United States
Department of
Agriculture

Forest Service

**National
Technology and
Development
Program**

7700—Transportation Mgmt
November 2005

NATIONAL INVENTORY AND ASSESSMENT PROCEDURE—For Identifying Barriers to Aquatic Organism Passage at Road-Stream Crossings

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ACKNOWLEDGMENTS

This procedure is based on several other fish passage evaluation procedures including: Taylor and Love (2001), USDA Forest Service Region 10 (2001) and USDA Region 6. We have also incorporated ideas from the Washington Department of Fish and Wildlife's manuals on fish passage design and barrier assessment (Washington Department of Fish and Wildlife 2000). Those sources are not responsible for any errors or misinterpretations herein.

I. INTRODUCTION

This inventory procedure is designed to be a nationally applicable, consistent method of identifying crossings that impede passage of aquatic organisms in or along streams. It is a how-to manual for approaching answers to two questions raised in United States Department of Agriculture (USDA) Forest Service Roads Analysis, [1999, p. 67, AQ(10)]: "How and where does the road system restrict the migration and movement of aquatic organisms; what aquatic species are affected and to what extent?"

Full answers to these questions are essential to managing roads and planning for restoration. A transportation plan must consider and be designed to mitigate the road network's effects on aquatic ecosystems and their continuity. And planning for restoring watersheds and setting priorities cannot logically proceed without considering how fragmented the aquatic habitat is and how important it is relative to the suite of restoration needs of the whole watershed.

The inventory protocol is data-intensive because it is designed to produce enough information from a single site visit to answer the following questions:

- Are crossing conditions are adequate for specific species and life stages?
- What is the approximate cost of replacement?

The inventory does not yield all the information needed to determine which crossings should be prioritized for replacement. Generally, data on species presence and habitat quality are needed in addition to the physical data collected here. The inventory also does not yield enough information for design of a replacement structure. Depending on the site, the design process may require much more information, such as a full site survey and a geomorphic assessment.

The site assessment procedure begins with an evaluation of the degree to which a crossing resembles the adjacent stream form and function. Crossings that maintain stream functions are essentially invisible to the stream, and so are more likely to pass the resident species inhabiting the stream. The research that could confirm the hypothesis that crossings resembling the adjacent stream pass all resident aquatic and semi-aquatic species has not been done. Given that direct evidence is unavailable, and crossing assessment and restoration will proceed, it is reasonable to assume that species movement needs will be accommodated by crossings that do not disrupt the stream channel's form and function.

If a crossing does not resemble the adjacent stream channel, then regionally defined measurable criteria (hereafter referred to as regional screens) are used for preliminary assessment of passage for a particular species, life stage, or species group. For fish, a hydraulic model is available when the regional screen fails to determine whether a crossing provides adequate conditions for the analysis species. The model we use is FishXing, which compares crossing hydraulics to swimming and leaping capabilities of individual fish species and life stages. Regardless of whether the analysis

is completed using the screen or the model, the process results in a defining a crossing category for each of the analysis species (see section V.C. for category definitions). Consistent identification of crossing category for individual species will permit unambiguous data aggregation across regions and the nation.

Streams and roads that cross affect each other in important, potentially destructive ways. Until recently, these two networks have been managed relatively independently by different groups of resource specialists. The sometimes destructive results have led to the realization that managing streams and road must consider the needs and character of both, something best accomplished by interdisciplinary teamwork. As noted in Roads Analysis (USDA-FS 1999 p. 67), a successful approach to these problems must draw from fisheries and wildlife biology, hydraulics, engineering, geomorphology and hydrology. Ideally an interdisciplinary team of trained specialists will be used to collect the data and interpret it in ways that address management questions.

In most cases, fisheries issues usually prompt culvert inventories. But many other aquatic and semi-aquatic species also use stream crossings and are affected by even low volume roads: amphibians, reptiles, invertebrates and small mammals. Information on passage needs and capabilities for these groups is scarce, but some information can be found at www.wildlifecrossings.info.

Inventory and Assessment Procedure Overview

The following summarizes the barrier inventory-assessment process and highlights important recommendations.

Establish the watershed context

- Build and overlay maps of streams, roads, land ownership, analysis species distributions, aquatic habitat types, and habitat quality.
- Population and habitat information from field surveys is highly preferred because the assumptions used to estimate these variables from maps are often inaccurate.

Collaboratively establish criteria for regional screens

- Develop analysis species lists and criteria with the assistance of aquatic experts and in collaboration with a group of stakeholders including land management and regulatory agencies, as well as other interested parties (such as, tribes, Departments of Transportation).
- Document assumptions and rationale.

Conduct the field inventory

- Include crossings on all land ownerships if possible; otherwise, conduct the analysis recognizing the gaps in knowledge.
- Collect the entire suite of variables on all crossings to permit later reevaluation if needed
- Use interdisciplinary teams to collect and interpret the data

Determine barrier category: natural channel resemblance or species-specific crossing category	• Use regional screens for rapid field assessment of natural channel simulation and barrier category. • Use hydraulic analysis where screens fail to determine barrier category. • Understand the limitations of the analytic procedure, such as: o For many species, movement capabilities and needs are unknown. o Estimates of culvert velocity are based on imprecise roughness values and may not accurately reflect the flow conditions faced by fish.
Map barrier locations and overlay on habitat-quality maps to set priorities for restoring connectivity	• Set priorities for replacements aimed at maximum biological benefit in conjunction with logistical considerations. • Collaborate with partners and other stakeholders to set priorities.

II. GEOGRAPHIC SCOPE AND SPECIFIC OBJECTIVES OF THE INVENTORY

A. Deciding where to conduct the inventory

Unless resources are available to cover an entire area of interest, (such as the whole forest), or funding is designated for a certain area, priorities must be set among areas to inventory. Ideally, watershed analyses are complete, and the road analyses are underway or complete. If so, answers to the following questions will already be available. If not, an interdisciplinary team should gather the background information needed to answer the questions. It is essential to think in terms of watersheds, rather than just about road systems, because the main issue is one of upstream-downstream continuity for the local biota.

1. Which watershed(s) should be surveyed first?

One of the functions of the barrier inventory is to identify the most biologically beneficial improvements. To meet this objective, we need a basic understanding of the needs of the biota and the condition of the aquatic ecosystem in the general area. We need to answer questions like: What spatial and temporal habitat needs are related to the life-history requirements of the species? What are the general conditions of the watershed's habitats as related to species requirements? Do road and topographic conditions in the watershed pose a risk to high quality habitats? For example, are there miles of infrequently maintained unclassified or legacy roads on steep lands, where crossing failures during floods could damage downstream habitat?

This information can then be used to identify watersheds that are high priority for barrier inventories. Some examples of watershed characteristics that may lead to high priority for inventory are:

- Watersheds that are important refugia for certain species or aquatic communities
- Watersheds that create a connected block of habitats needed to support the life history requirements of species in the general area
- Watersheds with critical or essential habitat for one or more threatened or endangered aquatic species or have species with economic or cultural value.
- Watersheds with high native biological diversity
- Watersheds with known barriers excluding species from critical habitats
- Watersheds with habitat quality problems that could result in greater species effects if barriers exist (such as, high temperature, low dissolved oxygen, or low food productivity)
- Watersheds where barriers may be desired to exclude invasive exotic species.

Other logistical or practical considerations may also focus an effort on a particular watershed. For example, existing major road maintenance or reconstruction needs, and existing or potential partnerships with other landowners could also be criteria for selecting a watershed for inventory.

2. Will crossings on all ownerships be inventoried? How will jurisdictional boundaries be handled? Are there any potential partners?

Building a general picture of the watershed before planning the inventory is essential for many reasons. An extensive coordination effort may be needed to inventory crossings in an area with multiple jurisdictions. Generally, one agency or entity spearheads the effort, with various amounts of commitment from other landowners. Additional opportunities may be found for leveraging funding from various sources when several landowners are cooperating to assess barriers.

If cooperation cannot be secured, landowners may agree to inventory only crossings on their own land or under their own jurisdiction. Information on habitat quality and quantity—and on upstream and downstream barriers—would still be needed for areas in the watershed under other ownership or jurisdiction. Without that information, the importance of removing barriers on any one jurisdiction may be hard or impossible to determine.

B. Deciding on inventory objectives

This inventory and assessment procedure supports one core objective and three additional objectives.

The **core objective** is to determine the crossing category for each analysis species.

The protocol includes two methods for achieving this objective. One method uses species and lifestage specific criteria in a flow chart (see section V.A. Regional Passage Screen); the other uses the hydraulic model FishXing (See section V.B. Hydraulic Analysis). Headings in bold on the inventory data sheets indicate the data are related to the core objective.

The **additional objectives** are to: 1) prioritize passage improvement projects, 2) develop replacement project budget cost estimates, and 3) field validate flows used to evaluate passage in FishXing. Headings in regular font indicate the data are related to the additional objectives, and optional.

There may also be other objectives for conducting the inventory. For example, a possible complementary objective is to assess crossings for risk of failure during floods, and their probable consequences on downstream areas. See #5 below for more information about this objective. The full set of objectives should be identified prior to going into the field in order to ensure the data needed to achieve those objectives are collected.

The field protocol described in this document will produce the information needed to accomplish the core objective and the additional three objectives listed above. To prioritize passage improvement projects, the inventory data will need to be combined with an understanding of up-and downstream habitat quantity and quality.

1. Is the objective simply to map sites that are barriers? Will you require additional information to help prioritize passage restoration projects?

The objectives for the inventory may be limited to defining the extent of the barrier problems in a watershed. More often, they will be broader, and include gathering information needed to prioritize crossings for treatment. While there are likely to be a wide variety of prioritization criteria developed by different administrative units, most will probably include information about the quantity and quality of the habitat that would be opened up when the site is improved. Both upstream and downstream movements can be impeded by crossing structures depending on the species (Warren and Pardew 1998), so it is important to understand the movement patterns of the analysis species (and life stages) to determine which movements need to be considered for prioritization. See section VI for more detail about how habitat information is used in the prioritization process.

2. For what species, life stages, or life stage groups will passage be evaluated?

Unless an ecological reason exists for excluding species, the ideal crossing is one that passes **all** aquatic and terrestrial species that require stream or streamside zones to move[8]. Although definitive data are lacking, we believe it is reasonable to assume that the aquatic and semi-aquatic organisms that normally move through an area will be able to pass through crossings that closely resemble the adjacent natural channel reaches. Such crossings generally do not require species-specific analyses. [See section V.A.2.a for criteria that can be used to determine if the crossing resembles the adjacent natural channel.] Most crossings, however, do not mimic the adjacent stream, and they require other methods of passage evaluation, including comparing conditions at the crossing to regionally developed species-specific criteria. For fish species with known swim performance, hydraulic assessments can be conducted.

Information about how to assess road crossings for passage by amphibians, reptiles, invertebrates, and small mammals is limited. These non-fish species groups may or may not be a focus of the inventory; where they are, passage determinations should be based on inferences from information about the basic capabilities and needs of the species, and professional judgments of experienced technical experts.

<u>The Analysis Species</u>—Passage determinations are based on criteria developed from swimming and leaping capabilities of individual species, life stages (size), or species groups with similar morphology or known swimming ability and behavior (hereafter collectively referred to as the analysis species). The procedure described in this document provides enough data to assess passage for many fish species in many situations. Your list of analysis species may be broader and include species other than fish, however. Because additional data might need to be collected for these non-fish species, we recommend identifying specific analysis species in the planning stages. These are the species, life stages, or species groups for which regional screens will need to be developed.

[8] Road construction and maintenance in streams is often permitted under the Corps of Engineers nationwide permit that includes the following General Condition [65 FR March 9, 2000, page, 112893; Section C.4 Aquatic Life Movements] "No activity may substantially disrupt the movement of those species of aquatic life indigenous to the waterbody including those species which normally migrate through the area É Culverts placed in streams must be installed to maintain low flow conditions".

The following steps are recommended in choosing analysis species:

- Make a list of the species currently or historically present in the inventory area that require passage.
- Contact state and federal agencies to determine if any species have established passage requirements or recommendations.
- Review available information about the movement requirements of the species on the initial list.
- Determine which species, life stages, or species groups have the greatest movement limitations or are the species of concern in your inventory area. These species should serve as the analysis species for passage evaluations.
- Document the rationale for your choice(s) in the analysis species, lifestage, or species group comment section on the field form, page 7 (such as, the weakest swimming species, lifestage, or species group, an ESA-listed species, a culturally or economically important species, an indicator species).

3. Will all crossing types be evaluated?

Although most crossings in the United States are culverts, crossings also include fords, vented fords, and various types of bridges. Bridges are generally assumed to be passable by all aquatic and most if not all riparian-dependent species; but there may be instances where there are passage issues. Some examples include: a short bridge that constricts channel width and increases water velocity, or where rip-rap placed for scour protection results in rock cascades that inhibit or prevent passage. Some structures that look like bridges may in reality be a series of embedded box culverts.

Even though fords are low profile crossings, they can be and often are barriers to aquatic species. For example, they may be:

- Low-flow barriers because of insufficient water depth, if the ford is too wide at streambed elevation;
- Velocity barriers at moderate to high flows, if the floor of the ford lacks sufficient roughness;
- Jump barriers, if perches have developed in the channel as a geomorphic adjustment to the flow acceleration across the smooth surface.

Given the core objective, the inventory should include at least a qualitative evaluation of passage at fords. The FishXing software does not address low-water crossings, except for the culvert of a vented ford. True fords can be hydraulically modeled by using open-channel flow models, but usually low-water crossings will require field observations to determine with confidence whether aquatic species can pass at the relevant times of year. The field-form instructions indicate which measurements may pertain to fords and how they are taken.

4. What hydraulic assessment tool(s) will be used to evaluate crossings' barrier category?

FishXing is the preferred software for assessing fish passage at culverts because it not only models flow conditions over a range of flows throughout the length of the structure, but it also compares those flow conditions to the swimming and leaping abilities of fish species and life stages for which information is available. The results identify the type and location of migration barriers. FishXing is public domain software, well documented and able to handle many culvert situations (see section V. B. for FishXing limitations). This inventory protocol is designed to produce the data needed

to analyze passage using FishXing. If another hydraulic model will be used (such as HEC-RAS), additional input data are required.

5. What other issues besides aquatic animal passage will be addressed in conjunction with the passage inventory?

Several issues other than those related to aquatic species could be addressed in the crossing inventory, and they should be considered in setting improvement priorities. For instance:

- Flood conveyance capacity (to ensure that crossings are sized to handle the design flood);
- Crossing condition and maintenance needs; and
- Crossing failure risk and consequences of failure. An undersized culvert in a steep stream moving large amounts of woody debris might be ranked higher as a replacement priority because of its potential for plugging. It would rate even higher if it has a high fill, has a high risk of failing and could damage downstream aquatic habitat if it fails in a flood.
- Passage status for terrestrial wildlife that habitually use riparian areas for movement.

This procedure includes data needed for flood conveyance capacity and requires some observations of crossing condition and maintenance. Only some simple components of a failure risk and consequences assessment are included here. The reason is that a full assessment of failure risk and consequences must be based on an understanding of geomorphic processes throughout the watershed. In addition, the set of crossings where failure would cause serious consequences to downstream resources is likely to be different from (although it may substantially overlap) those that affect aquatic species passage. For these reasons, combining inventories would increase the amount of time and effort needed, which does not mean the two should not be coordinated when feasible and efficient. For background information on designing a failure risk and consequences assessment, see Flanagan and others (1998).

The habits of terrestrial animals should be considered when evaluating crossings. While salamanders swim or crawl in shallow-water margins and between rocks and logs, some terrestrial animals seem to prefer to keep their feet dry. The latter may prefer to climb up and over the fill, even if they can walk through a culvert. This may be fine on a low volume road, but undesirable on high traffic roads, where jersey barriers are placed at the road edge, or where the fill is very high.

III. FIELD WORK PREPARATION

A. Locating the crossings to be inventoried

After the objectives, scope, and analysis species are defined, the next step is to locate the set of crossings to assess in the inventory area. You might include all crossings in the area, but more likely it will be a subset based on your objectives and the resources available.

To identify the subset of crossings that affect the analysis species, overlay maps of their distributions on a **reliable** map of road-stream intersections. Geographical information systems (GIS) can be used to locate these intersections, but **only** if the road and stream layers are sufficiently reliable. Users are cautioned to have a clear understanding of the accuracy of any GIS layers they use. Check the GIS road layer against aerial photos, digital ortho-photographs, or satellite imagery to determine if some roads were missed or were not correctly located.

Species distribution information may be available from several sources, such as State and Federal agencies, Tribal governments, commercial landowners or non-profit organizations. It should be remembered that surveys for species presence have not always included smaller streams. Species distribution maps may show a species is absent on small streams, but this is not necessarily true, and it is a good practice to check species presence up-stream during the crossing inventory. If no species presence information is available, then it may be possible to estimate distribution using criteria developed from areas which have been surveyed. For instance, many units in the Pacific Northwest have assumed that fish do not occur above stream gradients of 20 percent, and have not conducted passage inventories on crossings on steeper streams. If you do this, **be aware** that: 1) your assumptions about habitat preferences may be incorrect, and 2) the topographic or other data used to screen out some crossings may be inaccurate or low resolution. Experience in the Pacific Northwest shows that fish are often in areas where biologists did not expect to find them. Note also that not finding fish in one sampling event does not necessarily mean they do not use the habitat at some time during the year.

It will be difficult to prioritize crossing restoration or determine where to begin and end crossing surveys if species distribution information is not available. Wherever possible a species inventory should accompany a crossing inventory when species distribution information is unknown or cannot be reliably predicted.

A final concern in identifying the subset of crossings to be assessed is land ownership. As noted above, in areas of multiple land ownership, the owner or road maintenance agency should be identified for each crossing. Make sure each landowner has been contacted and ensure you have permission to access the crossings on the dates of the inventory.

B. Keeping track of the crossings

All National Forest system crossings should be identified by the INFRA control number if the crossing is already entered in INFRA. However, the inventory will usually include unclassified or unnumbered roads, and a naming or numbering scheme needs to be developed so that each crossing has a unique identifier. Because crossings missed on the maps are frequently found in the field, having a contingency plan for numbering these missed crossings is advisable. For example, all crossings might be numbered consecutively as they are inventoried. Labels identifying watershed or district or some other logical division so that the field forms can be easily sorted by watershed are also a good idea. A field map should be maintained with all the site locations and numbers.

IV. THE INVENTORY

A. Reviewing office information

Already completed broad-scale planning and assessment documents (watershed and road analyses, road-management plans) may include guidance for future management of the road or watershed to be inventoried. These should be identified and reviewed.

Page 7 of the inventory form includes information on the location of other crossings on the same stream, their barrier category, and the extent of blocked habitat upstream. These data provide context for future project planning. If any of this is unknown, you may want to gather this information during the crossing inventory to facilitate prioritization.

B. Collecting the necessary equipment

Use this list (modified from Taylor and Love, 2002) to be sure you have the equipment you need:

- Maps with site locations.
- GPS unit.
- Self-leveling level and tripod, acceptable instruments depend on the site characteristics (see discussion above).
- Tapes (two): 300 ft and 100 ft in 1/10 ft increments.
- Clamps (to secure tapes for longitudinal profiles and cross-section surveys).
- Leveling rod: 25 ft in 1/100 ft increments.
- Pocket leveling rod (to measure breaks-in-slopes within smaller diameter culverts).
- Camera, film, and extra batteries.
- Compass.
- Waders, hip boots, and wading shoes (felt-soled).
- Safety vests if working on road with traffic.
- Hardhat.
- Flashlight or headlamp.
- First-aid kit.

Optional Equipment:

- Brush-clearing tools.
- Traffic cones.

C. Training the field crew

Crews must consist of at least two people, although three would be ideal. Higher production rates are obtained with a three-person crew, but more importantly, there is a third person to help explore the details of the site and bring additional skills to the team. Expect to spend one to two hours surveying each crossing, depending on the difficulty of the survey and the experience of the crew. Productivity will depend largely on travel time.

Since this inventory procedure brings several very different scientific fields together for one task, there is a great opportunity to forge partnerships across disciplines working in the same administrative unit. Ideally, the

inventory team will be interdisciplinary and include crewmembers with fisheries, hydrology/geomorphology and engineering survey experience. Each of these disciplines brings important skills to the survey. Fisheries biologists can evaluate species habitat use, hydrologists or geomorphologists have expertise in river mechanics and stream behavior, and engineers are best qualified to accurately survey the terrain. Field crews can become familiar with the protocols by participating in a training session, and by conducting test runs at specific sites to compare results and discuss the methods. Results from several teams can then be used to test measurement repeatability.

A survey crew should be ready to begin the inventory after hands-on training by experienced personnel. Instruction should include techniques in surveying profiles and cross-sections using an instrument at least as accurate as a surveyor's self-leveling level. Training should also include how to determine what points to survey in order to accurately measure the topographic pontes essential to categorizing crossing status. Note that hand instruments such as hand levels, clinometers and abney hand levels do not possess the accuracy necessary for this survey. Use of a higher order of hand instrument such as a Rhodes Arc would also be questionable depending on site conditions. Acceptable instruments depend on site characteristics (such as, slope, site complexity, and need for turning points). The flatter the slope and the more complex the site, the more accuracy is needed.

D. Conducting field work

Fieldwork consists of visiting each crossing and collecting the physical measurements needed to assess passage. The protocol also includes notes, site sketches, and photographs describing the type and condition of each crossing structure and illustrating adjacent channel and habitat conditions. The inventory procedure is primarily designed to identify culverts that obstruct or delay movement of on or more species and life stages. Pertinent measurements and observations should also be taken for fords, unless the inventory objectives exclude them.

Data sheets and instructions for the crossing inventory are located in Appendix E. It is a good practice to regularly photocopy data sheets to provide back-ups, and to regularly enter data into electronic databases so that mistakes or missed data can be quickly noticed and corrected.

E. Ensuring safe procedures

A job hazard analysis (JHA) is required before the inventory begins (see example in Appendix D). Each crewmember should review the analysis during training and in weekly safety meetings.

Use proper safety equipment and carefully assess the specific characteristics of each crossing before conducting surveys. If the survey is being conducted on a road open to traffic, consider placing signs (such as "Survey Party") to announce your presence to oncoming traffic from both directions. Crewmembers should also wear bright orange vests to increase visibility. Two-way radios provide effective communication between crew members in spite of noise from road traffic and stream flow (Taylor and Love 2002).

Note: Field forms and instruction can be found in Appendix E.

V. PASSAGE ASSESSMENT

A. Developing the regional passage screen

1. Introduction

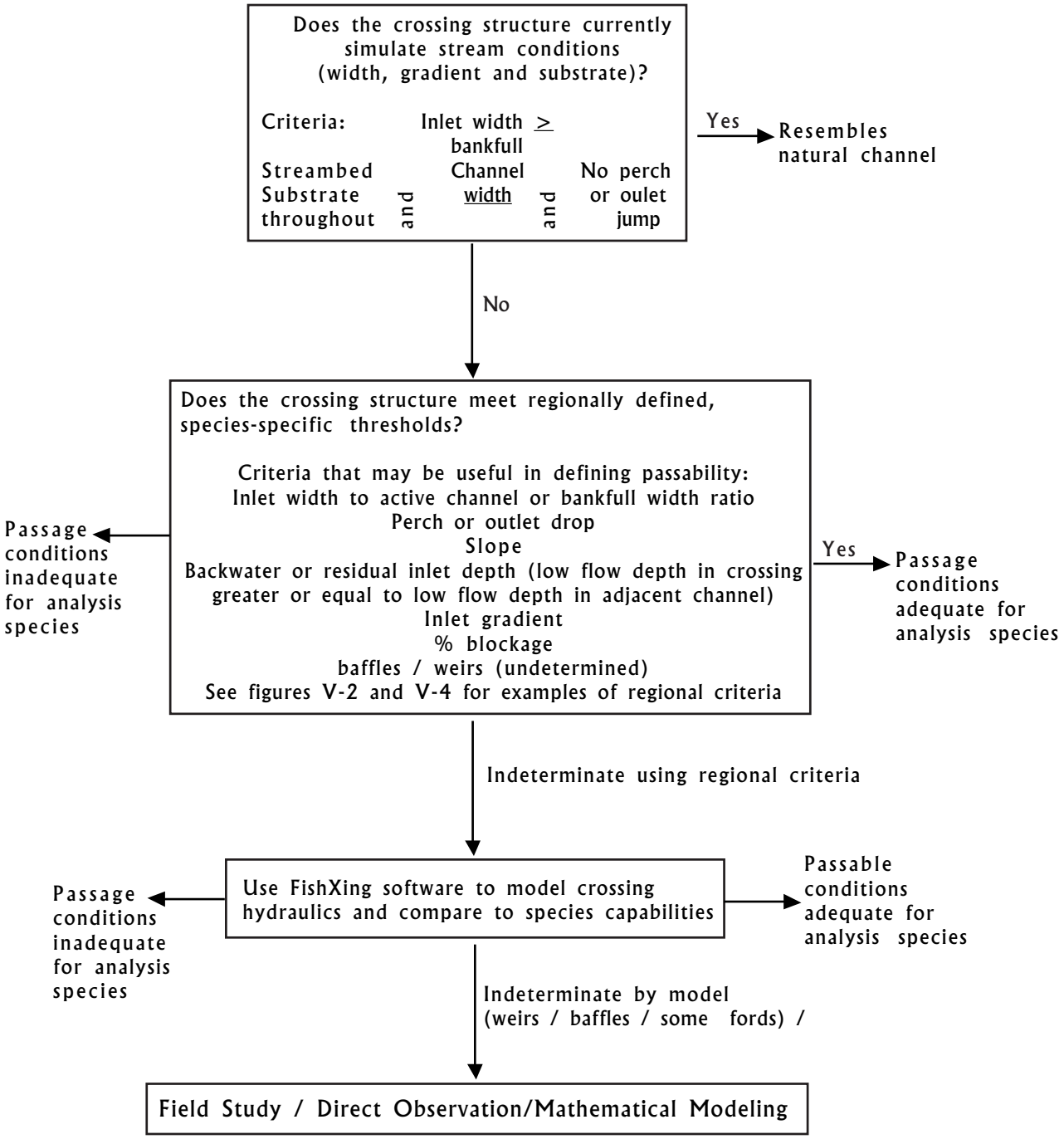
The assessment begins with a determination of whether the crossing resembles the adjacent natural channel. The top box in Figure V-1 lists specific criteria used to make this determination. The criteria are intended to distinguish crossings that allow a wide variety of species to pass the crossing including: amphibians, reptiles, some invertebrates, and numerous species and life stages of fish. They are based on the presumption that if the culvert physically resembles the adjacent channel, then flow and substrate conditions within the culvert will be similar enough to allow passage at the same times animals are moving in the natural channel. If a species has a critical movement window of only a few days, and this happens to coincide with above-bankfull flows in a specific year, these criteria would not assure passage.

When crossings do not resemble the natural channel they are taken to the next step in the screen. In this step, the crossing is compared to regionally or locally developed screen criteria that specifically address the passage needs of the analysis species. Examples of these screens are shown in Figures V-2 and V-4. The screening procedure is designed to quickly classify crossings into passage categories for each analysis species, species group, or lifestage.

The screen will not cover all possible scenarios. Some crossings have characteristics that may hinder passage but are not included in the screen—for example, debris or sediment blockages, debris screens and trash racks, and drop-inlets. We recommend using the screen criteria to categorize the crossing before leaving the site to permit the field crew to validate the result based on their observations.

FishXing would be used when the result of the screen places the crossing in the “indeterminate” category (that is, when screen criteria can not determine whether the crossing conditions are adequate or inadequate). There are some situations, such as culverts with baffles, weirs or other fishways, where the crossing category cannot be determined by either the regional screens or FishXing. These situations require field monitoring or detailed mathematical modeling.

Figure V-1. Passage assessment process



2. Screen Criteria

a) Crossings that resemble the natural channel

Characteristics that indicate that the crossing resembles the natural adjacent channel include:

- Streambed substrate is continuous throughout the crossing and the streambed slope, particle size and arrangement are similar to the adjacent channel;
- The crossing does not constrict the bankfull channel width. To meet this criterion, the inlet width must at least match the natural channel bankfull width, usually measured upstream of the structure and away from its zone of influence.

Note that these criteria are not necessarily the ones that would be used to design 'stream simulation' crossings.

Streambed substrate continuity—For crossings to resemble the natural channel, they must be able to transport all watershed products moving in the stream channel at least up to bankfull flow. Where this goal is met, bed material size, arrangement, and slope profile inside the structure are either similar to the adjacent channel sections, or they are designed to provide a similar rate of energy loss. In the field, evidence of similarity in embedded structures that have been in place for several years is: lack of bedload or debris accumulation upstream of the structure (caused by the structure), lack of downstream scour, and low flow depths similar to those in the natural channel. Upstream of the structure, look for unusual bank erosion, and for finer bed material and lower slopes than in adjacent sections (evidence of aggradation). Downstream, look for abrupt slope changes and larger bed material (evidence of degradation). Keep in mind that nearby tributaries can modify streambed particle sizes as well. Also keep in mind the age of the structure. If it is new, the channel may still be adjusting to installation, so determining whether the crossing will function like the adjacent natural channel may not be possible.

On slopes lower than about 3 percent, bed material size, arrangement and slope profile in the structure are expected to be identical to the nearby stream sections. On higher slopes, bed material may be larger than in the natural channel, in order to resist movement during larger than bankfull flows. To qualify in this category, however, the bed material must be arranged into stable bedforms that provide for flow diversity, energy dissipation, and continuity of bedload transport through the structure. For the purposes of this inventory, it is recommended that crews rely on the observations outlined above to make that determination.

Bankfull channel width—Compare the average of the adjacent bankfull channel widths recorded on page four of the field form to the width of the structure opening. Where channel types differ above and below the crossing, you will need to judge which width should be matched. Bedslope, bedforms, and width must all work together to maintain continuity of transport through the reach.

Regional adjustment of these criteria for natural channel resemblance will probably not be required.

b) Fishways: baffles and weirs

Many culverts have been modified or retrofit with baffles or weirs for fish passage. Baffles and weirs typically act to reduce velocities, provide resting pools, and consolidate low flows to provide more suitable depth. These structures are sometimes installed to retain streambed material inside the pipe. Where these are completely embedded the crossing can be considered to have continuous substrate. Baffled culverts that are not completely embedded are not easy to screen because the hydraulics can be complicated—even unsolvable. Many baffled culverts require field study to determine their passage category and are initially put in the 'indeterminate' category.

c) Regionally defined analysis species criteria

If the structure does not simulate the natural channel, then continue through the portion of the flow chart (Figure V-1) that includes the regionally developed analysis species criteria. Regional analysis species criteria are thresholds that reflect the species, life stage, or species group's ability to swim through or leap into crossing structures. If a culvert meets the regional analysis species criteria, then the passage conditions are categorized as adequate. If the regional criteria are not met, then either passage is inadequate or indeterminate using the screen. If it is indeterminate, then other analyses (eg. FishXing, monitoring) are needed.

The screening procedure should quickly classify crossings into one of four categories:

- Crossing resembles adjacent channel: passage assumed for aquatic species
- Meets criteria: passage conditions are adequate for the analysis species for which the screen is designed
- Fails criteria: passage conditions are inadequate for the analysis species for which the screen is designed
- Indeterminate barrier category: requires hydraulic or other analysis.

These barrier categories are species specific, so it is possible for a crossing to be in more than one category (eg. adequate for adults, indeterminate for juveniles).

The benefit of developing regional screens is that they speed up the process of categorizing many crossings. Where we can define certain observable characteristics (such as perch height) that make a crossing impassable for most individuals of the analysis species, this method is more efficient than hydraulic analysis. The risk, of course, is that we may not have all the information to select solid criteria, and so best professional judgment must frequently be used. Thus we are always at some risk of placing crossings in the wrong category.

It is important to remember that barrier determination is not an exact science. As with all biological characteristics, a range in swim performance is found when individuals are tested. Also, field conditions may vary considerably from those in a laboratory where much of the swim performance data are gathered. Swim performance data should be considered as a guidepost and you must use judgment to construct the screens.

If the screen criteria are based on the lowest numbers in the range reported for swim or leap performance for the analysis species, then some of the crossings will be placed in the "passage condition inadequate" category when they are actually passable to most individuals. If the criteria are based on the upper end of the range, then more crossings will fall in the "indeterminate" category, requiring the use of the hydraulic model. Inventory, analysis, and repair of culverts are expensive, and restoration dollars are limited. It is, therefore, important to consider the consequences of choosing criteria from various portions of the swim performance ranges reported in the literature. It is our recommendation that screens be tested on a sample of crossings that cover the full range of categories. A group of experienced professionals should be familiar with the test crossings and agree about their category. Testing will help to make sure the screens are performing as expected.

At least three screens have been developed to identify fish-passable crossings without a hydraulic analysis. Two are described here as examples, along with some discussion of the logic behind the criteria. Each of these screens is the result of substantial experience in assessing culverts for salmonid passage. **The examples presented here** may not be appropriate outside the regions for which they were developed. Remember that these screens were developed by regional teams representing agencies and organizations with interest in **fish** passage. If passage for non-fish species is important in your area, you may develop several screens for a broader range of analysis species. Regional screen development teams should include fish and wildlife management agencies and road managers of all jurisdictions. If this is done, barrier determinations will rest on a consensus definition that meets legal standards, and the data can be aggregated across the various ownerships in a watershed. Certainly, decisions about variables and values within any regional screen should be justified and documented.

The screen referred to above, but not presented here as an example, is included in the Washington Department of Fish and Wildlife's Fish Passage Barrier and Surface Water Diversion Screening Assessment and Prioritization Manual, August 2000. See page 17 at www.wa.gov/wdfw/hab/engineer/fishbarr.htm.

Example 1: California's first-phase passage evaluation filter

The flowchart screen (Figure V-2) is from Taylor and Love (2002). It is designed to cover both adult and juvenile anadromous salmonids. It puts crossings into three categories: red, gray, and green. Definitions in this scheme are as follows:

- Green: Conditions are assumed adequate for passage of all salmonids. Even the weakest swimming lifestage (juveniles) can pass the crossing during the entire period of migration.
- Gray: Conditions may not be adequate for all salmonid species or life stages presumed present. Additional analyses are required to determine extent of the barrier for each species and lifestage.
- Red: Conditions do not meet passage criteria over the entire range of migration flows for even the strongest swimming species and lifestage (adults) presumed present. Assume 'passage condition inadequate'.

The crossings that resemble the adjacent natural channel are categorized as green (see the left-hand side of this screen). They have streambed substrate

throughout and inlets as wide as the active channel. If either one of those criteria are not met, a crossing can still be considered "green", but only when its entire length is backwatered at extreme low flows (see Figure E-14 for illustration of 'residual inlet depth'). These criteria are designed so that even the weakest lifestage can pass a green crossing. Criteria leading to a red call are an outlet drop of 2 feet or greater, or a steep slope without baffles or weirs to modify velocity and depth. Other crossings are partial or unknown barriers, and the barrier category is undefined until hydraulic analysis is completed.

In this screen, the values assigned to critical variables are conservative, to accommodate passage by weaker-swimming individuals. Stronger (larger) individual fish can often pass successfully upstream through a red culvert under certain flows. The values also incorporate current National Marine Fisheries Service guidelines and California Department of Fish and Game design standards.

A benefit of using a flow-chart model is that values of specific variables can be easily changed to judge the sensitivity of the model to data sets. But because the California model covers all crossing structure types with one set of criteria, it does not allow the user to distinguish crossings that may permit easier passage than others (for example, larger corrugations on metal pipes). The California flowchart also includes all species of concern (namely, adult and juvenile coho salmon) in one flow chart, which results in a number of gray culverts. It would be possible to reduce the number of gray culverts and the required additional analysis by constructing two flowcharts, one for adult and one for juvenile fish. With two flowcharts many culverts would probably be red for juveniles (needing no more additional analysis) and gray for adults (needing additional analysis with FishXing).

For regional teams wanting to use the flow-chart model to develop regional species or species-group criteria for an initial screen, we have included a fill-in-the-blank version in Appendix B. Brief explanations of the criteria are included there. Note that the example variables may or may not be appropriate for all species. Other types of information may be required for passage of amphibians, reptiles, invertebrates, or small mammals.

Example 2: Alaska's initial screen

The screening matrix developed in Alaska (by a group comprising USFS Region 10, the Alaska Department of Fish and Game, Alaska Department of Transportation, the Environmental Protection Agency, and the FishXing development team) is for juvenile coho salmon only. It is applied for juveniles of all species in southeast Alaska (Figure V-4). This matrix explicitly recognizes the mix of characteristics that, if present together, permit passage for juvenile fish through the various listed crossing types. Building a detailed matrix like this one obviously requires considerable information on the movement of the analysis species and direct experience observing movement through many different crossing structure types. Note that crossings passable by adult but not juvenile fish are red, unlike in California where they would be gray.

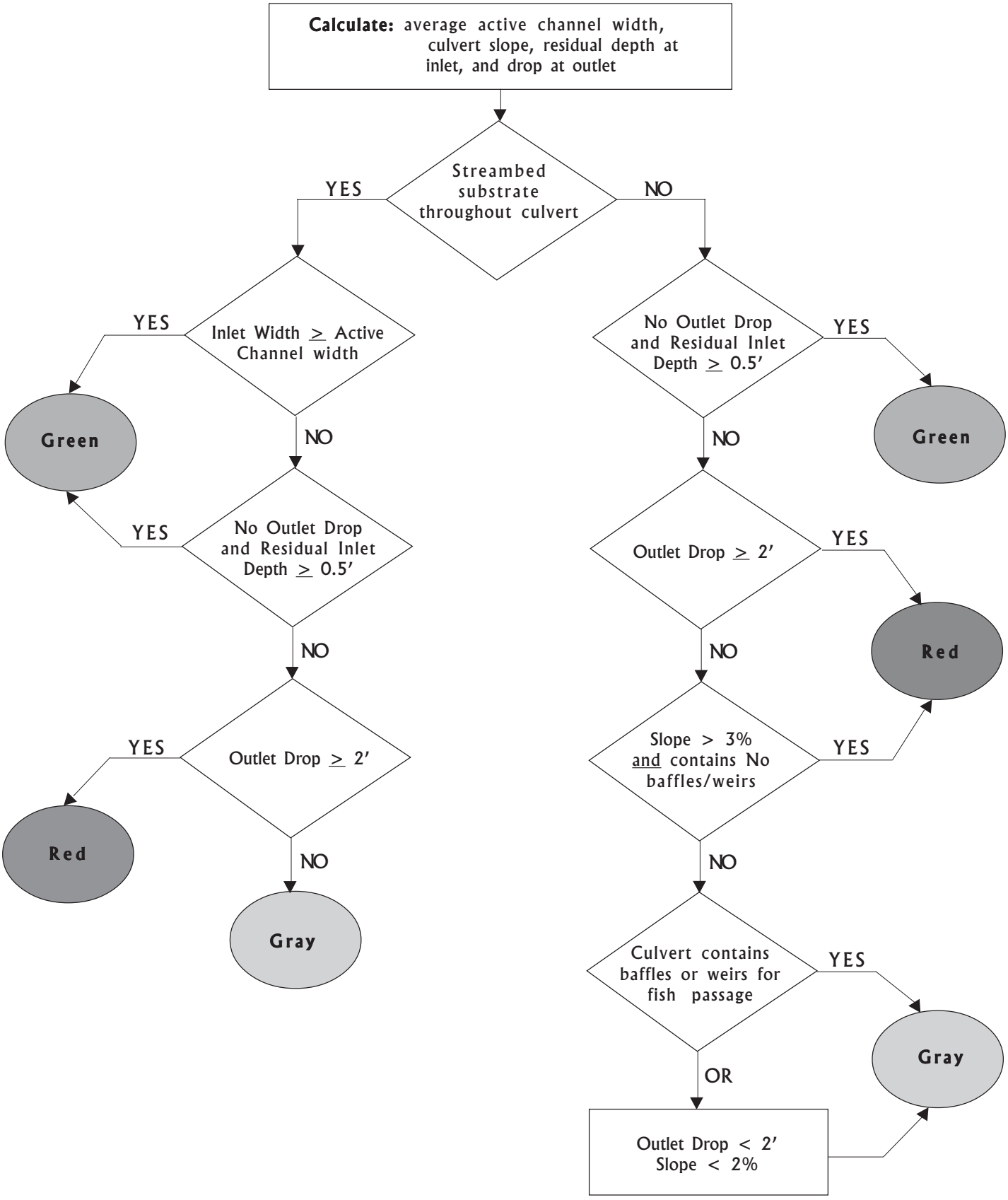


Figure V-2*. EXAMPLE ONLY: Green-Gray-Red screen developed for California's anadromous adult and juvenile salmonids (Taylor and Love 2002).*

Example Only

Figure V-3. Alaska fish-passage evaluation criteria (juvenile coho) USDA Forest Service Region 10

	Structure	Green[1]	Gray[2]	Red[3]
1	Bottomless pipe arch or countersunk pipe arch, substrate 100% coverage and invert depth greater than 20% of culvert rise.	Installed at channel grade (+/- 1%), culvert span to bedwidth ratio of 0.9 to 1.0, no blockage.	Installed at channel grade (+/- 1%), culvert span to bedwidth ratio of 0.5 to 0.9, less than or equal to 10% blockage.	Not installed at channel grade (+/- 1%), culvert span to bedwidth ratio less than 0.5, greater than 10% blockage.
2	Countersunk pipe arches (1x3 corrugation and larger). Substrate less than 100% coverage or invert depth less than 20% of culvert rise.	Grade less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75.	Grade between 0.5 to 2.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 2.0%, greater than 4" perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
3	Circular CMP 48 inch span and smaller, spiral corrugations, regardless of substrate coverage.	Culvert gradient less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Culvert gradient 0.5 to 1.0%, perch less than 4 inches, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Culvert gradient greater than 1.0%, perch greater than 4 inches, blockage greater than 10%, span to bedwidth ratio less than 0.5.
4	Circular CMPs with annular corrugations larger than 1x3 and 1x3 spiral corrugations (>48" span), substrate less than 100% coverage or invert depth less than 20% culvert rise.	Grade less than 0.5%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75.	Grade between 0.5 to 2.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 2.0%, greater than 4" perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
5	Circular CMPs with 1x3 or smaller annular corrugations (all spans) and 1x3 spiral corrugations (>48" span), 100% substrate coverage and substrate depth greater than 20% of culvert rise.	Grade less than 1%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Grade 1.0 to 3.0%, perch less than 4 inches, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Culvert gradient greater than 3.0%, perch greater than 4 inches, blockage greater than 10%, culvert span to bedwidth ratio less than 0.5.
6	Circular CMPs with 2x6 annular corrugations (all spans), 100% substrate coverage and substrate depth greater than 20% of culvert rise.	Grade less than 2.0%, no perch, no blockage, culvert span to bedwidth ratio greater than 0.75	Grade 2.0 to 4.0%, less than 4" perch, less than or equal to 10% blockage, culvert span to bedwidth ratio of 0.5 to 0.75.	Grade greater than 4.0%, greater than 4 inch perch, greater than 10% blockage, culvert span to bedwidth ratio less than 0.5.
7	Baffled or multiple structure installations		All	
8	Log stringer or modular bridge	No encroachment on bedwidth.	Encroachment on bedwidth (either streambank).	Structural collapse.

Note: Larger corrugations increase roughness allowing for fish passage at steeper culvert gradients.

[1]Green – Conditions at the crossing are assumed adequate for fish passage
[2]Gray – Conditions at the crossing may not be adequate for fish passage, additional analysis required.
[3]Red – Conditions at the crossing are assumed to be not adequate for fish passage, additional fieldwork and analysis required.

B. Conducting hydraulic analysis

When the status of a crossing cannot be determined by applying the regional screens, hydraulic modeling can often be used to determine if the crossing has adequate passage characteristics for the analysis species.

1. Flow selection

Hydraulic models require the user to select the pertinent flows. Designing road crossings to pass fish at all flows is impractical (NMFS 2000; Robison and others, 2000; WDFW SSHEAR 1998). Most aquatic species take refuge during larger flood events. Conversely, during low flow periods shallow water depths in many small streams can make the channel itself impassable. Generally there will be an upper and a lower flow threshold beyond which passage need not be accommodated. In some areas, fish management or regulatory agencies have defined the range of flows where movement must be accommodated (See appendix C).

2. Swim Performance

The field data needed to support the FishXing software are gathered during this inventory. FishXing is available on line at www.stream.fs.fed.us/fishxing. The current version (2.2) calculates velocities and depths throughout the pipe for a specific flow and then compares them to default or user-input values for fish swim speeds and depth requirements. The default values should not be assumed appropriate across regions. Developing a regional model should include selecting user-input values for swimming ability. The program identifies the locations of velocity and lack-of-depth barriers in the pipe, and the jump height barriers at perched outlets.

3. Fish Crossing Limitations

FishXing models a limited set of the most common culvert shapes It does not model complex crossing structures such as multiple pipes, aprons, fords or culverts with internal grade breaks, (although multiple runs can sometimes simulate this condition). The software calculates a composite roughness value for pipe bed and walls at each node in the pipe (about every 3 feet) based on water depth (the solution is iterative because depth and composite roughness are interdependent variables). FishXing assumes that embedded and open bottom culverts have flat homogeneous beds. This frequently results in a "passage condition inadequate" determination, because true low flow depth is underestimated. For this reason, FishXing should be used with extreme care, if at all, when there is continuous streambed material through the crossing structure.

Other hydraulic evaluation models include CulvertMaster (http://www.haestad.com), the Federal Highways Culvert program HY-8 and HEC-RAS. The Federal Highway Administration Bridge Technology website http://www.fhwa.dot.gov/bridge/hydsoft.htm) includes links to several of these software packages. These models do not incorporate the swim performance information that FishXing offers, and additional calculations comparing fish swim performance to the hydraulic properties in the pipe are required.

C. Summarizing crossing category for analysis species

Some crossings block all species and life stages at all flows, others block some species and life stages only at certain flows, and still others block some species and life stages at all flows. These characteristics can be crucial for prioritizing passage restoration projects. While it is tempting to describe crossings as "partial" or "total" barriers, the meaning of these terms has not

been standardized. Important information is lost when these terms are used; for example: what does partial mean? Is it a barrier some of the time for all species present, or all of the time for some of the species present? Because these terms are vague and easily misinterpreted, we recommend that summaries be limited to tables that list the analysis species and its crossing category from the screening process (such as, passage condition adequate, passage conditions inadequate, indeterminate). Consistent use of these terms by units using this protocol will permit information exchange and prioritization across units and jurisdictions. [The meanings of these terms are essentially the same as the green, red, and grey used by previous inventory protocols. Each protocol uses different regional criteria to define green, grey and red, just as different geographic regions will need to use different criteria to define adequate, inadequate and indeterminate.]

VI. PRIORITIZATION OF ROAD CROSSING TREATMENTS

A. Establishing the larger watershed context

Stream restoration projects, such as removing passage barriers, are most effective when they are planned and priorities are set based on an understanding of the watershed's condition, use by resident biota, its production potential, and its relation to the larger basin. For example, two streams similar in size and type of barrier problems could have very different priorities if one is tributary to an area of high fish production, while the other is not. To fully understand passage restoration needs in a drainage system, we need to understand the ecology of the local biota. What role does the blocked area play in the life history of individual animals, and in the structure and dynamics of populations or communities? What are the biological consequences of not restoring passage? The nature and importance of ecological consequences of a barrier is the standard against which passage restoration costs must be weighed. An understanding of the other restoration needs within the watershed is also crucial. For example, fixing passage barriers may be less important if water or habitat quality is low. A watershed approach (McCammon et al 1998) should be taken to ensure that priorities are set based on a full assessment of watershed conditions, not on a limited site-scale view.

Where transportation plans are completed, they are an important part of establishing the context for restoration. The long term plans for the road can inform decisions about whether or not to restore passage at the culvert. It may be that the road is planned for removal or upgrade; if so, passage issues can be addressed when the removal or upgrades are done.

B. Protecting areas from invasive species

Before any treatment planning starts, consider these questions: Are exotic invasive species present in the area? Should barriers be maintained?
In freshwater ecosystems, non-native invasions are one the primary causes of species extirpations and population declines (Miller and others 1998, Allan and Flecker 1993). Crossings sometimes inhibit upstream spread of non-native or undesirable species. However, if exclusion is truly desired, an obstruction should be designed to keep the specific invader from moving upstream. Crossings often function as incomplete barriers to upstream movement. Passage may be possible during certain infrequent flow events, or larger individuals may be able to pass at some flows. Also, while it may be possible to protect a native species by retaining a crossing barrier, this may also have the undesirable effect of increasing that population's extinction probability. Barriers can prevent re-colonization of the upstream reaches after catastrophic disturbances (Brown 1986, Frissell 1993, Angermeier 1995). The tradeoffs related to improving access at road crossings when non-native species are present should be very carefully considered.

C. Developing a scheme for setting priorities

This discussion relies heavily on Taylor and Love (2002).

Because sufficient funding in any one fiscal year to correct all passage problems is unlikely, setting priorities is usually necessary. Some federal, state and local agencies, tribes, and watershed councils may already have developed methods for setting priorities based on local issues and species needs. If your local area does not already have a plan, what follows can help you and your partners develop a method that ranks road-crossing treatments by whatever combination of criteria is most critical.

When you develop your scheme for ranking treatment of road crossings consider the following:

- Quantity and quality of upstream and downstream habitat that would be made accessible.
  Example 1: A somewhat shorter but higher quality habitat may be more important to open up than a lower quality, but longer, habitat area.
  Example 2: Seasonal water-quality problems may increase the importance of ensuring access between stream sections because aquatic species' survival may depend on their ability to move in response to seasonal changes in water quality. For example, juvenile salmonids may need to move to cooler tributaries when mainstream channel temperatures rise in summer.
- Species status
  Passage problems affecting ESA-listed species should rank higher than those affecting species not currently imperiled.
- Crossing failure risk
  Potential adverse effects to aquatic systems will be avoided by replacing crossings at high risk of failing because they are undersized or in poor condition.
- Presence of upstream and downstream barriers (movement requirements vary by species and life stage).
  Example 1: For anadromous fish species, the presence of other barriers downstream is an important issue because their survival depends on having accessible stream corridors from the ocean to upstream spawning grounds. Fixing upstream barriers is less productive when downstream barriers are still in place. Effective treatments generally proceed in an upstream direction.
  Example 2: For resident species, individuals need to move in both directions to avoid predators, find mates or food, or reduce competition for local resources.
- Habitat use
  Opening corridors to high quality habitat may be more important than fixing barriers across several drainages.
- Extent to which the barrier blocks native or desirable aquatic species, or alters native biological diversity.
  Removing a total barrier will assist more species and life stages than removing a partial barrier, and so may be more effective in re-establishing the native biological community. Also, restoration of access in areas where native biological diversity is intact may have higher priority than an area where native biodiversity has already been compromised.
  When considering which species are excluded, considering the role of barriers in preventing exotic species invasion.

- Known barriers.
  Restoring passage where attempts to pass frequently fail and where predators or poachers congregate to take advantage of the blocked animals may be more important than other places. These sites also have a high probability of fostering immediate recolonization of upstream habitat.

The objective of setting priorities is to assess the biological risks and consequences of crossing barriers and to rank them in order of importance for passage restoration. Naturally, other factors—such as social, economic, or scheduling efficiencies—will enter into the actual scheduling of treatments. For example, equipment move-in costs may make addressing all barriers on a particular road system at the same time more economical, even though some of the crossings are of low biological priority.

Schemes for setting priorities can be simple or complex depending on your local capabilities and needs. Keep the scheme as simple and clear as possible for consistent application so that your prioritization decisions can be easily explained. An example scheme slightly modified from one being developed in California is shown in Appendix A.

D. Finding sources of habitat quality and quantity information

Information about habitat upstream and downstream of culvert locations can be obtained from previously conducted habitat typing or population surveys. Habitat information is often available in reports on file at state Fish and Wildlife agencies, federal (FS, BLM, EPA), or tribal offices. Private sector biologists, watershed groups, coordinators, restorationists, and large landowners can assist in acquiring additional information on drainages in their jurisdictions.

Information on habitat quality throughout the watershed is needed to provide a watershed-scale context for each barrier culvert. Some examples:

- Certain blocked areas may be able to provide high-quality winter rearing in a watershed where that type of habitat is critically short;
- The area downstream of a crossing with a high risk of failure in a flood might be extraordinary habitat for an endangered species; and
- A barrier culvert may be protecting an endangered amphibian from predation by introduced fish.

Quantitative field assessments of habitat quality are desirable, but if none are available then other types of information can be used as indicators of habitat quality. Examples include disturbance indicators available on GIS coverages, such as the percentage of watershed area in young vegetative stands (recently harvested), road density, riparian area grazing density, mining disturbance acres, and the amount of impervious surface or urbanization. Note that these indicators are much less reliable than habitat quality variables measured or even estimated in the field. Their relation to habitat quality is frequently indirect, and real habitat quality may or may not reflect the assumed relations. At a minimum, we recommend that a fisheries biologist or aquatic scientist look at the stream to estimate its quality.

Summer water-temperature or other water quality data are helpful in identifying tributaries that may provide high quality habitat. Knowledge about water quality can help to identify water-quality refuges and non-structural impediments to movement from poor quality to higher quality habitats. Such movements are often key to the growth and survival of aquatic organisms. This information may be available from state environmental agencies for streams listed on 303(d) lists as having beneficial use impairment (such as, temperatures outside natural regime, low dissolved oxygen, elevated toxins).

NOTE: Field forms and instructions are located in Appendix E.

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APPENDIX A EXAMPLE SCHEME FOR SETTING PRIORITIES— MODIFIED FROM THE CALIFORNIA METHOD

This ranking method is slightly generalized from a draft developed for California by Taylor and Love (2002); it is shown here with their permission. The original was devised primarily for coastal watersheds with potential habitat for anadromous salmonids. Some terminology has been modified to be consistent with this document, the emphasis on anadromous fish has been eliminated, and the extent-of-barrier variable has been simplified (2, below).

The ranking method assigns scores for the following parameters at each barrier crossing.

1. Species diversity

For each road crossing, add up ESA-listing status scores for each species known to be within the stream reach (now or historically). Score: Endangered = 3 points; Threatened = 2 points; not listed = 1 point Consult your local State Fish and Wildlife agency, USFWS, or NMFS for species distribution and listing status.

2. Extent of Barrier

For each species and lifestage of concern at the crossing, determine whether it is a total or partial (passable at some flows) barrier. Add the scores to get a total barrier extent score. Score: Total barrier for a species and lifestage= 2 points; partial barrier for a species and lifestage=1 point.

3. Habitat quantity

Score length in feet or meters above the road crossing to the limit of distribution of the analysis species. Score: We suggest starting at some agreed on minimum (such as, 500 ft); and assign 0.5 points for each size class unit (example: 0 points for <500 ft; 1 point for 1,000 ft; 2 points for 2,000 ft; and 5.5 points for 5,500 ft).

4. Habitat quality

Assign a habitat-quality score after reviewing available habitat information as follows.

- **Score: 1.0 = Excellent**. Relatively undeveloped, “pristine” watershed conditions. Habitat features include dense riparian zones with mix of mature native species, frequent pools, high-quality spawning areas, high water quality, near natural water temperature regimes, complex in-channel habitat, channel floodplain relatively intact. High likelihood of no future human development. Presence of one or more migration barriers is obviously the watershed’s limiting factor.

- **0.75 = Good**. Habitat is fairly intact, but human activities have altered the watershed, and that activity is likely to continue. Habitat still includes dense riparian zones of native species, frequent pools, spawning

gravels, good water quality, near- natural water temperature regimes, complex in-channel habitat, floodplain relatively intact. Presence of one or more migration barriers is most likely one of the watershed's primary limiting factors.

- **0.5 = Fair**. Human activities have altered the watershed. Expect continued or increased human activity that will continue to affect watershed processes and features. Habitat effects include riparian zone present that lacks mature vegetation and has non-native species, infrequent pools, sedimentation evident in spawning areas (pool tails and riffle crests). Water quality and water temperature regimes have been altered to the point that they periodically exceed stressful levels for analysis species. There is sparse in-channel complex habitat, floodplain intact or slightly modified. Presence of one or more migration barrier is probably one of the watershed's limiting factors (out of several factors).

- **0.25 = Poor**. Human activities have significantly altered the watershed with high likelihood of continued (or increased) activities, with apparent effects to watershed processes. Habitat effects include intact riparian zones absent or severely degraded, little or no pool formations, excessive sedimentation evident in spawning areas (pool tails and riffle crests), water-quality problems are stressful to lethal to analysis species, lack of in-channel habitat, floodplain severely modified with levees, riprap, and residential or commercial development. Other limiting factors in watershed most likely have higher priority for restoration than remediation of migration barriers.

5. Total habitat score

Multiply the scores for habitat quality and habitat quantity for each blocked species of concern. Add all the species together to get the total score.

6. Sizing (risk of failure)

Score each culvert according to the size of flow it was designed to accommodate. **Score**: sized for at least a 100-year flow at headwater/depth = 1, low risk = **1**; sized for at least a 50-year flow = **2**; sized for at least a 25-year flow = **3**; sized for less than a 25-year flow = **4**; sized for less than a 10-year flow = **5**.

7. Current condition

for each culvert, assign one of the following values. **Score**: good condition = **1**; fair (problems exist but are not likely to cause culvert to fail) = **2**; poor (problems could cause failure) = **3**.

For each road crossing, enter the scores into a spreadsheet and compute the total. Then, sort the list by "total score" to determine a first-cut ranking. Other sorts can be done to isolate certain kinds of crossing problems. For example, sites that have poor habitat quality may be sorted separately so that ranking at these sites can focus on culvert sizing and risk failure.

Additional Ranking Considerations

The results of the ranking matrix provide a rough, first-cut prioritized list of crossings requiring treatment. Other important factors will be considered when you decide the exact scheduling of remediation efforts.

On a site-specific basis, some or all of the following factors should be considered in refining the first-cut ranking.

1. Amount of road fill. At structures that are undersized or in poor condition, consider the volume of fill material in the road prism potentially deliverable to the stream channel if the culvert were to fail. Also consider diversion potential.

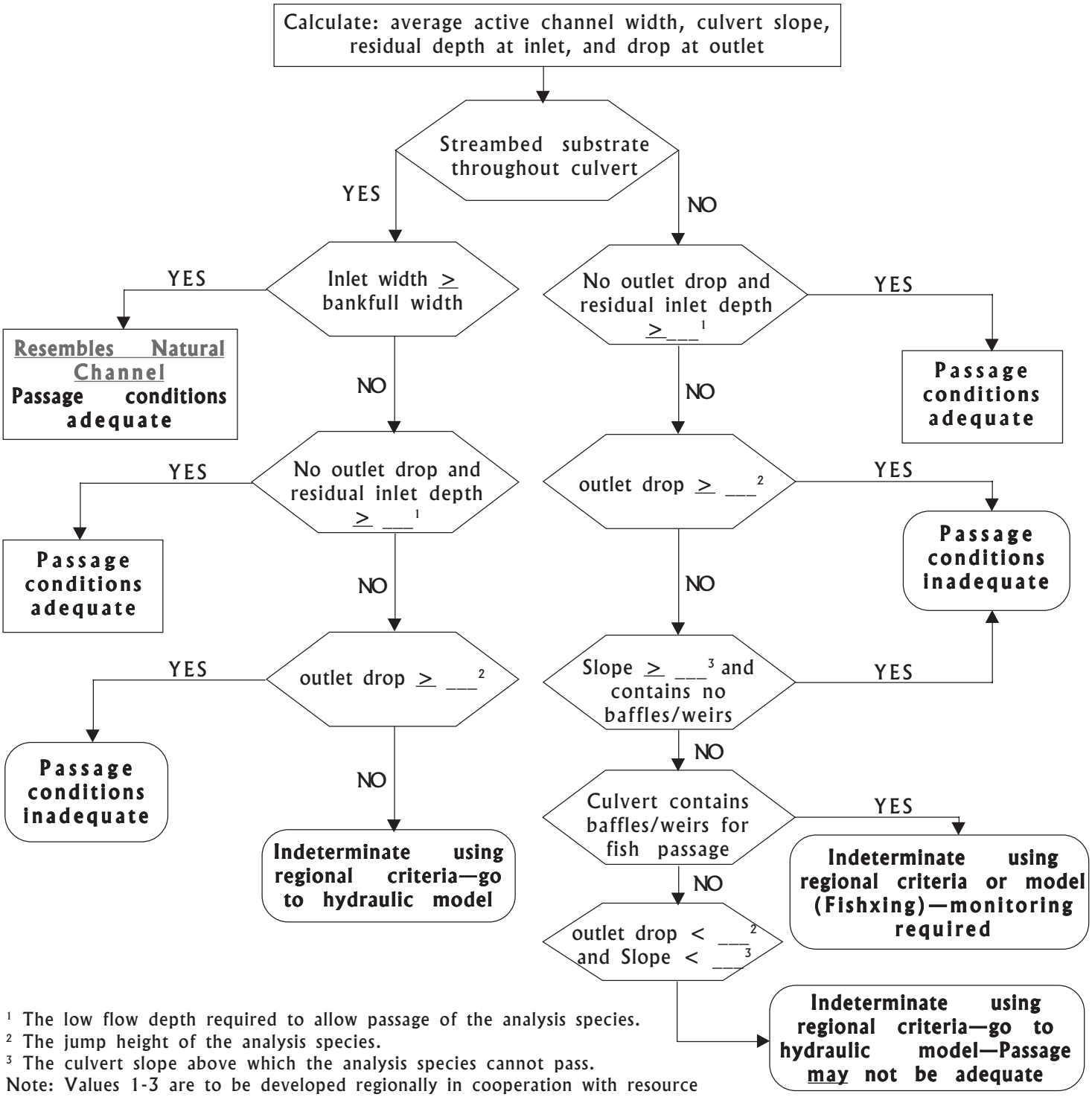
2. Presence or absence of other road crossings. Multiple roads under a variety of management or ownership may cross a single stream. Then, close communication with other road managers is important. If multiple culverts are migration barriers, a coordinated effort is required to identify and treat them in a logical sequence.

3. Presence of aquatic organisms attempting to migrate past a barrier. In Northern California, several crossings were ranked higher because of the annual presence of adult salmonids below total barriers. After treatments, the upstream habitat was immediately recolonized the following winter.

4. Remediation project cost. You should examine the range of treatment options and associated costs when determining the order in which to proceed and what should be implemented at specific sites. Where federally listed fish species are present, costs must also be weighed against the consequences of failing to comply with the ESA by not providing unimpeded passage.

Other limiting factors. Other limiting factors besides migration barriers often exist in a watershed and limit production of aquatic species. On a watershed or sub-basin scale, restoration decisions must be made after carefully reviewing potential limiting factors, the source of the effects, range of restoration options available, and what restoration activities are actually feasible.

APPENDIX B Fill-in-the-Blank Regional Screen, California model



[1] The low flow depth required to allow passage of the analysis species.
[2] The jump height of the analysis species.
[3] The culvert slope above which the analysis species cannot pass.
Note: Values 1-3 are to be developed regionally in cooperation with resource management

Passage inadequate: Crossing does not meet the criteria for the analysis species for which the screen is designed.
Indeterminate barrier category: for analysis species using the screen.

Several states have defined flows at which fish passage should be provided. Except for Alaska and Idaho, these requirements apply only to hydraulic designs (not stream simulation).

STATE AND AGENCY GUIDELINES FOR FISH PASSAGE FLOWS

Alaska	Washington	Oregon	NMFS SW Region	California Dept Fish & Game guidelines)	NMFS NW Region (draft salmonid	Idaho
High Flow Capacity (crossing must pass this flow, but fish passage is not required)						
Q_{50} or Q_{100}	Q_{100} with debris	Q_{100}	Q_{100} at headwater/depth = 1	Q_{100} at headwater/depth = 1.5		
High Fish Passage Flow						
"Q2d2": the discharge 24 hours before or after the 2-yr flood	10% exceedance flow during migration period: species-specific	10% exceedance flow during migration period: species-specific. Approximate by $Q_{10\%} = 0.18*(Q_2)+36$ where $Q_2 > 44$ cfs. Where $Q_2 < 44$ cfs, use Q2.	for adult salmon & steelhead 1% annual exceedance flow or 50% Q_2. For juveniles, 10% annual exceedance flow	standards vary from 1%-10% annual exceedance for various groups of fish	5% exceedance flow for period of upstream migration	< 2-day delay during period of migration
Low Fish Passage Flow						
None	2-yr, 7-day low flow	2-yr, 7-day low flow or 95% exceedance flow for migration period: species-specific	for adult salmon & steelhead, the greater of 3 cfs or 50% annual exceedance flow. For juveniles, the greater of 95% annual exceedance flow or 1 cfs	standards vary from 50%-95% annual exceedance for various groups of fish	95% exceedance flow during months of upstream migration	

Q_{100} means the peak flow equaled or exceeded on average once in 100 years. Determined based on annual peak flow data set.

10% exceedance flow during the migration period means the daily average flow that is equaled or exceeded 10% of the days in the period the selected fish species are moving. That period is usually established by the state fish and wildlife management agency. Based on period of record daily-flow data set for the migration period.

1% annual exceedance flow means the daily average flow that is equaled or exceeded 1% of the days of the year. Determined based on period of record daily mean flow data set for the entire year.

APPENDIX D Example Job Hazard Analysis from Umatilla NF

JHA provided courtesy of John Sanchez, Umatilla NF

The Occupational Safety and Health Administration has requirements related to working in confined spaces [Safety training and Education – 1926.21(b)(6)(i)]. These requirements can be found at their website: www.osha.gov/pls/oshaweb.

U.S. Department of Agriculture Forest Service **JOB HAZARD ANALYSIS (JHA)** References-FSH 6709.11 and -12 (Instructions on Reverse)	1. WORK PROJECT/ ACTIVITY **FISH PASSAGE CULVERT ASSESSMENT JUNE/SEPT 2001**	2. LOCATION **UMATILLA NATIONAL FOREST**	3. UNIT **R6-14**
	4. NAME OF ANALYST **J.SANCHEZ**	5. JOB TITLE **FISH BIOLOGIST**	6. DATE PREPARED **05/25/2001**
7. TASKS/PROCEDURES	8. HAZARDS	9. ABATEMENT ACTIONS Engineering Controls * Substitution * Administrative Controls * PPE	
* Driving on main roads as well as 4wd and other secondatry roads which are heavily used by public, working long days	*potential for heavy traffic/fast vehicles; uneven roads; atv and bike use by recreationists; being tired while driving/ lack of concentration on tasks /mental and physical errors	*follow safe and defensive driving practices; take rest breaks as needed; change drivers as needed	
*working in roadway and crossing the road	*high traffic volume on main roads; sites close to bends in roadway decreasing visibility	*watch for traffic and check both directions before crossing; post a lookout if needed; use caution especially at sites close to bends in the road. Wear hard hats and safety vests to increase crew visibility to oncoming drivers	
*climbing up/down banks, over rock and loose fill in wading boots	*poor foot traction in wading boots; easy to slip and fall; kicking loose rocks down onto workers below	* look for safest way down bank; don't rush; use a pole to help balance; make sure others are not directly below you as you climb up or down the bank	
*walking in culverts and in streams in wading boots	*culverts and rocks are slippery when wet and covered with algae; uneven surfaces in culverts and streams; strong flow	*don't rush; wear wading boots with felt bottoms; use a wading staff for support; be confident of your footing before taking next step in fast moving water	

7. TASKS/PROCEDURES	8. HAZARDS	9. ABATEMENT ACTIONS Engineering Controls * Substitution * Administrative Controls * PPE	
*climbing over/under/around timber and walking over uneven terrain and over vegetation covered ground in wading boots	* logs are slick when wet; hard to see the ground; unstable snags may fall; debris piles may be unstable; twisted ankles; snagging waders on limbs and fences	* find safest and easiest route around logs; go around or under instead of over; step cautiously on piles of debris; identify unstable snags and stay clear; use rod to help find stable/unstable spots	
*working outside in weather (heat/rain/cold/snow/thunder and lightning)	*dehydration; hyper and hypothermia; threat of storms	*drink plenty of water; dress appropriately for weather; monitor weather reports; carry a radio and extra batteries; keep dry clothes in vehicle.	
*working outside-encounters with snakes, bees, wasps, biting flies etc	*allergic reations such as anaphylactic shock/ rash/swelling etc	*identify all crew member's allergies and inform all crew of potential health problems; always carry a first aid kit equipped with antihistamines/epi pin/benadryl as necessary in vehicle and in packs; discuss first aid techniques and training for all crew members as needed	
*conduct tailgate safety meetings as needed			
*use proper department check in / check out procedures	*		
*driving an all-terrain vehicle on forest roads		*follow safe operating procedures for atv; wear all appropriate safety gear (helmut, gloves, boots, long pants and long sleeved shirt); maintain safe and proper speed; scan ahead for hazards; keep all items strapped down tightly to avoid unexpected shifting of weight; carry a radio and 1st aid kit in case of emergency	
10. LINE OFFICER SIGNATURE		11. TITLE	12. DATE

Previous edition is obsolete (over)

APPENDIX E Explanations and Instructions for Passage Through Road/Stream Crossings Inventory Form

These instructions accompany the Passage Through Crossings Assessment forms. The inventory collects information required to assess passage of fish and other animals through crossing structures on both roads and trails. The procedure does not handle bridges because most often these structures do not obstruct aquatic organisms. The data sheet can be modified if need be for field convenience. However, it is critical to preserve the definitions of the variables and the methods of measurement prescribed in this document. New database structures are being modeled now for storage of this data in Forest Service Infrastructure database (INFRA) and Natural Resources information system (NRIS).

Once the field data have been collected, a passage assessment is made in the field. First, determine whether the crossing resembles the adjacent natural channel. If it does, we assume it passes most organisms. The criteria for making this determination are listed under "Field Passage Evaluation" in these instructions. Second, if the crossing does not resemble the stream channel, then use the regionally developed species, lifestage, or species group-specific criteria to determine whether the structure's passage conditions are adequate, inadequate or are indeterminate.

If you cannot determine whether the crossing is a barrier, and the analysis species is a fish for which swim performance information is available, then hydraulic analysis using FishXing can be conducted for many types of crossings. The FishXing software is available on the web at: http://www.stream.fs.fed.us/fishxing. See instructions and help files prior to running the program.

In addition to the information collected through this inventory the following inputs are also needed to run FishXing:

- Hydrologic criteria, including low passage flow and high passage flow.
- Fish information, including swimming capabilities and depth requirements.

Although the field assessment form is designed primarily for culverts, fords can also be inventoried. Instructions for taking measurements on fords are included. The survey measurements can support limited open channel flow analysis, but passage assessments on fords are usually a matter of directly observing animal passage. In these cases, more than a single visit may be needed to adequately assess their passage. Other complex installations difficult to model hydraulically, such as baffled culverts, may also require multiple visits.