork Anker Creek #2	Fieldbrook Road	1	Poor condition, extremely undersized (floods road), a total barrier to adult and juvenile fish. Treating all county culverts in Lindsay Creek should be a priority because of the potential coho production.

Table 5 (continued).

Final Rank	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
10	Painter Creek	Shelter Cove Road	30	Perched outlet is total barrier to juveniles and probably to coho adults. Only steelhead observed upstream of culvert. Potential coolwater refugia. Relatively inexpensive treatment to raise outlet pool elevation with two sets of weirs.
11	Mather Creek	Murray Road	14	Riprap drop at outlet creates velocity chute that Fish Xing couldn't model. Also in poor condition and extremely undersized. Lots of cutthroat observed below culvert, coho too.
12	Cloney Gulch	Kneeland Road	10	Used by all four salmonid species. Observations and video footage suggest jump at outlet is more difficult than Fish Xing indicates. Good habitat upstream. Relatively inexpensive treatment costs.
13	Indian Creek	Mattole Road	31	Raised in priority because of relatively inexpensive treatment to fix velocity and depth barriers. Site of kingfisher predation on migrating juveniles.
14	Stanley Creek	Whitethorn Road	33	Raised in priority because of extremely poor condition and potential habitat gain in upper Mattole River watershed.
15	Bear Creek	Lighthouse Road	24	Extremely undersized and in poor condition, floods road regularly. Potential coolwater refugia if reconnected to South Slough, requires landowner access to re-connect.
16	Saunders Creek	Mattole Road	26	Raised in priority because of relatively inexpensive treatment to fix velocity and depth barriers. Site of kingfisher predation on migrating juveniles.
17	East Mill Creek #1	Conklin Creek Road	18	Steep gradient and damaged inlet probably creates worse barrier than Fish Xing indicates, also undersized and in poor condition.
18	Gibson Creek	Whitethorn Road	23	Nearly a complete barrier to adult coho, also undersized and in extremely poor condition.
19	East Anderson Creek	Whitethorn Road	25	Nearly a complete barrier to adult coho, also undersized and in extremely poor condition.
20	Mill Creek	Lighthouse Road	20	If feasible to raise elevation of downstream weirs is a relatively inexpensive to treat existing culvert. Best tributary habitat in lower Mattole River, with potential coolwater refugia for juveniles. Site requires additional consideration for bridge as the best long-term solution for unimpeded access to high-quality habitat.
21	Noisy Creek	Glendale Road	46	Raised in priority because of repeated flooding that occurs at this extremely undersized culvert. Potential road hazard that should be addressed by County. Coho still present in watershed.
22	Rocky Gulch	Old Arcata Road	7	Extremely undersized, historically a good coho, steelhead and cutthroat stream. Floods road to north of culvert on a regular basis. Dropped in priority due to decline in habitat condition from past and current landuse practices. Passage at Highway 101 (tidegates) needs evaluation. Potential of flood damage to downstream landowner is a concern when evaluating treatment options.
23	McNutt Gulch #1	Mattole Road	34	Because of large road prism, requires modification of existing culvert to cost-effectively treat. Severe rusting of floor prevents low flow from reaching outlet – could strand or kill outmigrating juveniles.

Table 5 (continued).

Final Rank	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
24	Warren Creek	Warren Creek Road	5	Dropped in priority because existing weirs and baffles made passage evaluation difficult. Replacement would be expensive, but best long-term solution. Baffles have caught debris and further reduce capacity of an already extremely undersized culvert. Jump pool weirs have failed from storm damage and are an observed barrier to juveniles.
25	Mill Creek #4	Azalea Road	22	Dropped slightly because only resident trout are present. However, is a total barrier in middle of long reach of suitable habitat. Also is extremely undersized and floods road. Possible candidate for treatment with urban stream grant sources.
26	Strawberry Creek #2	Dows Prairie Road	8	Dropped in priority because located above two other potential barriers. However, extremely undersized with poor alignment with stream channel. Also located in middle of long stream reach of resident trout habitat.
27	Grassy Creek	Fieldbrook Road	17	Dropped in priority because treated with weirs prior to priority ranking. Minimal fish activity at culvert over four seasons of observations.
28	Luffenholtz Creek #2	Westhaven Drive	27	A barrier to resident rainbow and cutthroat trout located in middle of long fish-bearing stream reach. Treatment with baffles, weirs, and outlet beam relatively inexpensive.
29	Graham Gulch	Palco Camp Road	13	Dropped in priority because of large expense required for treatment. Culvert is adequately-sized, but it's perched location at mouth of creek prevents treatment with weirs to raise pool elevation. Potential for future degradation of marginal (and declining) habitat quality.
30	Widow White Creek #1	Murray Road	12	Dropped in priority because of potential passage problem under Highway 101. Recent migration of lower Mad River may soon disconnect creek from access to ocean. Relatively cheap treatment to further raise outlet pool elevation.
31	Widow White Creek #2	McKinleyville Avenue	28	Needs an increase in outlet pool elevation to reduce entry jump. Should treat site at Murray Road first. For any Widow White passage projects, possible funding source could be grants focused at urban stream issues.
32	Strawberry Creek #1	Central Avenue	15	Dropped in priority because of probable passage problem under Highway 101 (about 500' downstream). Culvert is undersized, but would be expensive to replace. Large fill prism allows for ponding of flood flows.
33	Luffenholtz Creek #1	Trinidad Scenic Drive	21	Dropped in priority because of steep set of natural falls below culvert (just above beach) inhibits access to culvert outlet. Current culvert is adequately-sized, yet extremely perched.
34	McNutt Gulch #2	Mattole Road	29	Has steep break-in-slope near inlet that probably increases degree of passage problem. However, steep falls below culvert may prevent adults from reaching culvert outlet. Evidence of unfenced grazing along channel above culvert.
35	McCready Gulch	Kneeland Road	35	Box culvert at grade allows for low-flow passage. Degree of juvenile barrier probably overestimated by Fish Xing. Potential passage problem is perched concrete box culvert on private road immediately upstream.

Final Rank	Stream Name	Road Name	Initial Rank	Comments to Final Ranking
36	East Mill Creek #2	Chambers Road	36	Is a bit undersized, but set at grade and allows for low flow passage. Crushed inlet may require attention by County Road's crew – bend back and provide riprap for wingwalls.
37	Norton Creek	McKinleyville Avenue	37	Is undersized, but allows for adult passage. Amount of upstream habitat probably overestimated. Current watershed impacts include grazing, residential development, and a golf course.
38	Baywood Golf Course Creek	Jacoby Creek Road	38	At grade, not an adult barrier. Degree of juvenile barrier probably overestimated by Fish Xing.
39	Widow White Creek #3	Central Avenue	39	Not an adult barrier and partial barrier to juveniles. Several downstream culverts require attention to improve passage to this point.
40	Harris Creek	Whitethorn Road	40	Not an adult barrier and adequately-sized. Pools formed in culvert floor probably increase % of juvenile passage estimated by Fish Xing.
41	Mill Creek #2	Central Avenue	41	Culvert set at grade, not a barrier. Located just upstream of natural barrier, set of 20' falls.
42	Frenchman Creek	Harris Road	42	Not a barrier to adult steelhead, but is located upstream of a natural barrier on Jewett Creek. Limited habitat upstream of culvert too.
43	Baker Creek	Whitethorn Road	43	Is not a barrier and is properly-sized. Short of a bridge, this is the BEST crossing we observed on Humboldt County road system.
44	Mill Creek #3	Bartows Road	44	Just replaced, not a barrier and properly-sized.
45	Mill Creek #1	Turner Road	11	Dropped because of natural barrier of 20' high falls 200' upstream. Concrete box culvert is undersized, but ample road prism allows for extensive ponding. Would be very expensive to replace, resulting in minimal gain in anadromous habitat.

Site-Specific Treatments and Scheduling

During the past year, several sources of restorations funds have been available for treating priority culverts – SB271 and more recently, $750,000 of federal money often referred to as "the President's money". In the spring of 1999, Humboldt County (with assistance from the Five-Counties Salmon Group and Ross Taylor and Associates) submitted proposals to SB271 to treat nine of the top ten sites on the priority list. Information and data generated from the culvert inventory were used to develop treatment options and estimated costs. These nine sites are scheduled for treatment during the summer of 2000 - pending timely development of contracts with CDFG and the processing of paperwork for necessary permits. Morrison Gulch is also scheduled for replacement during the summer of 2000 with other restoration funds and cost-shares from Humboldt County.

In December 1999, the next tier of priority culverts (numbers 11 through 20) were submitted by Humboldt County Public Works to the Humboldt County Board of Supervisors for consideration as projects worthwhile addressing with some or all of the $750,000 coming to Humboldt County in early 2000. Again, the priority ranking matrix and site-specific information collected during the culvert inventory assisted personnel from Humboldt County's engineering staff in developing treatment options and estimated costs.

Of the 20 top sites, tentative recommendations are for 17 replacements and three modifications to existing crossings. At three sites, the existing culverts are adequately sized, and fish passage can be improved by installing baffles and an outlet beam within the culverts and raising outlet pool elevations with weirs. Treatment costs for these modifications range from $7,000 to $30,000 per site. Replacement cost estimates ranged from a low of $60,000 up to approximately $200,000 per location.

For the first 20 culvert locations, site-specific treatments were made using the following guidelines. These general guidelines draw from design standards used in Oregon and Washington, and hopefully will be consistent with upcoming NMFS's guidelines. However, site-specific characteristics of the crossing location should always be carefully reviewed prior to selecting the type of crossing to install. These characteristics include local geology, slope of natural channel, channel confinement, and extent of channel incision likely from removal of a perched culvert. Bates et al. (1999) is recommended as an excellent reference to use when considering fish-friendly culvert installation options. Robinson et al. (1999) provides a comprehensive review of the advantages and disadvantages of the various treatment alternatives.

Order of Preferred Alternatives

1. Bridge
2. Open bottom arch culverts
3. Culvert set below stream grade (countersunk or embedded)
4. Culvert set at grade with baffles installed to allow low-flow passage and reduction of velocities during higher migration flows.
5. Culvert perched with outlet pool weirs and baffles throughout culvert. Entry jumps should never exceed 1.0 feet for adults or 0.5 feet for juveniles.

Design Criteria for Proper Sizing and Alignment

1. Pass a 100-year storm flow at less than 100% of the culvert's height. This allows for passage of woody debris during extremely high flows.
2. Culvert width sized at least equal to active channel width – base winter flow, about at line of vegetation growth. Should reduce constriction of flows at the inlet associated with fish migration. (NMFS may recommend sizing to a wider channel width).
3. Avoid projecting culvert inlets.
4. Align culvert with the general direction of channel – avoid sharp bends in channel at approach to inlet.
5. Avoid installing trash racks at culvert inlets.

The third tier of culvert locations requiring treatment to improve fish passage includes nine locations (#21 –32). The exact scheduling of these treatments is unknown at the time because:

1. Humboldt County Public Works has a daunting task of completing the scheduling, contracting and permitting required to treat the top 20 locations. The county should focus on completing these higher priority projects with properly designed and constructed treatments before addressing the third tier of sites.

2. Humboldt County is a participant in the Five-Counties Salmon Group, which plans to acquire treatment funds for passage problems in all five counties (Del Norte, Trinity, Siskiyou, Mendocino, and Humboldt). Thus, the third tier of Humboldt county culverts should be ranked/evaluated with respect to priority culverts located in the other four counties. Culvert inventories are currently underway in Del Norte and coastal Mendocino counties, and will be started in Trinity and Siskiyou counties in the late summer – early fall of 2000.

3. When addressing the third tier of culverts, the current biological condition and/or importance (such as quantity) of the streams starts to diminish. Thus, these sites may not rank well compared to other types of projects proposed to state and federal funding sources. However, other sources of funding, such as urban stream programs should be considered. Sites in poor condition and/or undersized should be eventually treated with County maintenance and repair funds.

The Humboldt County culverts # 33 and #34 are of very low priority to treat because of natural falls located immediately below each location that probably limit or prevent anadromous fish from reaching the culverts (Table 5). Both of these culverts are also properly-sized for flow conveyance.

The remaining sites (#35-45) located on streams with habitat quality multipliers of 1.0 and 0.5 do not warrant treatment. The right hand column of Table 5 explains the various reasons that these sites are adequate as currently configured.

Low-Priority Culvert Sites

Most of the sites with a 0.25 habitat quality multiplier are of lower priority for fish passage because of extremely poor habitat conditions that will probably persist into the foreseeable future. The three most common activities impacting these Humboldt County streams are timber harvesting, unfenced grazing, and residential development. These creeks generally exhibited some or all of the following characteristics:

1. Lack of pools and habitat complexity;
2. Denuded or non-existent riparian zones;
3. Extensive straightening, berming, and diking of channel;
4. High volumes of fine sediment; and
5. Warm summer water temperatures.

Limited fisheries restoration dollars should probably not be spent on improving fish passage in these streams, unless significant improvements occur. However, the County should carefully examine this list and determine which locations may be treated with existing maintenance funds. For example, Humboldt County has a general plan for improvements to Old Arcata Road within the next several years. Planners should examine the current condition and sizing of all culverts along Old Arcata Road and budget for replacement of all undersized and/or culverts in poor condition. Also, when low-priority culverts fail during winter storms, planners should examine the sizing of the failed structure and budget for properly-sized replacements. When applying for FEMA funds, Humboldt County Public Works should utilize this report to explain why the replacement should be a larger and higher-quality crossing (for both fisheries and future-flood benefits).

Table 6. Ranking of low-priority culvert locations on the Humboldt County road system.

Rank	Stream Name	Road Name	Comments
46	Titus Creek	Lighthouse Road	Extremely undersized and in poor condition. Floor is completely worn through. Road fill on upstream side has been scoured by high flows.
47	Mill (Watek) Creek	Riverside Drive	Extremely undersized and floods county road which has caused damaged to Simpson Timber's nursery on several recent storms. Culverts are in poor condition too.
48	Wolverton Gulch #1	River Bar Road	Extremely undersized and in poor condition. Although habitat is generally poor, there is several miles above habitat that steelhead still utilize. Should treat concurrently with Wolverton Gulch #2. Habitat improves above Higfhway 36.
49	Wolverton Gulch #2	River Bar Road	Extremely undersized and in poor condition. Although habitat is generally poor, there is several miles above habitat that steelhead still utilize. Alders growing at outlet have high potential to plug culvert (see photo in Appendix B). Should treat concurrently with Wolverton Gulch #1.
50	High Prairie Creek	Wilder Ridge Road	Undersized concrete box culvert that was modified for passage in the 1980's. Baffles appear ineffective and damaged. Outlet pool lacks depth for entry jump.
51	Reas Creek #3	Deschger Road	Extremely undersized culvert. Habitat is extremely poor from unfenced grazing and timber harvest.
52	Washington Gulch	Old Arcata Road	Moderately undersized and in fair condition, these side-by-side culverts are partial barriers. Chinook salmon recently seen spawning about 1/2 mile above culverts.
53	Hall Creek	Glendale Road	Moderately undersized and in fair condition. Over two miles of habitat upstream of culvert. Prior to replacement, investigate origin of excessive sediment load evident at culvert. Partial barrier may exist at private road culvert near Highway 299.
54	Granny Creek	Mattole Road	Extremely long (130') culvert with rusted out floor requires a lining with concrete and baffles to improve passage. Length and slope create nearly a total barrier.
55	Jewett Creek	Jewett Road	Perched culverts are a jump barrier at most flows for steelhead. However, limited length of poor-quality habitat upstream and a partial, natural barrier downstream lessen biological importance.
56	Barber Creek #1	Grizzly Bluff Road	Box culvert is a total barrier due to excessive jump (>6') over sill at culvert inlet. Would require a series of concrete weirs (built into culvert) to allow passage to poor habitat impacted by unfenced grazing and timber harvesting.
57	Barber Creek #2	Price Creek-School Road	Extremely undersized and in very poor condition. Has huge jam of live alders and woody debris at outlet (see photo in Appendix B). However, habitat is poor and Barber Creek #1 is a total barrier due to excessive entry jump.
58	Cochran Creek #1	Old Arcata Road	Undersized crossing where creek floods road. Poor channel alignment at outlet, creek takes 90 degree turn. Habitat is poor, creek is severely channelized. However, salmonids still occasionally observed. County should consider upgrade in Old Arcata Road general plan

Table 6 (continued).

59	Cochran Creek #2	Ole Hanson Road	Undersized concrete box culvert occasionally floods over road. Channel highly aggraded with fine sediment.
60	Martin Slough #1	Herrick Road	Undersized according to flow estimates, but at grade and a swimthrough for fish. Coho still seen it tributary upstream of Herrick Road. Overall, habitat is poor from past timber harvest and channelization. Recent residential development has impacted creek too.
61	Martin Slough #2	Campton Road	Undersized according to flow estimates, but at grade and a swimthrough for fish. Habitat is poor from past timber harvest and channelization. Recent residential development has impacted creek too.
62	Russ Creek	Centerville Road	Properly-sized box culvert would require baffles and outlet beam to improve passage, but habitat is very poor due to unfenced grazing and timber harvest. Creek has been channelized too.
63	Reas Creek #1	Port Kenyon Road	Undersized, but at grade so not a barrier during most migration flows. Road shows signs of flooding. Creek is channelized and even damned in summer for stock watering. Habitat described as “trainwreck” in field notes.
64	Reas Creek #2	Centerville Road	Large concrete box culvert would require baffles to improve low-flow passage, but habitat is very poor from unfenced grazing and timber harvest. Creek is channelized and even damned in summer for stock watering. Habitat described as “trainwreck” in field notes.
65	Francis Creek	Port Kenyon Road	Is an adequately-sized box culvert that is nearly full of fine sediment. Extremely poor habitat upstream, plus creek flows through numerous culverts and concrete ditches in downtown Ferndale.
66	Perington Creek	Harris Road	Very steep channel, questionable if currently used by steelhead. Also located above natural barrier on Jewett Creek
67	Wolverton Gulch #3	Rohnerville Road	Is a new crossing, set at grade, adequately-sized, and not a barrier to fish on most flows.

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