North Coast Instream Flow Policy: Scientific Basis and Development of Alternatives Protecting Anadromous Salmonids

Task 3 Report
Administrative Draft

Prepared for:

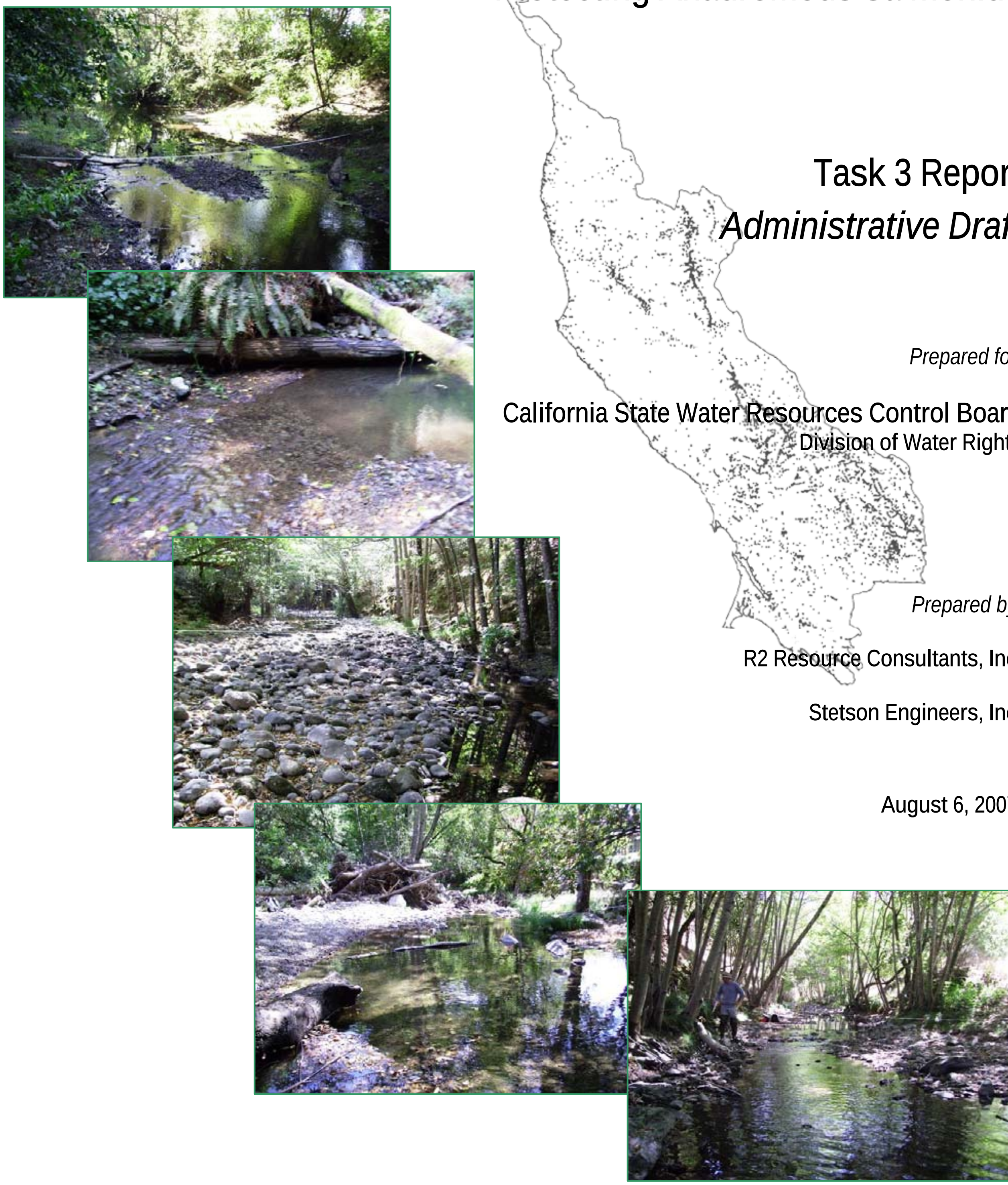
California State Water Resources Control Board
Division of Water Rights

Prepared by:

R2 Resource Consultants, Inc.

Stetson Engineers, Inc.

August 6, 2007



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LIST OF ACRONYMS AND ABBREVIATIONS

BMI	Benthic Macro Invertebrate
CDF	California Department of Forestry
CDV	Cumulative Diversion Volume
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFII	Cumulative Flow Impairment Index
DA	Drainage Area
DFG	California Department of Fish and Game
Division	Division of Water Rights
DP	On-Stream Dam Permitting
DS	Diversion Season
DWR	California Department of Water Resources
EIR	Environmental Impact Report
ESA	Endangered Species Acts
ESU	Evolutionarily Significant Unit
EUR	Estimated Unimpaired Runoff
FP	Fish Passage and Protection
HSPF	Hydrologic Simulation Program – Fortran
HSI	Habitat Suitability Index
MBF	Minimum Bypass Flow
MCD	Maximum Cumulative Diversion
MOC	Monitoring Oversight Committee
NCRCD	Napa County Resource Conservation District
NMFS	National Marine Fisheries Service
NPS	National Park Service
PHABSIM	Physical Habitat Simulation
POD	Point of Diversion
POI	Point of Interest
Policy	North Coast Instream Flow Policy
QA/QC	Quality Assurance/Quality Control
Q	Flow
Q_m	Unimpaired Mean Annual Flow
Q_{MBF}	Minimum Bypass Flow
R2	R2 Resource Consultants
SEC	Sonoma Ecology Center
SED	Substitute Environmental Document
State Water Board	State Water Resources Control Board
Stetson	Stetson Engineers
USGS	US Geological Survey
WUA	Weighted Usable Area

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EXECUTIVE SUMMARY

Background

The State Water Resources Control Board (State Water Board) is responsible for administering water rights in the State of California. Assembly Bill 2121 (Stats. 2004, ch. 943, §1-3) added Sections 1259.2 and 1259.4 to the California Water Code. Water Code §1259.4 (as amended in July 2005) requires the State Water Board to adopt by January 1, 2008, a policy for maintaining instream flows in coastal streams from the Mattole River to San Francisco, and in coastal streams entering northern San Pablo Bay. The policy, termed the North Coast Instream Flow Policy, (hereinafter "Policy") will be prepared and adopted in accordance with state policy for water quality control for the purposes of water right administration. In addition, the State Policy for Water Quality Control requires preparation of a Substitute Environmental Document (SED) that analyzes the potential significant adverse environmental impacts, including cumulative impacts, of the Policy.

In developing the Policy, Water Code section 1259.4 authorized the State Water Board to consider the draft "Guidelines for Maintaining Instream Flows to Protect Fisheries Resources Downstream of Water Diversions in Mid-California Coastal Streams," which were developed by the California Department of Fish and Game (DFG) and National Marine Fisheries Service (NMFS) (DFG-NMFS 2002). The DFG-NMFS (2002) Draft Guidelines were specifically developed pursuant to respective agency mandates and missions to protect and restore endangered and threatened anadromous salmonids and their habitats. The DFG-NMFS (2002) Draft Guidelines contained three elements governing restrictions on flow, and an element governing restrictions on instream barriers. The DFG-NMFS (2002) Draft Guidelines also allow, under some circumstances, for site specific studies to be conducted as a means to evaluate whether additional water diversion, the presence of an on-stream dam, and/or a reduction in protective measures can be allowed without adversely affecting anadromous salmonids and their habitat. These same four elements and the option for site-specific studies have been carried through into the development of the Policy. The Division of Water Rights (Division) currently considers the DFG-NMFS (2002) Draft Guidelines when evaluating water right applications, but the Division has not adopted them as formal State Water Board policy.

This report presents the results of an evaluation of the technical basis and rationale behind the DFG-NMFS (2002) Draft Guidelines, and assesses the regional protectiveness of Policy element alternative criteria for anadromous salmonids in the Policy area. The technical evaluation included identification and analysis of possible alternative criteria and/or refinements to the DFG-NMFS (2002) Draft Guidelines that might afford a higher level of protectiveness to anadromous salmonids at the regional level, in terms of biologically desirable instream flows and permissible diversion rates.

The alternative criteria were developed considering comments received during the California Environmental Quality Act (CEQA) scoping process and from earlier reviews of the DFG-NMFS (2002) Draft Guidelines. The alternative criteria furthermore address many of the substantive comments and recommendations made in 2000 by the State Water Board's Peer Review Panel (Moyle et al. 2000) and by Trout Unlimited (prepared by McBain-Trush; MTTU 2000) concerning the protectiveness of proposed State Water Board instream flow management guidelines that preceded the DFG-NMFS (2002) Draft Guidelines. The comments and recommendations included, notably: addressing effects of channel size on anadromous salmonid passage and spawning instream flow needs in smaller streams; basing instream flow standards on clearly defined objectives; using biological and hydrological criteria that can be expressed as testable hypotheses; developing a monitoring program that tests the hypotheses; avoiding cumulative diversion rates that adversely affect habitat downstream in the watershed; restricting on-stream impoundments only to cases where they do not affect anadromous salmonids either locally or downstream; generally operating on-stream dams to allow passage, prevent losses of fish to diversion, avoid causing cumulative effects on habitat downstream, and control exotic species; and considering the potential for future recolonization of habitat lost due to development.

Report Outline

There are ten main chapters in this report, followed by references and appendices containing more detailed supporting technical information and data.

- Chapter 1 provides background information on the Policy, its general applicability, and the target resources that are being protected.

- Chapter 2 identifies general features of protectiveness relative to instream flow needs of anadromous salmonids. Important habitat and biological needs potentially affected by the Policy are identified, and their dependence on various instream flow attributes discussed. Important flow requirements are summarized and protective metrics are identified for assessing each habitat need.

- Chapter 3 describes the four potential elements of the Policy for which protective alternatives were developed.

  Three policy elements place restrictions on the timing and amount of flow diverted:

  - Diversion Season – The period during which new diversions could be permitted without adversely affecting anadromous salmonids and their habitat.

- Minimum Bypass Flow (MBF) – The minimum instream flow rate that is protective of anadromous salmonid spawning and passage. It is the flow rate of water that must be moving past the point of diversion before water may be diverted under a permit.

- Maximum Cumulative Diversion (MCD) –The maximum amount of water, either by flow rate or volume, that may be withdrawn from a watershed by multiple diverters before new diversions begin to negatively impact the natural instream flow variability needed for maintaining adequate channel structure that protects anadromous salmonid habitat.

The last policy element places restrictions on instream barriers:

- Permitting of On-Stream Dams – Measures recommended for protection of instream flows and anadromous salmonid habitat in situations where existing unauthorized dams occur or new on-stream dams are proposed.

- Chapter 4 describes the data collection and analytical approach used to evaluate the protectiveness of the three Policy elements restricting flow.

The next four chapters describe the protectiveness of each of the four elements and include:

- Chapter 5, which describes the Policy element alternative criteria restricting diversion season, and evaluates their protectiveness.

- Chapter 6, which describes the Policy element alternative criteria restricting minimum bypass flow, and evaluates their protectiveness.

- Chapter 7, which describes the Policy element alternative criteria restricting maximum cumulative diversion rates, and evaluates their protectiveness.

- Chapter 8, which describes the Policy element alternative criteria related to the permitting of on-stream dams, and evaluates their protectiveness.

The last two chapters present further issues for protectiveness related to implementation of the Policy:

- Chapter 9 describes general fish passage and screening protection needs at diversion and dam facilities.

- Chapter 10 presents attributes and recommendations for an effectiveness monitoring program designed to assess the protectiveness of the Policy. The data gathered in the effectiveness monitoring program could be used to provide the supporting basis for future revisions to the Policy.

The information and results detailed in these chapters are summarized below. The information in this report will ultimately be integrated into the SED, where the various Policy elements will be evaluated for effects on non-target aquatic resources and other environmental resources.

Definition of Protectiveness

Because anadromous salmonid species listed under the federal and California Endangered Species Acts (ESA) inhabit the Policy area, the protectiveness of the Policy elements should be conservative (i.e., risk averse) and have broad applicability over the range of streams and channels directly or indirectly used by these species. At the same time, the Policy needs to be relatively simple to understand and apply. Attributes of instream flow and diversions that are associated with protectiveness for anadromous salmonids and that were considered in this evaluation include:

- Having flows that support important biological functions (e.g., spawning) available during the seasons they are needed.
- Providing a minimum bypass flow (below diversions) that creates suitable upstream passage, spawning, incubation, emergence, and rearing conditions.
- Allowing within- and across-year, natural flow variability to maintain suitable channel morphology, riparian habitat, and upstream/downstream passage conditions.
- Maintaining connectivity of habitats, by providing unobstructed upstream and downstream passage at dams and diversions.
- Providing protective screens to prevent loss of fish into diversion canals.
- Limiting the amount of water that can be cumulatively withdrawn from a system (both above and within the range of anadromous salmonids) to avoid or minimize impacts to downstream habitats.
- Maintaining the natural upstream to downstream transport of energy and materials (e.g., sediment, wood, food) that are important for the sustainability of anadromous salmonids and their habitats.

Methods for Analyzing the Protectiveness of Policy Element Alternative Criteria

Policy element alternative criteria were assessed for protectiveness by identifying their effects on important anadromous salmonid habitat components, including: upstream passage, spawning and incubation, juvenile winter rearing, smolt outmigration, channel and riparian maintenance, and estuarine habitat and connectivity to the Pacific Ocean. A particular flow-related alternative was considered protective if its effects on habitat components were either undetectable, meaning it caused no effect relative to unimpaired flow conditions; or minimal, meaning it would cause non-biologically significant effects relative to unimpaired flow conditions. Because the elements related to instream barriers were all directed toward protecting anadromous salmonids, the assessment of these elements was focused on the sufficiency of their protection of salmonids and their habitat.

In addition to reviewing existing literature and data related to the flow needs of anadromous salmonids and their habitat, physical and hydraulic cross-sectional data were collected from 13 streams within the Policy area in late summer of 2006. These data were used to specifically assess the effects of the flow-related elements on anadromous salmonid upstream passage and spawning habitat availability, as these two fishery attributes could be most directly related to the effects of diversion using numerical habitat-flow criteria. Impaired flow time series (i.e., with diversion) were compared with estimated unimpaired flow conditions (i.e., without diversion). This provided an estimate of the extent to which each flow-related element could affect primarily anadromous salmonid passage and spawning habitat availability, but also other habitat needs as well.

Overview of Policy Element Alternative Criteria

As described above, the proposed Policy consists of four elements intended to protect fishery resources, specifically targeting anadromous salmonids. Alternatives proposed for the three Policy elements restricting flow diversions (diversion season, minimum bypass flow, and maximum cumulative diversion) are summarized in Table 1. Alternatives proposed for the element restricting instream barriers are summarized in Table 2. Tables 3, 4, 5, and 6 summarize the relative protectiveness of each of the alternatives on a policy element-specific basis.

Table 1. Policy Element Alternatives Proposed to Restrict Diversions.

Diversion Season (DS)	Minimum Bypass Flow (MBF)	Maximum Cumulative Diversion (MCD)
DS1. 12/15 – 3/31 **DS2.** Year Round **DS3.** 10/1 – 3/31	**MBF1.** February median daily flow **MBF2.** 10% Exceedance Flow **MBF3.** Drainage Area (DA) < 290 mi^2: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ Drainage Area > 290 mi^2: $Q_{MBF} = 0.6\ Q_m$ Q_m = unimpaired mean annual flow (cfs); For streams above anadromous habitat, DA is determined at the upper limit of anadromy **MBF4.** Drainage Area < 0.11 mi^2: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ Drainage Area = 0.11-500 mi^2: $Q_{MBF} = 5.1\ Q_m\ (DA)^{-0.71}$ Drainage Area ≥ 500 mi^2: $Q_{MBF} = 0.06\ Q_m$ For streams above anadromous habitat, DA is determined at the upper limit of anadromy	**MCD1.** MCD Rate = 15% of 20% Winter (12/15-3/31) exceedance flow **MCD2.** MCD Rate = 5% of 1.5 yr flood peak flow **MCD3.** MCD Volume = 10% estimated unimpaired flow (no restriction on diversion rate) **MCD4.** MCD Rate = diversion rate which results in a maximum reduction of the time flow is above the MBF to ½ day during a 1.5 yr flood event

Table 2. Policy Element Alternative Criteria Proposed to Restrict Instream Barriers.

Stream Class	Permitting of On-stream Dams (DP)
Class I	**DP1.1** On-stream dams may not be issued water right permits. **DP1.2** New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. Fish passage and screening is provided; 2. A passive bypass system is provided to bypass the minimum instream flow requirements; 3. An exotic species eradication plan is implemented; 4. A gravel and wood augmentation plan or bypass system is implemented; and 5. Disturbed riparian habitat will be mitigated
Class II	**DP2.1** On-stream dams may not be issued water right permits. **DP2.2** New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. A passive bypass system is provided to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.

Table 2. Policy Element Alternative Criteria Proposed to Restrict Instream Barriers.

Class II (cont)	**DP2.3** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.
Class III	**DP3.1** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. The on-stream dam will not dewater a Class II stream; and 2. The on-stream dam will cause less than 10% cumulative instantaneous flow impairment at locations where fish are seasonally present. **DP3.2** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; and 3. A gravel and wood augmentation plan or bypass system is implemented. **DP3.3** A water right permit may be considered for an on-stream dam.

Diversion Season

A summary of the regional protectiveness of the diversion season Policy element alternative criteria is presented in Table 3. The protectiveness analysis indicated that water temperatures may become critical before October 1 and after March 31 and could be adversely affected by new diversions. Maintaining protective minimum bypass flow and maximum cumulative diversion criteria would preclude any adverse effects of flow diversion to anadromous salmonid habitat between October 1 and December 15.

Table 3. Summary of Protectiveness of Diversion Season (DS) Alternatives.

Policy Element: Diversion Season		
Alternative	**Regionally Protective?**	**Basis**
DS1: 12/15 – 3/31	Yes	Start date is protective of water temperatures that are suitable for summer habitat and fall upstream migration. End date avoids adverse water temperature effects on steelhead incubation and smolt outmigration.
DS2: Year Round	No	New diversions cannot be permitted during the late spring, summer, and early fall because instream flows during these periods generally limit anadromous salmonid rearing habitat quantity and quality in the Policy area.
DS3: 10/1 – 3/31	Yes	Start date is protective of water temperatures that are suitable for summer habitat and fall upstream migration. End date avoids adverse water temperature effects on steelhead incubation and smolt outmigration.
Biological Recommendation:	**Apply Alternative DS3**	

Minimum Bypass Flow

A summary of the regional protectiveness of the minimum bypass flow (MBF) Policy element alternative criteria is presented in Table 4. The protectiveness analysis indicated that the MBF provides the first level of protection for upstream passage and spawning habitat during the diversion season, whereas the maximum cumulative diversion rate provides a second order (i.e., lower) level of protection. Two of the four alternative criteria were previously identified: DFG-NMFS (2002; MBF1) and MTTU (2000; MBF2). The other two alternative criteria, MBF3 and MBF4, were developed based on a review of regional data describing upstream passage and spawning habitat-flow needs, and were considered to define upper and lower bounds of instream flow needs, respectively.

Table 4. Summary of Protectiveness of Minimum Bypass Flow (MBF) Alternatives.

Policy Element: Minimum Bypass Flow		
Alternative	**Regionally Protective?**	**Basis**
MBF1: February Median Daily Flow	Partially	Protective of upstream passage and spawning habitat flow needs in streams draining more than about 5 mi^2. Under-protective in smaller streams.
MBF2: 10% Exceedance Flow	Partially	Protective of upstream passage and spawning habitat flow needs in streams draining more than about 4 mi^2. Under-protective in smaller streams.
MBF3: <u>Drainage Area (DA[1]) < 290 mi^2</u>: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ <u>Drainage Area > 290 mi^2</u>: $Q_{MBF} = 0.6\ Q_m$ Q_m = unimpaired mean annual flow (cfs); For streams above anadromous habitat, DA is determined at the upstream limit of anadromy	Yes	Generally protective of upstream passage and spawning habitat flow needs across a wide variety of stream sizes in the region. Protects winter rearing habitat as well. Does not affect outmigration, channel and riparian maintenance, and estuarine habitat flow needs.
MBF4: <u>Drainage Area < 0.11 mi^2</u>: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ <u>Drainage Area = 0.11-500 mi^2</u>: $Q_{MBF} = 5.1\ Q_m\ (DA)^{-0.71}$ <u>Drainage Area ≥ 500 mi^2</u>: $Q_{MBF} = 0.06\ Q_m$ For streams above anadromous habitat, DA is determined at the upstream limit of anadromy	No	Protective of upstream passage and spawning habitat flow needs in some streams, but a majority of streams in the region are under-protected with respect to upstream passage and spawning habitat flow needs for steelhead and coho. Appears to under-protect Chinook upstream passage and spawning habitat flow needs in nearly all streams. In all cases, the MBF is sufficiently low that adverse effects could occur to upstream passage and spawning opportunities even with small diversion rates.
Biological Recommendation:	**Apply Alternative MBF3**	

[1] Drainage area (DA) is evaluated in square miles.

Maximum Cumulative Diversion Rate

A summary of the regional protectiveness of the maximum cumulative diversion (MCD) Policy element alternative criteria is presented in Table 5. The analysis of protectiveness suggested that the MCD element has the greatest effect on channel and riparian maintenance conditions. The analysis indicated, however, that there is no clear guidance for specifying a protective flow threshold level of MCD with respect to avoiding changes to channel morphology that would adversely impact salmonid habitat. The change in channel morphologic response was predicted to occur roughly proportionally to the change in the bankfull flow rate resulting from the MCD (approximated by the change in the 1.5 year peak flow event). However, the level of change in channel morphologic response that would adversely affect salmonid habitat and production potential could not be determined with certainty. Therefore, in the absence of a clearly defined protective flow threshold level for channel and riparian maintenance, no additional alternative MCD criteria were developed. Instead, the MCD criteria proposed by DFG-NMFS (2002) and MTTU (2000) were assessed for protectiveness. Assessment of protectiveness was based on the relative changes to channel morphology and effects on upstream passage and spawning habitat.

Restrictions on Permitting of On-Stream Dams

The DFG-NMFS (2002) Draft Guidelines recommended against permitting on-stream dams on streams that are classified as Class I or II pursuant to the California Department of Forestry (CDF) stream classification system. In general, the analysis completed as part of this study indicated that on-stream dams are not protective of anadromous salmonids unless they are constructed in such a way that they do not: (1) impede upstream or downstream passage where appropriate, (2) interrupt the downstream transport of bedload or larger pieces of wood during high flows, (3) provide habitat for non-native, exotic aquatic species that compete with or prey on juvenile salmonids, and (4) cause increased water temperatures downstream. The DFG-NMFS (2002) Draft Guidelines and selected variations thereof were considered for their protectiveness (Table 6).

Fish Passage and Protection Measures

The analysis of protectiveness concurred with general conclusions of the DFG-NMFS (2002) Draft Guidelines regarding the importance and protectiveness of requiring fish passage and screening requirements as part of diversions.

Table 5. Summary of Protectiveness of Maximum Cumulative Diversion (MCD) Alternatives.

Policy Element: Maximum Cumulative Diversion		
Alternative	**Regionally Protective?**	**Basis**
MCD1 (Rate): MCD Rate = 15% of 20% Winter (12/15-3/31) Exceedance Flow	Yes	Generally allows the lowest instantaneous rate of diversion. Likely results in negligible channel change over the long term.
MCD2 (Rate): MCD Rate = 5% of 1.5 yr flood peak flow (annualized series)	Yes	Allows a higher instantaneous rate of cumulative diversion than MCD1 and MCD4. This alternative will likely result in long term adjustment and reduction in channel size, but the potential change is thought to be minor in terms of bankfull width, depth, and surface grain size distribution. Basing a MCD rate on the 1.5 year flood peak flow rate more directly accounts for the relation between channel size and instream flow need.
MCD3 (Volume): MCD Volume = No restriction on diversion rate, stop diversion after the ratio of total cumulative diverted volume to unimpaired runoff volume = 10%	Partially	May not be protective of coho and Chinook upstream passage and spawning habitat flow needs during the first month of the diversion season (for DS1 or DS3) in dry and average years. May not be protective of channel maintenance flow needs. Protectiveness is related more defensibly to flow rate rather than volume.
MCD4 (Rate): MCD Rate = Diversion rate that corresponds to a half-day reduction in the duration of time that flow is above the MBF during a 1.5 year flood event	Yes, but impractical to apply	Provides a comparable level of instantaneous diversion rate to MCD1 (15% of 20% winter exceedance flow). Likely results in negligible channel change over the long term. Impractical because its implementation requires detailed hourly hydrograph information for each stream.
Biological Recommendation:	**Apply Alternative MCD2.** There is uncertainty in defining the maximum amount of change in channel maintenance flows that could occur that would still be protective of anadromous salmonid habitat. Regardless of which MCD alternative is chosen for the Policy, effectiveness monitoring data collected over a period of 10 to 20 years would be needed to assess whether the Policy could be reopened in the future to include a less restrictive MCD that would still be protective of channel maintenance flows while offering the opportunity for higher diversion rates.	

Table 6. Summary of Protectiveness of the On-Stream Dam Permitting Restrictions (DP) Alternatives.

Policy Element: Restriction of On-Stream Dams/Reservoirs			
Stream Class	**Alternative**	**Regionally Protective?**	**Basis**
Class I	**DP1.1** On-stream dams may not be issued water right permits.	Yes	DFG-NMFS (2002) Guidelines
	DP1.2 New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. Fish passage and screening is provided; 2. A passive bypass system is provided to bypass the minimum instream flow requirements; 3. An exotic species eradication plan is implemented; 4. A gravel and wood augmentation plan or bypass system is implemented; and 5. Disturbed riparian habitat will be mitigated.	Partially – dependent on success of mitigation measures	Although this alternative allows some existing on-stream dams on Class I streams to receive water right permits, it contains criteria to mitigate existing adverse impacts to anadromous salmonids and protect and/or restore important ecosystem functions to those streams.
Class II	**DP2.1** On-stream dams may not be issued water right permits.	Yes	DFG-NMFS (2002) Guidelines
	DP2.2 New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. A passive bypass system is provided to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.	Yes	Although this alternative allows some existing on-stream dams on Class II streams to receive water right permits, it contains criteria design to protect and/or restore important ecosystem functions to those streams and still afford a high level of protectiveness.

Table 6. Summary of Protectiveness of the On-Stream Dam Permitting Restrictions (DP) Alternatives.

Class II (cont)	**DP2.3** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.	Partially	Multiple on-stream dams on Class II streams have potential to cause adverse cumulative effects on downstream spawning and rearing habitat quantity and quality in Class I streams.
Class III	**DP3.1** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. The on-stream dam will not dewater a Class II stream; and 2. The on-stream dam will cause less than 10% cumulative instantaneous flow impairment at locations where fish are seasonally present.	Partially	DFG-NMFS (2002) Guidelines Protectiveness could be increased via inclusion of additional fish protection measures as provided in DP 3.2.
	DP3.2 A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; and 3. A gravel and wood augmentation plan or bypass system is implemented.	Yes	This alternative contains criteria that must be met before on-stream dams would be allowed on Class III streams. The criteria are designed to protect and/or restore important ecosystem functions, and provide an additional level of protectiveness not provided by the DFG-NMFS (2002) Guidelines.
	DP3.3 A water right permit may be considered for an on-stream dam.	Partially	With no restrictions imposed, cases would likely occur where protectiveness would not be assured. Multiple on-stream dams built without restrictions on Class III streams are likely to cause adverse cumulative effects on downstream spawning and rearing habitat quantity and quality in Class I and II streams.
Biological Recommendation:		**Apply DP1.1, DP2.2 and DP3.2**	

Site-Specific Studies

Site-specific studies provide the most detailed and accurate information regarding instream flow needs for a particular stream. Such studies can be conducted by applicants seeking to adjust/reduce specific restrictions of diversion that are imposed by various Policy elements. Site-specific studies should be designed in consultation with and approved by applicable state and federal resource agencies including the California Department of Fish and Game, and the National Marine Fisheries Service. The results of such studies could then be evaluated by respective resource agencies to determine whether and to what extent adjustments could be made to the Policy elements in question.

Effectiveness Monitoring Recommendations

The protectiveness analyses suggested certain levels or attributes of each Policy element that are protective of anadromous salmonids and their habitat. Once the Policy is implemented, the next step would be to initiate a monitoring program to evaluate the effectiveness of the Policy for protecting anadromous salmonids. The effectiveness monitoring program described in this report is designed to assess the effectiveness of the Policy elements that are aimed at maintaining minimum bypass flows, protecting natural flow variability, and avoiding cumulative impacts. Nine steps are recommended and described for establishment of the effectiveness monitoring program, and a study design outline is provided as a guide to the approximate level of effort that may be required for its implementation. The final design of the effectiveness monitoring program will reflect technical input from a Monitoring Oversight Committee and the availability of funds.

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1. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The State Water Resources Control Board (State Water Board) is responsible for administering water rights in the State of California. The State Water Board's mission is to preserve, enhance and restore the quality of the State's waters, and ensure their proper allocation and efficient use for present and future generations. In administering the water right process, the State Water Board's Division of Water Rights (Division) must consider the effects of its actions on the public trust, the public interest, and the environment, including adverse impacts on threatened and endangered species (SWRCB 2005).

Assembly Bill 2121 (Stats. 2004, ch. 943, §1-3) added sections 1259.2 and 1259.4 to the California Water Code. Water Code section 1259.4 (as amended in July 2005) requires the State Water Board to adopt by January 1, 2008, a policy for maintaining instream flows in coastal streams from the Mattole River to San Francisco, and in coastal streams entering northern San Pablo Bay. The policy, termed the North Coast Instream Flow Policy, (hereinafter "Policy") will be prepared and adopted in accordance with state policy for water quality control for the purposes of water right administration.

The State Water Board consequently contracted in May 2006 with a team led by Stetson Engineers (Stetson), and including R2 Resource Consultants (R2) to help develop the Policy and supporting technical and environmental documents. The Stetson Team is in the process of assisting the State Water Board in preparing the Policy, in accordance with Water Code section 1259.4. The State Policy for Water Quality Control requires preparation of a Substitute Environmental Document (SED) that analyzes the potential significant adverse environmental impacts, including cumulative impacts, of the Policy. The SED replaces an Environmental Impact Report (EIR), pursuant to Public Resources Code section 21080.5. The SED must include, at a minimum, a Policy description, Policy alternatives, and mitigation measures to avoid or reduce the Policy's effects on the environment (SWRCB 2005).

In developing the Policy, Water Code section 1259.4 authorizes the State Water Board to consider the draft "Guidelines for Maintaining Instream Flows to Protect Fisheries Resources Downstream of Water Diversions in Mid-California Coastal Streams," which were developed by the California Department of Fish and Game (DFG) and National Marine Fisheries Service (NMFS) in 2002, referred to from here forward as the "DFG-NMFS (2002) Draft Guidelines." The DFG and NMFS recommended that permitting agencies (including the State Water Board), planning agencies, and water resource development interests use the DFG-NMFS (2002) Draft Guidelines when evaluating proposals to divert and use water from northern California coastal streams. The DFG-NMFS (2002) Draft Guidelines were specifically developed pursuant to respective agency mandates and missions to protect and restore endangered and threatened anadromous salmonids and their habitats (DFG-NMFS 2002). The Division currently considers the DFG-NMFS (2002) Draft Guidelines when evaluating water right applications, but they have not been adopted as formal State Water Board policy (SWRCB 2005).

As part of the overall Policy review process, the Division requested that Stetson and R2 evaluate the technical basis and rationale behind the DFG-NMFS (2002) Draft Guidelines and assess its overall protectiveness to anadromous salmonids (i.e., steelhead trout [*Oncorhynchus mykiss*], coho salmon [*O. kisutch*], and Chinook salmon [*O. tshawytscha*]), which are the target aquatic resources for which the DFG-NMFS (2002) Draft Guidelines were developed. In addition, the State Water Board requested that Stetson-R2 evaluate the technical basis and level of resource protectiveness provided by other alternative criteria, and document the science forming the basis. The evaluation included identification and analysis of possible alternative criteria and/or refinements to the DFG-NMFS (2002) Draft Guidelines that might afford a broader, regional level of protectiveness and restoration potential to the target resources in more streams, in terms of biologically desirable instream flows and permissible diversion rates. Alternative criteria were developed based on comments received during the California Environmental Quality Act (CEQA) scoping process and from earlier reviews of the DFG-NMFS (2002) Draft Guidelines.

Given the focus by DFG and NMFS on anadromous salmonids as the target resource based on requirements of the Endangered Species Act (ESA), the emphasis of this report is on the technical evaluation of the levels of protectiveness offered these species by various Policy elements alternatives. The elements, described in Section 1.4, provide a clearly defined framework for evaluating the benefits of implementing the Policy on anadromous salmonids. Use of the elements as a framework for evaluation is consistent with the history of the development of the DFG-NMFS (2002) Draft Guidelines, which is summarized in Appendix A.

This report is organized as follows:

- Chapter 1 provides important background information on the Policy purpose and applicability.
- Chapter 2 summarizes the important flow needs for anadromous salmonids and their habitat, and identifies specific quantitative criteria or other indirect measures used in assessing protectiveness.
- Chapter 3 identifies specific elements of the Policy, alternative criteria considered for each element, and how they were formulated.

- Chapter 4 describes the analytic methods and results of the evaluation of protectiveness of Policy elements restricting flow diversion.
- Chapter 5 discusses the protectiveness of alternative criteria identified for the Policy diversion season element.
- Chapter 6 discusses the protectiveness of alternative criteria identified for the Policy minimum bypass flow element.
- Chapter 7 discusses the protectiveness of alternative criteria identified for the Policy maximum cumulative diversion element.
- Chapter 8 discusses the protectiveness of alternatives identified for the Policy on-stream dam permitting element.
- Chapter 9 discusses the protectiveness of providing for fish passage and screening.
- Chapter 10 describes an effectiveness monitoring program designed to assess the protectiveness of the Policy.
- Chapter 11 is the list of references used in the report and appendices.
- Eleven appendices describe technical details and supporting references relied on in the main report.

The information in this report will ultimately be integrated into the SED, where the various Policy elements will be evaluated for effects on other non-target aquatic resources.

1.2 SPATIAL APPLICABILITY OF THE POLICY

The Policy area encompasses coastal and inland channels located in Marin, Sonoma, and portions of Napa, Mendocino, and Humboldt counties (Figure 1-1). The Mattole River constitutes the northern-most coastal basin under consideration, and the Napa River the eastern-most basin draining into San Pablo Bay. Major coastal salmon and steelhead stream basins from north to south include the Mattole, Ten Mile, Noyo, Big, Navarro, Garcia, Gualala, Russian, Walker, and Lagunitas drainages. Major salmon and steelhead stream basins draining to San Pablo Bay include Sonoma Creek and the Napa River. There are also numerous smaller basins draining directly into the Pacific Ocean and San Pablo Bay that either currently or historically supported anadromous salmonids. Policy area streams range widely in size as well as geologic, geomorphic, hydraulic, hydrologic, and biologic characteristics. Such characteristics manifest themselves in streams that differ in channel size, channel slope, valley

Figure 1-1. Policy area, pursuant to Water Code §1259.4, as required by Assembly Bill 2121.

confinement, channel incision, topographic relief, soil type, hillslope and riparian vegetation, annual precipitation, and other abiotic and biotic features. As such, they present a variety of channel conditions that may be utilized by anadromous salmonids over a range of temporal and spatial scales that render coincident flow responses highly variable. Specific physical features of the Policy area influencing stream flow and fish habitat are described in greater detail in Appendix B.

The Policy likely will set restrictions on diversions in the Policy area that are conservatively protective for anadromous salmonids and their habitat. These restrictions may be superseded on a case-by-case basis if a site-specific study can demonstrate, for example, that higher water usage or a watershed-based approach used to coordinate usage amongst diverters to maximize water usage would still be protective of anadromous salmonids and their habitat.

There is no distinction made in the analysis of the protectiveness of the Policy concerning the value of different streams containing historical habitat for anadromous salmonids. The NMFS follows a similar principle when establishing critical habitat ranges. Critical habitat is defined under Section 3 of the ESA as (1) specific areas within the geographical area occupied by the species at the time of listing, on which are found those physical or biological features that are essential to the conservation of the listed species and that may require special management considerations or protection, and (2) specific areas outside the geographical area occupied by the species at the time of listing that are essential for the conservation of a listed species (70 FR 52488). Establishing equal importance to critical habitat in different streams recognizes (1) the species' use of diverse habitats and underscores the need to account for all of the habitat types supporting the species' freshwater and estuarine life stages, from small headwater streams to migration corridors and estuarine rearing areas, and (2) the importance of natural variability in habitat use (e.g., some streams may have fish present only in years with abundant rainfall, whereas other streams may have better spawning habitat conditions during dry years) (65 FR 7764). Federal regulations further provide that unoccupied areas be designated when the present range would be inadequate to ensure the conservation of the species (50 CFR 424.12(e)). Similar fundamental principles apply to permitting of water right applications in a protective manner under the Policy. In view of the multitude of impacts to anadromous salmonids listed under the ESA and the degraded condition of populations that warrant listing, as broad an area should be protected as possible (as logically conditioned by historical range limits) to buffer against or offset temporary reductions in stock size that may occur locally. This need in part reflects uncertainty in the precise amount of habitat needed to sustain anadromous salmonid species in the Policy area, and uncertainty in the complex relations between minimum viable population size, habitat conditions and carrying capacity, and instream flows (e.g., Castleberry et al. 1996; IFC 2002). It also reflects the need to maintain diversity of habitat and flows for sustaining healthy aquatic ecosystems (Poff et al. 1997).

1.2.1 Applicability Upstream of Passage Barriers

Questions were raised during the CEQA scoping process regarding whether restrictions on diversion and on-stream dams need to be applied to streams above existing upstream passage barriers caused by human actions. For example, comments dated September 15, 2006, by Wagner & Bonsignore Consulting Civil Engineers, James C. Hanson Consulting Civil Engineer, and the law firm Ellison, Schneider & Harris L.L.P. (Consulting Engineers), included a recommendation to limit restrictions on diversions to streams only where anadromous fish and habitat are currently sustainable.

There are numerous artificial barriers that have influenced historical distribution. Figure 1-2 depicts potential structural barriers identified by CalFish in their Passage Assessment Database [http://www.calfish.org]. These potential barriers include points of diversions which are usually assigned an unknown barrier status. Lifting Policy limitations above structural barriers would not be protective of the anadromous salmonid resource if the possibility exists that historically accessible habitat will be re-opened by correction of passage barriers. This has proven to be an effective, high-return method for restoring anadromous salmonid populations elsewhere (e.g., Roni et al. 2002).

Efforts have been made, and will likely continue, to inventory and characterize passage barriers throughout the Policy area, with the eventual goal of restoring runs upstream. For example, fish passage barrier surveys conducted by the Sonoma Ecology Center (SEC) in the Sonoma Creek watershed identified over 100 potential man-made barriers, including 23 full barriers and 48 partial (flow-dependent) obstacles to passage. Habitat was estimated to have been lost in approximately 170 miles of stream length due to barriers, amounting to approximately 25% of stream length in the freshwater portion of the Sonoma Creek watershed. It was hypothesized that the potential maximum fish population supported by available habitat may be reduced to a similar degree (SEC et al. 2004). Elsewhere, Taylor et al. (2003) visited 545 stream crossing sites and surveyed 183 of them for their potential as passage barriers in the Russian River watershed. They created a ranked list of 125 crossings for use by DFG in prioritizing the order in which specific barriers should be corrected. RTA (2003) similarly visited and assessed passage conditions at 90 sites in Marin County.

In summary, current trends in fisheries management within the Policy area are to identify and correct passage barriers caused by human actions. Once barrier problems are corrected, it is likely that efforts will be undertaken to subsequently improve habitat conditions above the former barrier location (e.g., DFG 1996; Flosi et al. 1998; DFG 2002; Roni et al. 2002; DFG 2004). Hence, the Policy should also apply above existing barriers to stream reaches potentially supporting anadromous salmonids, or that influence flow and habitat in such downstream reaches, in anticipation of restored runs in the future.

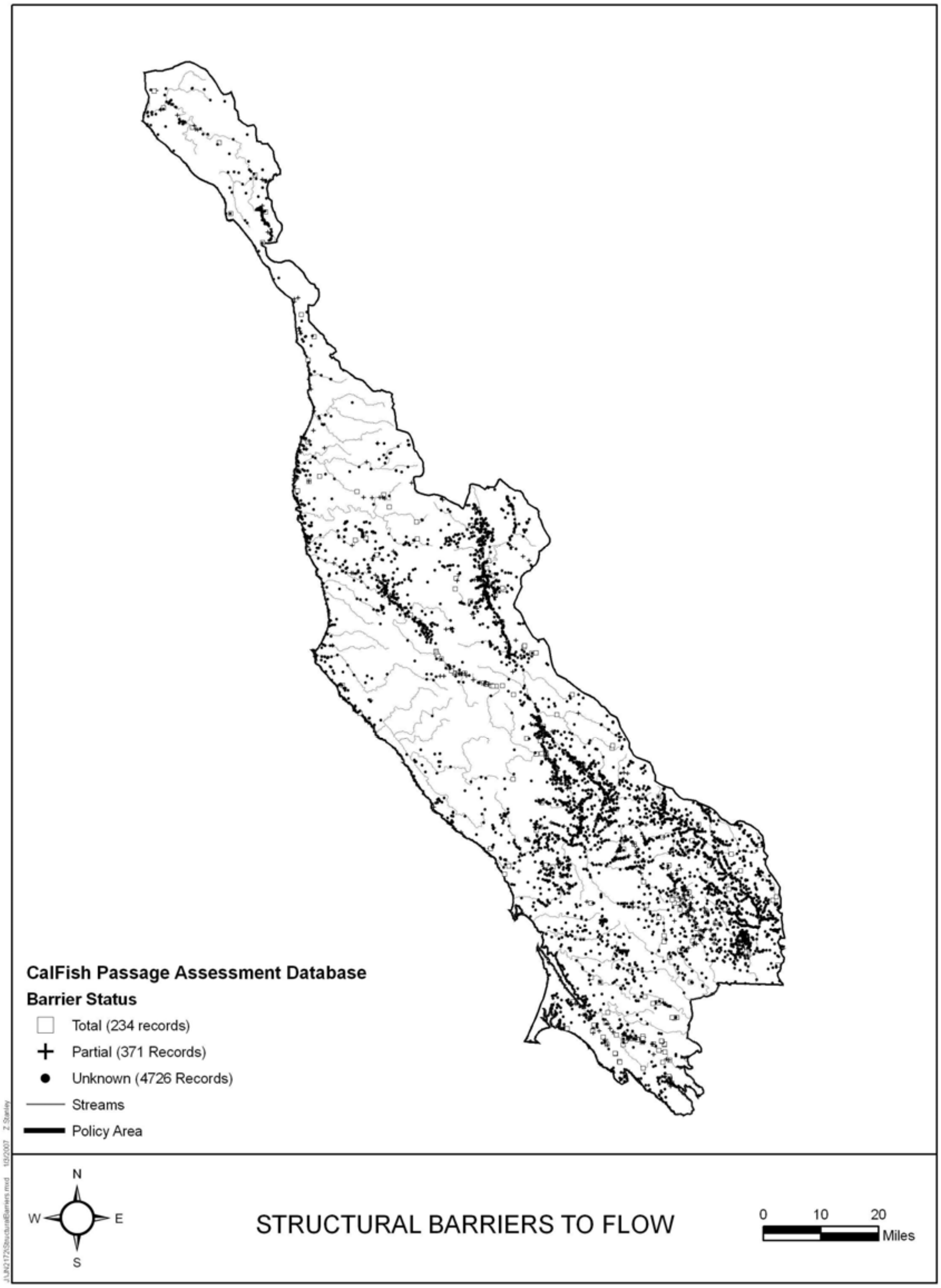

Figure 1-2. Potential fish passage barriers identified in CALFISH for the Policy Area.

1.2.2 Applicability to Ephemeral Streams

A similar question was raised in the scoping comments regarding the protection of winter flows in ephemeral streams. Studies have shown that even relatively small, ephemeral streams (i.e., streams that flow seasonally or in response to storm events, but that typically become dewatered or dry during a portion of the year) have been used for spawning and rearing by anadromous salmonids. In these instances, adult fish move into and spawn within the streams when they contain flow, and assuming flows remain sufficient throughout egg incubation and fry emergence, then, as flows recede, newly emerged fry move downstream to larger systems where flow conditions are more suitable for rearing. For example, steelhead trout are capable of spawning in tributaries in the Policy area that dry up in summer, where fry emigrate downstream soon after hatching (Moyle 2002). Juveniles may also move up into tributaries to overwinter and then emigrate in the spring before the stream dries up. Coho salmon juveniles for example have been observed to use ephemeral tributaries for over-winter rearing (e.g., Ebersole et al. 2006). For these reasons, and because of potential cumulative effects of upstream diversion on downstream flows and gravels, ephemeral streams also require flow protection.

1.2.3 Stream Classification for Defining Spatial Applicability of Policy Elements

The spatial applicability of specific Policy elements will depend in part on the type of stream channel potentially affected by granting an application for water right. There are correspondingly two important implementation issues for the Policy related to the type of stream concerned: (1) Which streams the Policy should be applied to in order to be protective toward anadromous salmonids, and (2) whether different stream types (or classes) require different levels of protection depending on location in the channel network and biological characteristics. These types of issues have been and can be addressed by the use of a stream classification system. Such a system can be identified here for purposes of implementing the Policy and protecting anadromous salmonids. The DFG-NMFS (2002) Draft Guidelines referenced an existing system developed by the California Department of Forestry (CDF; Cal. Code Regs., tit. 14, section 916.5, Table 1) which defines three stream type classes. Appendix D includes a review of issues related to stream classification in the context of setting protective instream flow standards, in which it was concluded that the CDF classification system can be used with the addition of clarifying language including distinguishing between anadromous and non-anadromous fish species. The corresponding stream classification definitions given in Section 916.5, Table 1 are as follows:

- Class I – Fish always or seasonally present onsite, includes habitat to sustain fish migration and spawning;

- Class II – Fish always or seasonally present offsite within 1,000 feet downstream and/or aquatic habitat for non-fish aquatic species; excludes Class III waters that are tributary to Class I waters;
- Class III – No aquatic life present, water course showing evidence of being capable of sediment transport downstream to Class I or Class II waters under normal high water flow conditions.

1.3 ANADROMOUS SALMONID SPECIES OF CONCERN

There are three anadromous species of concern found in the Policy area: steelhead trout, coho salmon, and Chinook salmon. Of these, steelhead trout have the broadest, and Chinook salmon the narrowest historical distribution. Current distributions are much reduced over historical extents because of habitat degradation, habitat loss, and other factors caused by human settlement and development. For purposes of the Policy, it was assumed that historically available habitat could become useable again through appropriate habitat restoration, and implementation of improved land and water management practices. It is because of the currently low population numbers that NMFS and DFG have listed various Evolutionarily Significant Units (ESUs) of each species as threatened, endangered, and/or species of concern within the Policy area, as defined under the federal Endangered Species Act (ESA), and/or the California Endangered Species Act (CESA). Critical habitat designations by NMFS indicate the likely range that could support salmonid populations. Actions adversely affecting critical habitat cause “take” as defined under the ESA.

The important general features of the three species’ life histories and distributions that may be affected by implementation of the Policy are summarized in Appendix C.

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2. PROTECTING ANADROMOUS SALMONID HABITAT FLOW NEEDS

The State Water Board has continuing authority to protect public trust uses and to prevent the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water in the state, regardless of basis of right. Accordingly, the State Water Board must carefully consider and decide on the appropriate level of resource protectiveness that must be achieved (to meet its public trust responsibilities) via Policy adoption and implementation. In the case of anadromous salmonids, this is a difficult proposition and requires an understanding of important life history functions and flow dependence. A review of the literature on this is provided in Appendix D which includes an overview of the issues and problems related to defining and quantifying protective instream flow levels. Specific flow-related criteria are reviewed and selected for analysis in Appendix G. This chapter summarizes instream flow requirements and criteria of anadromous salmonids for each important life history stage potentially influenced by winter diversions under the Policy. It has previously been shown that new diversions cannot be permitted during the late spring, summer, and early fall because instream flows during this period are generally limiting anadromous salmonid rearing habitat quantity and quality in the Policy area (e.g., SEC et al. 2004).

2.1 UPSTREAM PASSAGE FLOW NEEDS

Adult salmonids returning to streams to spawn must do so at the proper time and with sufficient energy to complete their life cycle (Bjornn and Reiser 1991). Delays in migration may impact at least a portion of the spawning population and lead to reduced egg and fry production. Upstream migration appears generally to coincide with the decline in flow following a runoff event, and thus it is the occurrence of a flow pulse that appears to be most important, not necessarily its magnitude. Furthermore, the requisite magnitude of attraction flow to the mouth of a stream may be larger than the minimum passage flow, but its magnitude is uncertain (SWRCB 1995).

In general, the degree to which stream flow conditions may become problematic to upstream migrating adults relates directly to their migration period. Thus, stocks that migrate during the late fall and winter under high stream flow conditions (e.g., winter steelhead) would be less likely to encounter flow related impediments, than stocks that migrate in late summer or early fall, such as Chinook salmon. The approximate dates of upstream passage for anadromous salmonid species in the Policy area, coinciding with the proposed range of Policy diversion season element alternative criteria defining the winter diversion season, are (see Chapter 3 and Appendices C and G):

Steelhead: 11/1 – 3/31
Coho: 10/1 – 2/28
Chinook: 10/1 – 1/31

The level of flow necessary for upstream passage through shallow water constrictions depends on the ability of fish to negotiate specific water depths. This ability reflects predominantly body size, with larger bodied Chinook requiring deeper water than smaller bodied coho salmon. Criteria for critical depths needed for successful upstream passage are discussed in detail in Appendix G. Table 2-1 presents summary upstream passage criteria considered applicable to evaluating protectiveness of the Policy for the three anadromous species of concern.

Table 2-1. Minimum Upstream Passage Depth Criteria for Analyzing the Protectiveness of the Policy for Upstream Passage Needs (see Appendix G for sources).

Species	Minimum Passage Depth Criterion (ft)
Steelhead	0.7
Coho	0.6
Chinook	0.9

In addition to riffle constrictions, physical barriers such as waterfalls, debris jams, and diversion structures can delay or prevent upstream migration of adults. Low stream flow can directly influence the passage conditions at potential barriers, but the flow needed for upstream passage is highly specific to site geometry, more so than riffle passage. It is generally not feasible to develop a regional policy protecting passage over such obstructions without collecting extensive data, and thus it must be assumed that a Policy protecting riffle passage at the regional scale will also protect upstream passage over select channel obstructions.

Other anadromous salmonid habitat needs influenced by instream flow include cover, water temperature, dissolved oxygen, and turbidity. These needs are discussed in Appendix D. They are generally assumed to be associated with secondary effects of flow diversion during the winter compared with flows needed for sufficient passage depth.

2.2 SPAWNING AND INCUBATION HABITAT FLOW NEEDS

Flow is an important influence on the reproductive capacity of anadromous salmonid populations. The conditions that exist during the period in which eggs are deposited in the gravels, embryos incubate and hatch, and fry subsequently emerge can be primary determinants of year-class-strength and the ultimate numbers of fish that may be recruited into the population. Spawning and egg incubation success is dependent on both the quantity and quality of spawning habitat, both of which are modified by the amount of stream flow.

Stream flow influences the amount of spawning habitat available within a stream by determining the extent to which spawning gravels are wetted with suitable combinations of water depth and velocity. Embryos in redds constructed closer to the channel thalweg may under certain circumstances be more vulnerable to effects of scour and fine sediment deposition than embryos in redds constructed higher up on the cross-section. Large decreases in stream flow can result in redd dewatering. Low winter flows may also expose eggs to freezing temperatures. Adverse effects include reduced embryo growth and alevin size, accelerated or delayed hatching and emergence depending on temperature, and mortality.

Stream flow also plays an important role in providing and maintaining the quality of the spawning gravels. High flows mobilize and transport fine sediments from spawning gravels, which increased gravel permeability and facilitates transport of oxygen to, and metabolic wastes from the developing embryos.

In addition to incubation duration, the timing of spawning of salmon and trout in streams is also closely linked to water temperatures. In the streams within the mid-California coastal area, water temperatures are important determinants of when fish spawn, how long the eggs incubate (development is directly related to water temperature), and when fry emerge. Flow diversion can lead directly and indirectly to thermal alteration due to changes in flow and condition of the riparian zone. The approximate dates of peak spawning by anadromous salmonid species in the Policy area, coinciding with the proposed range of Policy diversion season element alternative criteria defining the winter diversion season, are (see Chapter 3 and Appendices C and G):

Steelhead:	12/1 – 3/31
Coho:	11/1 – 2/28
Chinook:	11/1 – 1/31

The level of flow necessary for spawning reflects the size of the fish and other factors that influence habitat selection including depth, velocity, and spatial distribution and quantity of suitably-sized spawning gravel. Depths and velocities must be suitable over areas with suitable gravel at the correct time. Depth is generally limiting only in terms of shallowness, whereas there are lower and upper limits to suitable velocities for spawning. The criteria vary with species. As for upstream passage, larger bodied Chinook require deeper water than smaller bodied coho salmon. Criteria for critical depths and velocities needed for successful spawning are discussed in detail in Appendix G. Table 2-2 presents summary depth and velocity criteria considered applicable to evaluating protectiveness of the Policy alternatives for the three anadromous species of concern.

Table 2-2. Minimum Depth, Favorable Velocity, and Substrate Spawning Criteria for Analyzing the Protectiveness of the Policy for Spawning Habitat Needs (see Appendix G for sources).

Species	Minimum Depth (ft)	Favorable Velocities (ft/s)	Useable Substrate D_{50} (mm)
Steelhead	0.8	1.0-3.0	12-46
Coho	0.8	1.0-2.6	5.4-35
Chinook	1.0	1.0-3.0	11-78

The general number of days for spawning and incubation in the Policy area are presented in Table 2-3. It can be seen in the table that embryos in redds constructed in late winter/early spring generally emerge sooner after fertilization than from redds constructed earlier in the winter. This is because of increasing water temperatures in the late winter/early spring. The data used to generate these criteria are discussed in Appendix G.

Table 2-3. Summary of General Lengths of Incubation Time and Maximum Intragravel Residence Time from Initiation of Spawning to Emergence for Anadromous Salmonids in the Policy Area. The Total Duration Numbers were Used in the Analysis (see Appendix G for sources).

Species	Approximate Time to Emergence From Fertilization (days)		Total Duration of Vulnerability to Dewatering (days)	
	Nov 1–Feb 28	Mar 1–April 30	Nov 1–Feb 28	Mar 1–April 30
Steelhead	60	47	65	52
Coho	75	62	80	67
Chinook	90	70	95	75

2.3 JUVENILE WINTER REARING HABITAT FLOW NEEDS

The habitats that constitute rearing areas are diverse and perhaps more complex than any other life history stage. For some stocks of salmon and trout, the upper drainages represent spawning and initial rearing areas, where fry and juveniles can grow in relatively protected areas that are generally free from large predators, and that contain excellent water quality characteristics. The conditions afforded to fry and juvenile anadromous salmonids in many instances establish the overall carrying capacity of the stream and therefore factor directly into defining numbers of returning adults. Stream flow is an important determinant of the capacity of a stream to support a certain number of juvenile salmonids, through the direct influence on the distribution and quantity of water depths and velocities utilized by fry and juvenile salmonids, particularly at lower base flows when physical living space becomes limiting.

Water depths used by rearing salmonids can be quite variable depending on the factors associated with such depths, e.g., substrates, cover, food, velocity, predator density. Newly hatched fry often utilize the extreme edge habitats of a stream where velocities are low and there are few predators. As salmonid juveniles grow they are capable of using deeper waters with limits of use generally related to some other interrelated parameter such as velocity. Shifts in velocity usage by fish have also been observed seasonally, presumably in response to increased water flows and decreases in water temperature. The shifts are generally from higher velocities in the summer feeding periods to lower velocities during the winter holding periods. During these periods, coho salmon have been observed moving into side channels, alcoves and beaver ponds containing large woody debris for cover and overwintering habitat. The availability of high flow can influence accessibility to such habitat.

High flows are also important for maintaining juvenile habitat quantity and quality, through channel maintenance and flushing flows. In addition to transporting sediments from pools and cobble areas used for rearing and over-wintering, and riffles serving as food production areas, high flows are necessary to create habitat-structure in the form of large wood and boulder deposits. High flows are also needed to inundate riparian and floodplain vegetation that serve to increase bank stability, provide shade and contribute allochthonous (out of stream) materials/nutrients to the stream.

Rearing habitat locations are more widely dispersed in a stream network than passage, and spawning habitat locations and instream flow needs for juvenile salmonids are correspondingly more difficult to quantify. Specific types of rearing habitats, such as side channels in larger rivers, tend to have the most specific flow requirements at which they become connected with the main channel and experience flow-through. Such habitat can be especially important in larger channels for all three species. However, this and other types of rearing habitat are also more difficult to analyze for suitable instream flows because of scale-related effects where fish size is much smaller than channel size, such that depth-averaged velocities may not be a reasonable approximation of what juveniles are selecting.

Experience with Physical Habitat Simulation (PHABSIM) and other flow assessment methods indicates that minimum instream flows for juvenile salmonids as defined by depth and velocity distributions tend to be lower than minimum instream flows for adults and spawning, irrespective of channel size (Vadas 2000; R2 2004). Hence, for this analysis, it was assumed that flows that meet spawning habitat criteria will also provide sufficient water to protect juvenile rearing habitats.

2.4 OUTMIGRATION FLOW NEEDS

There is evidence that salmon and steelhead smolts migrate downstream to the ocean in the spring in large numbers in response to a variety of factors including high flows. Some factors act through influencing the onset of smolting, and appear to include water temperature, lunar rhythms, photoperiodicity, and annual physiological rhythms. Some research results point to the potential importance of the timing and duration of short-term flow changes to stimulating downstream migration of juvenile salmonids. Elevated water temperatures in late spring, which may be exacerbated by low flows, can inhibit or reverse smoltification in late outmigrants, especially steelhead. This can lead to fish remaining in the stream an extra year, and increased mortality if summer low flows limit holding capacity and survival.

There is also evidence that Chinook salmon juvenile survival increases with flow variability in the spring and early summer outmigration period, as defined by the ratio of mean to median flow rate evaluated over the same period. In the Policy area, higher velocities commensurate with higher flows reduce the time it takes for anadromous species to reach the estuary, where increased growth rates can occur.

There are no specific criteria for defining a suitable flow regime to stimulate and/or facilitate downstream passage on a regional basis. Hence, protectiveness can be assessed by specifying the outmigration season and comparing its overlap with the diversion season. Information reviewed in Appendix C indicates that the primary dates of outmigration by anadromous salmonid species in the Policy area are from March through June. Juvenile Chinook begin outmigrating about a month earlier, reflecting their ocean type life history and earlier fall spawning dates. Outmigration behavior is also exhibited by steelhead juveniles in the November-February period, and may reflect searching for or redistribution across over-wintering habitat.

2.5 CHANNEL AND RIPARIAN MAINTENANCE FLOW NEEDS

It has been demonstrated that large flood events, which may impart short term impacts to a population, are key to the continuous renewal of high quality physical habitats and ecological functions that promote population viability and health. Channel and riparian conditions, and their influence on anadromous salmonid habitat quantity and quality, are strongly dependent on high flow variability. The overall weight of scientific evidence indicates that a range of flow levels, rather than just one, are needed to be protective of instream habitat and riparian conditions.

Channel maintenance flows influence both the quantity and quality of anadromous salmonid habitat. Channel maintenance is a long-term process whereby the basic habitat structure of a stream is formed and maintained by multiple, variable high flow events occurring on an annual basis. These flows effectively maintain channel structure and the riparian zone to the extent that the characteristic variability represented in anadromous salmonid habitat persists over time. Diversions during high flows will reduce flow magnitude. Evaluating morphologic responses to reductions in high flow magnitude is complicated because channels are generally free to adjust their width, depth, slope, and bed grain size distribution in response to changes in flow regime. These attributes may adjust in concert or individually depending on circumstance.

Establishment and maintenance of riparian vegetation can be particularly dependent on flow variation. Indeed, some species of riparian plants (e.g., cottonwoods) are especially dependent on flood events that serve to stimulate germination of seeds leading to new plant growth. The existence of a healthy riparian zone in part controls channel form, water quality, and other features and functions that comprise anadromous salmonid habitat. Removal of riparian vegetation can lead to increased summer water temperatures, changes in water quality and quantity, decreased habitat for aquatic-origin adult insects, decreased bank stability and increased sediment inputs, and decreased wood recruitment that provide instream habitat structure. Reducing peak flows by diverting water has the potential to affect riparian vegetation primarily through three mechanisms: (1) reduction in groundwater recharge through the stream banks, (2) reduction of scouring flows that create new surfaces for riparian vegetation, and (3) reduction in growth rates during the early spring. Thus, the degree of protectiveness of diversion restrictions reflects the amount of water that may be diverted without adversely affecting the health, diversity, and future potential of the riparian zone.

However, suitable criteria for both channel and riparian maintenance flows are less well defined than criteria for upstream passage, spawning/incubation, and rearing. The primary quantitative metrics for assessing protectiveness are the degrees of change in channel morphologic characteristics, expressed as changes in surface grain size distribution, and bankfull width and depth. As discussed in Appendix D in greater detail, minor to moderate changes in these channel values are approximately linear with changes in bankfull flow (as represented by the 1.5 year peak event magnitude) (Figure 2-1). Because the changes to channel values never reach a lower limit (i.e., bottom out) and the linkage between reduction in channel size and anadromous salmonid production cannot be identified with great accuracy and precision, there is no readily discernable flow reduction limit suggested for identifying a protective channel and riparian maintenance flow.

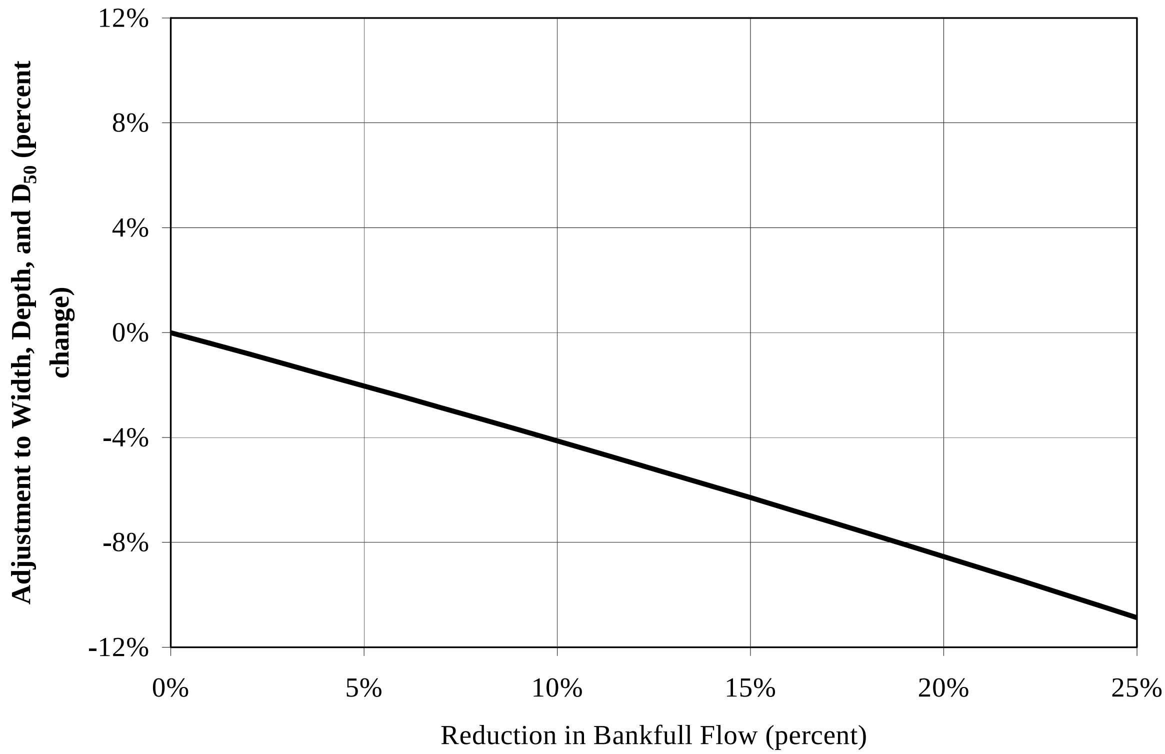

Figure 2-1. Predicted long-term potential changes in channel width, depth, and grain size distribution resulting from a reduction in bankfull flow due to diversion in Policy area streams potentially supporting anadromous salmonids.

2.6 ESTUARY HABITAT/OCEAN CONNECTIVITY FLOW NEEDS

Estuaries are an important interface between the freshwater and saltwater phases of the anadromous salmonid life cycle for both upstream and downstream migrants, although the importance can vary greatly from relatively little to a critical bottleneck depending on river and species. There are two flow-related influences on the suitability of estuaries for anadromous salmonids in the Policy area:

1. Reducing access to returning adult salmon and steelhead in the fall through sand bar closures across the mouth of the estuary, and

2. Providing suitable freshwater over-summer habitat conditions.

Sand bars at the entrance of some California coastal streams can create temporary upstream migration barriers to salmon and steelhead trout. The processes controlling the breaching of these sand bars are complicated and depend on the resource and basin in question. Estuaries in the Policy area tend to become blocked during the low flow summer months, typically some time during July, August, and/or September. Blocking has the potential to delay entry of returning adults, with greatest potential effects occurring in the Policy area to Chinook salmon that return the earliest of the three target species.

Estuaries in the policy area are used over the summer as rearing habitat by steelhead and Chinook. Although Chinook salmon downstream migration occurs earlier in the spring, juvenile fish at the end of the season may be trapped in the lagoon for the summer. Available data suggest that these lagoons may provide more productive rearing habitat for salmonids than open systems in the Policy area, allowing increased growth that improves ocean survival.

The primary flow needs related to estuary habitat implementation of the Policy therefore pertain to breaching in the fall months to facilitate the return of adults to freshwater. However, specific flow requirements for breaching vary with the basin, making it difficult to identify a regional flow-based criterion. Protectiveness of the element alternatives can be indirectly evaluated by comparing the general level of impaired base flows occurring during the diversion resulting from the element alternatives with flow characteristics required for sand bar breaching as reported in the literature (see Appendix D).

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3. INSTREAM FLOW POLICY ELEMENT ALTERNATIVE CRITERIA

Four fishery protection elements contained in the DFG-NMFS (2002) Draft Guidelines (see Appendix A) provided the framework for defining potential Policy elements. These followed two main themes: elements restricting flow diversion and an element restricting instream barriers. A number of alternative criteria have been identified for each of the elements restricting flow diversion. In the case of the element restricting instream barriers, alternative criteria were composed of the DFG-NMFS (2002) Draft Guidelines and modifications thereof that varied in restrictiveness. Each of the four fishery protection elements, as well as alternative criteria identified during the scoping process, are identified and described below in the context of how they would function to benefit anadromous salmonids.

3.1 POLICY ELEMENTS RESTRICTING FLOW DIVERSION

Three potential elements of the Policy involve restrictions on diversions to benefit anadromous salmonids: (1) diversion season, (2) requirements for a minimum bypass flow during the diversion season, and (3) the maximum permissible cumulative diversion rate or volume. Table 3-1 lists the various alternative criteria evaluated for each element.

Two sets of alternative criteria were provided that encompassed all three elements, the first in the DFG-NMFS (2002) Draft Guidelines (Alternatives DS1, MBF1, MCD1, MCD2, and MCD3 in Table 3-1) and the second in a proposal provided by Trout Unlimited (MTTU 2000; Alternatives DS2, MBF2, and MCD4). Background on the DFG-NMFS (2002) Draft Guidelines and the Trout Unlimited proposal is provided in Appendix A.

The DFG-NMFS (2002) Draft Guidelines recommended modifications to the State Water Board staff proposals for the administration of applications for water diversions (SWRCB 1997, 1998) that withdraw less than 3 cfs or 200 acre-ft/yr by implementing measures described below. Diversions that withdraw more than 3 cfs or 200 acre-ft/yr would require site-specific studies and monitoring. The measures specified for smaller diversions would apply to cases where site-specific studies were not conducted. However, the option to conduct site-specific studies would also be available for small diversions, the results of which could be used to justify different criteria for each element than were recommended by the DFG-NMFS (2002) Draft Guidelines.

The Trout Unlimited (MTTU 2000) proposal included the same elements as the DFG-NMFS (2002) Draft Guidelines, but differed with respect to the timing and levels of permissible extraction, and was to be applied to streams with drainage areas smaller than about 10 mi^2. In addition, the Trout Unlimited proposal made no distinction between (1) existing, legally permitted, and (2) new permit applications for diversion, and would apply to all diversions in perennial and ephemeral streams with or without anadromous salmonids.

Table 3-1. Policy Element Alternative Criteria Proposed to Restrict Diversions

Diversion Season	Minimum Bypass Flow	Maximum Cumulative Diversion
DS1. 12/15 – 3/31 **DS2.** Year Round **DS3.** 10/1 – 3/31	**MBF1.** February median daily flow **MBF2.** 10% Exceedance Flow **MBF3.** Drainage Area (DA) < 290 mi^2: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ Drainage Area > 290 mi^2: $Q_{MBF} = 0.6\ Q_m$ Q_m = unimpaired mean annual flow (cfs); For streams above anadromous habitat, DA is determined at the upstream limit of anadromy **MBF4.** Drainage Area < 0.11 mi^2: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ Drainage Area = 0.11-500 mi^2: $Q_{MBF} = 5.1\ Q_m\ (DA)^{-0.71}$ Drainage Area ≥ 500 mi^2: $Q_{MBF} = 0.06\ Q_m$ For streams above anadromous habitat, DA is determined at the upstream limit of anadromy	**MCD1.** MCD Rate = 15% of 20% Winter (12/15-3/31) exceedance flow **MCD2.** MCD Rate = 5% of 1.5 yr flood peak flow **MCD3.** MCD Volume = 10% estimated unimpaired flow (no restriction on diversion rate) **MCD4.** MCD Rate = diversion rate which results in a maximum reduction of the time flow is above the MBF to ½ day during a 1.5 yr flood event

Several other specific alternative criteria were identified for discrete elements restricting diversion and are described in Table 3-1 and in the following sections. In particular, the MBF3 and MBF4 alternatives summarized in Table 3-1 were both developed to account for variation in instream flow needs for different channel sizes, but respectively approximated the maximum/minimum amounts of water that might be left instream without substantially over-/under-protecting anadromous salmonids.

3.1.1 Diversion Season (DS) Element

The proposed Policy would restrict the season of operation of new diversions to the period of highest winter flows when water is most available and the impacts of water withdrawals on fishery resources would be minimized. New diversions would not be permitted during the summer, fall, or late spring months, which are periods when streamflows are especially important to limiting anadromous salmonid populations. The primary question concerning the protectiveness of this element of the Policy is to determine which dates bracketing the winter diversion season are the most biologically appropriate for the target species. Three alternative criteria were identified for the diversion season.

3.1.1.1 DFG-NMFS (2002) Draft Guidelines Diversion Season DS1

The DFG-NMFS (2002) Draft Guidelines proposed a December 15 – March 31 diversion season that reflected biological timing (i.e., periodicity) of various anadromous salmonid life stages, and the availability of water, the latter based on an analysis of five gages in the Russian River basin (SWRCB 1997).

3.1.1.2 Trout Unlimited (MTTU 2000) Diversion Season DS2

Trout Unlimited (MTTU 2000) proposed no limitation to the diversion season as long as instream flow restrictions were met (see sections below on minimum bypass flow and maximum cumulative diversion).

3.1.1.3 Consulting Engineers (2006) Diversion Season DS3

A set of comments and recommendations provided on September 15, 2006 during the CEQA scoping process by Wagner & Bonsignore Consulting Civil Engineers, James C. Hanson Consulting Civil Engineer, and the law firm Ellison, Schneider & Harris L.L.P. (Consulting Engineers) proposed that the diversion season begin on October 1 instead of December 15. The early date would allow on-stream reservoirs to fill and subsequently spill earlier in the fall depending on the magnitude of instream flows.

3.1.2 Minimum Bypass Flow (MBF) Element

The minimum bypass flow (MBF) element of the Policy would set a minimum instream flow that must be moving past a point of diversion before water may be diverted under a permit. The term, 'bypass,' refers to flow that is not impounded or diverted and hence remains in the stream. This element reflects the need to provide and maintain sufficient instream flows downstream of diversions and on-stream dams for anadromous salmonid habitat.

3.1.2.1 DFG-NMFS (2002) Minimum Bypass Flow Alternative Criterion MBF1

The DFG-NMFS (2002) Draft Guidelines recommended a MBF equal to the February median daily unimpaired flow. The month of February was chosen because analysis indicated it was generally the highest median flow during the winter period (based on hydrologic analysis of Russian River tributaries), and would thus be expected to protect spawning and egg incubation habitat of salmonids in other months. A median statistic was considered preferable to a mean because it better reflected flow duration, and was not influenced as strongly by infrequent, high flow events.

3.1.2.2 Trout Unlimited (MTTU 2000) Minimum Bypass Flow Alternative Criterion MBF2

Trout Unlimited (MTTU 2000) proposed a geomorphic measure, defined as the active channel stage height, for determining the magnitude of the MBF. The active channel was defined as corresponding to the lower limit of woody riparian vegetation, particularly white alder, and the concomitant edge of a defined gravel-sand bench in straight reaches. The bench and white alder roots were reported to contain lower flows, thereby keeping the active channel bed and any anadromous salmonid redds therein wetted during declining flows (MTTU 2000). However, in lieu of site-specific studies for determining the active channel stage height, Trout Unlimited recommended the annual 10% exceedance flow as an approximation of the flow resulting in the active channel water level. This metric would therefore allow diversions to occur approximately 36.5 days per year on average.

3.1.2.3 Minimum Bypass Flow Alternative Criterion MBF3

The MBF3 alternative criterion was developed based on comments from the 2000 State Water Board workshop peer review panel (Moyle et al. 2000) and those from MTTU (2000). The development of this criterion is presented in Appendix E. The alternative criterion incorporated basin size (drainage area) and hydrology (mean annual flow) into the development of the following criteria for MBF (Q_{MBF}) that are focused on protecting spawning habitat and upstream passage:

- Basin Area < 290 mi^2: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ (3.1)
- Basin Area > 290 mi^2: $Q_{MBF} = 0.6\ Q_m$
- Locations Above Anadromous Habitat: $Q_{MBF} = 8.7\ Q_m\ (DA_2)^{-0.47}$

where Q_m and DA are the estimated mean annual flow and drainage area at the point of diversion (POD), respectively, and DA_2 is determined at the upper limit of anadromous habitat. These criteria are displayed in Figure 3-1.

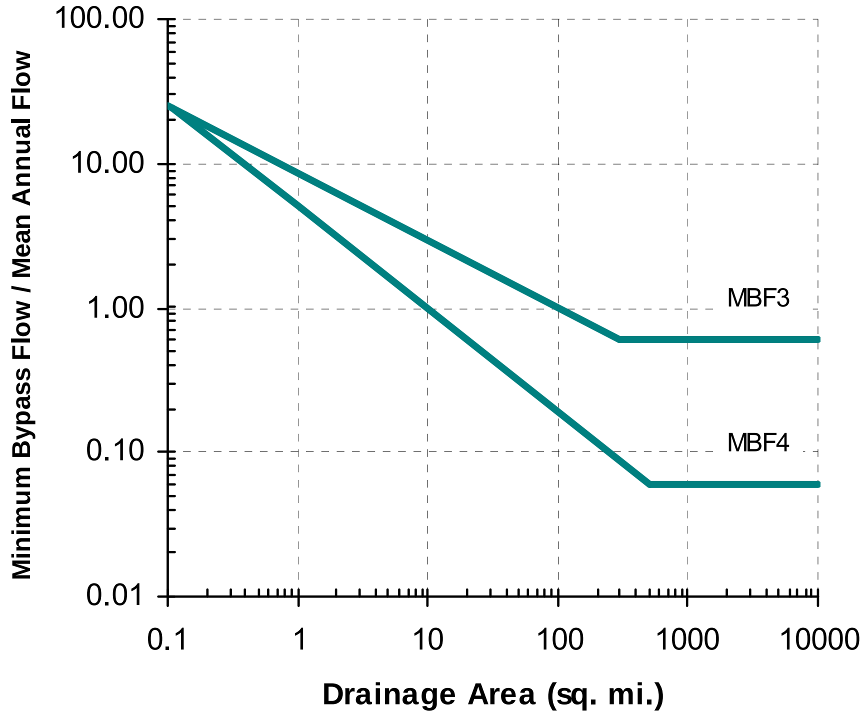

Figure 3-1. Comparison of the MBF3 and MBF4 alternative criteria for the Minimum Bypass Flow (MBF) element of the Policy, which account for variation in instream flow needs with stream size at different levels of protection.

The alternative's format is consistent with Moyle et al.'s (2000) comment that the DFG-NMFS (2002) Draft Guidelines should include a separate minimum passage depth criterion for smaller streams used by anadromous salmonids. The normalization of instream flow needs by mean annual flow was accordingly done to account for channel size effects on flow needs vs. stream flow.

This alternative criterion was developed to be protective of anadromous salmonid habitat in as many streams as possible based on measures of channel size expressed in terms of drainage area and mean annual flow. In cases where proposed diversions would cause flows to drop below stated criteria, site specific studies could be conducted in consultation with resource agencies to determine if lower MBFs could be allowed that would still be protective. Analysis of this alternative criterion (which is described in detail in Appendix E) suggested that while a more restrictive minimum bypass flow could be imposable on diversions, doing so would likely not provide significant additional, quantifiable benefits to the three anadromous salmonid species.

3.1.2.4 Minimum Bypass Flow Alternative Criterion MBF4

The MBF4 alternative criterion was developed in part from existing instream flow studies which provided a minimum negotiated level of protection for anadromous salmonids (see Appendix E). The alternative criterion would allow diverters to extract as much water as possible, while still providing MBFs that ostensibly would not imperil the sustainability of anadromous salmonids. This alternative criterion was developed to be protective of anadromous salmonid habitat based on a lower level of protection compared with the MBF3 alternative and was similarly based on measures of channel size expressed in terms of drainage area and mean annual flow.

The MBF4 criterion for MBF (Q_{MBF}) consists of the following criteria that are based on protecting spawning habitat and upstream passage:

- Basin Area (DA) < 0.11 mi^2: $Q_{MBF} = 8.7\, Q_m\, (DA)^{-0.47}$ (3.2)
- Basin Area = 0.11-500 mi^2: $Q_{MBF} = 5.1\, Q_m\, (DA)^{-0.71}$
- Basin Area ≥ 500 mi^2: $Q_{MBF} = 0.06\, Q_m$
- Locations Above Anadromous Habitat: $Q_{MBF} = K\, Q_m\, (DA_2)^M$

where K and M depend on the drainage area as indicated above, and DA_2 is the drainage area determined at the upper limit of anadromous habitat. These criteria are plotted in Figure 3-1 for comparison with the MBF3 alternative criterion.

3.1.3 Maximum Cumulative Diversion (MCD) Element

This element of the Policy was focused on defining the magnitude of the maximum cumulative diversion (MCD) rate or total volume of diversions that could be allowed when stream flows exceed the MBF while still being protective of fishery resources. The overall intent of the MCD element is to allow for some flow diversion while still preserving natural flow variability downstream (see Appendices D and E for discussion of the ecological importance of flow variability). Detailed geomorphic analysis (see Appendix D) did not reveal a clearly defined, protective threshold MCD rate (or equivalent volume) for protecting channel and riparian maintenance flows. Four alternative criteria were thus identified based on existing recommendations: three formulated from the DFG-NMFS (2002) Draft Guidelines and one from MTTU (2002).

Comments received during scoping from the Consulting Engineers (2006) recommended that determination of water availability should involve estimating the actual seasonal depletion due to cumulative diversions in the watershed above the POD, rather than the cumulative amount appropriated. Water would be considered available for diversion as long as the actual average annual cumulative depletion remained below the estimated average annual stream flow in more than half the water years considered. However, there is no legal mechanism preventing all water rights holders from simultaneously diverting their full appropriated amounts of water from the stream, provided such flows are available at the time of diversion and regardless of past diversion practices. It follows then that evaluation of the MCD element requires a worst-case scenario in which it is assumed that all appropriated water is diverted, rather than an estimate of actual current use. Thus, this recommendation was not evaluated further.

3.1.3.1 DFG-NMFS (2002) Maximum Cumulative Diversion Alternative Criteria MCD1, MCD2, and MCD3

The DFG-NMFS (2002) Draft Guidelines contained two primary approaches for maintaining natural flow variability and avoiding significant cumulative effects due to diversion. Absent site-specific information and analyses demonstrating otherwise, the DFG-NMFS (2002) Draft Guidelines stated that the natural hydrograph should be protected by either:

a. Limiting the cumulative instantaneous rate of withdrawal (i.e., MCD rate) to 15% of the winter 20% exceedance flow during the period December 15-March 31, subject to a limiting cumulative rate of withdrawal that does not appreciably diminish (qualified as <5% of) the natural hydrograph flows needed for channel maintenance (considered to be approximated by the 1.5 year peak annual flood) and upstream fish passage;

OR

b. Limiting the total cumulative volume of water to be diverted, at historical limits of anadromous fish distributions, to 10% of the unimpaired runoff during the period December 15-March 31 during normal water years, using a Cumulative Flow Impairment Index (CFII). Hydrologic analysis is required for projects with CFIIs between 5%-10% to demonstrate that a diversion will not impair geomorphic processes and salmonid migration and spawning.

The procedure proposed for calculating the CFII was:

$$CFII = \frac{Cumulative\ Diverted\ Volume\ From\ 10/1-3/31}{Estimated\ Unimpaired\ Runoff\ \ From\ 12/15-3/31}$$

The CFII was recommended as a screening method of determining which water right applications can be permitted without further study and which points of interest (POI) require detailed evaluation of potential cumulative impacts. Technical considerations in the evaluation of the protectiveness of the CFII are discussed further in Appendix J.

The analysis in Appendix D indicated that the limiting condition identified in option (a) of the DFG-NMFS (2002) Draft Guidelines above, whereby a MCD rate should not exceed a level equaling 5% of the 1.5 year annual peak flood, could potentially be the least restrictive option identified relative to cumulative flow diversion while still protecting channel maintenance processes. A review of local gage data identified in Appendix F indicates this level is, on average, roughly five to seven times the 15% of 20% exceedance flow rate proposed under the first component of the DFG-NMFS alternative criterion.

These criteria were used to develop three MCD alternatives which were separately assessed for protectiveness:

1. Maximum cumulative diversion rate = 15% of the unimpaired Dec 15 - Mar 31 20% exceedance flow (MCD1)
2. Maximum cumulative diversion rate = 5% of the 1.5 year flood magnitude (MCD2); and
3. Maximum cumulative diversion volume (CDV) = 10% of the unimpaired Dec 15 – Mar 31 normal year volume (MCD3).

The MCD3 alternative was formulated to provide a worst-case evaluation of the 10% CFII threshold with respect to hydrograph impairment during the beginning of the diversion season. In applying this alternative, it was assumed that:

1. There is no maximum limit imposed on the instantaneous rate of diversion.
2. The diversion demand is set equal to 10% of the estimated unimpaired runoff volume from December 15 until March 31.
3. All flows above the MBF are diverted until the diversion demand is satisfied.

3.1.3.2 Trout Unlimited (MTTU 2000) Maximum Cumulative Diversion Alternative Criterion MCD4

Trout Unlimited recommended that the MCD be calculated based on changes in flow timing, with the goal of minimizing the reduction in total time available for spawning. Explicit guidance was not given regarding how much can be diverted when flows exceed the MBF, but examples given by MTTU (2000) implied that the diversion rate resulting in a shift of the descending limb of the event hydrograph of half a day at the time the MBF occurs is the MCD at any time during the event (Figure 3-2). Trout Unlimited proposed that the 1.1-year to 1.5 year event be used as the basis for determining the MCD (MTTU 2000). Given hydrograph recession characteristics, the corresponding time that the hydrograph is compressed at higher flows will typically be shorter.

From a practical standpoint, implementation of this proposal is problematic as it effectively requires hourly hydrograph data to evaluate pending water right applications, data that are not readily available in most Policy area streams. Its application is further complicated by the observation that each runoff event would, in principle, be associated with a different MCD aimed at resulting in no more than one-half day shortening of flow at the MBF level.

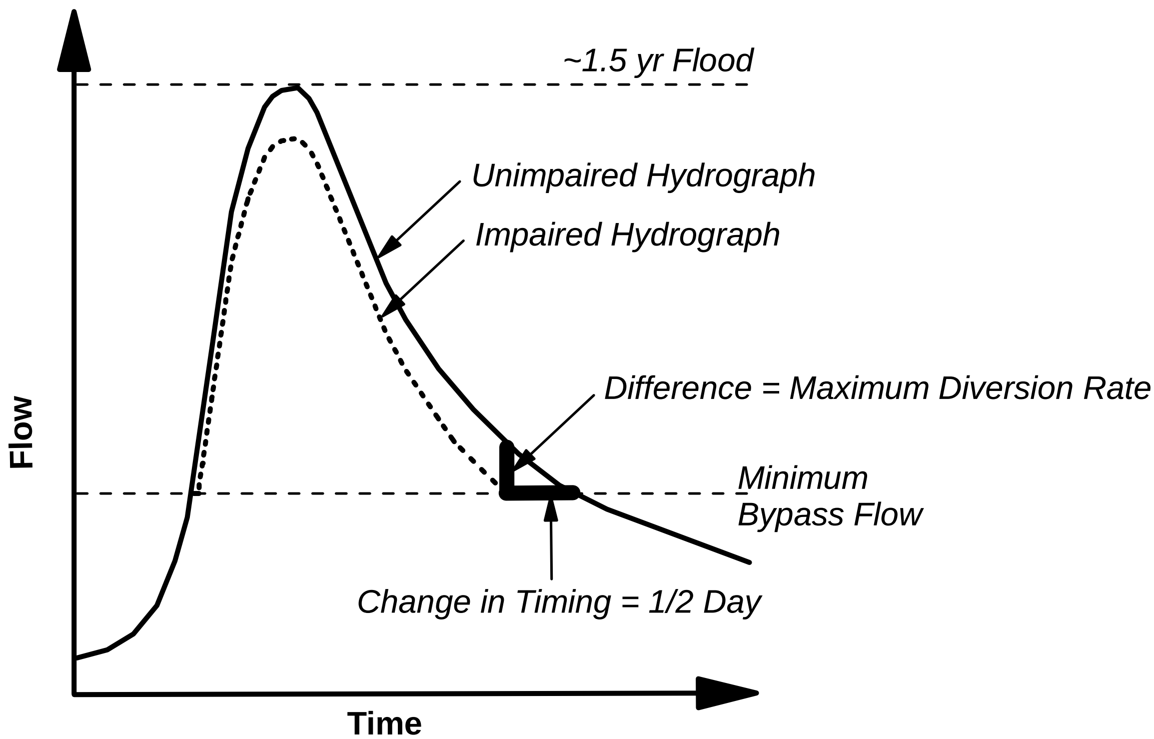

Figure 3-2. Conceptual determination of maximum cumulative diversion (MCD) rate following Trout Unlimited's proposal to base it on a maximum reduction in the time instream flows are at, or above the minimum bypass flow by one-half day.

3.2 POLICY ELEMENT RESTRICTING INSTREAM BARRIERS

There is one element of the Policy concerning instream barriers, and that is whether an on-stream dam could or should be permitted. This element involves measurable actions whose costs and benefits to water users and natural resources are more definitive and quantifiable than elements involving measures of flow quantity. The alternatives considered are shown in Table 3-2.

The alternatives range in degree of restrictiveness. For the protectiveness analysis, all alternatives were assumed to be applied in conjunction with the Policy elements restricting flow, including diversion season, MBF, and MCD. In some cases, exceptions to the imposed barrier restrictions may be possible, but only if site-specific studies conducted in cooperation with resource agencies demonstrate such.

3.2.1 Permitting of On-Stream Dams (DP) Policy Element

Construction of on-stream dams can result in a number of direct and indirect impacts to anadromous salmonids, including the local loss of free-flowing stream habitat and food production, loss of upstream fish production, providing habitat for non-native species, trapping of spawning gravels, and regulation of downstream flows. The objective of this Policy element is to avoid, reduce and/or mitigate for these impacts. Questions relevant to evaluating the effects of implementing this element concern how changes in methods of water diversion and storage practices may affect riparian resources and summer low flows, and if there are certain conditions where on-stream dams could still be allowed without impacting downstream resources.

The Consulting Engineers (2006) comments included a recommendation that dams and on-stream impoundments be permitted; (1) in channels, swales, or water courses that have surface runoff only during and immediately following precipitation events; (2) in water courses where there are existing downstream dams or other barriers; (3) in streams where there is no salmonid habitat or species at the POD and no significant impact to flows at the current upstream limit of anadromy; or (4) when the impoundment contains 10 acre-ft or less of water. The applicability of these recommended modifications to a given stream or channel would require site specific studies to be conducted, and therefore they were not considered as potential modifications to the DFG-NFMS (2002) alternative for regionally applied criteria.

Table 3-2. Policy Element Alternative Criteria Proposed to Restrict Instream Barriers.

Stream Class	Permitting of On-stream Dams (DP)
Class I	**DP1.1** On-stream dams may not be issued water right permits. **DP1.2** New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. Fish passage and screening is provided; 2. A passive bypass system is provided to bypass the minimum instream flow requirements; 3. An exotic species eradication plan is implemented; 4. A gravel and wood augmentation plan or bypass system is implemented; and 5. Disturbed riparian habitat will be mitigated
Class II	**DP2.1** On-stream dams may not be issued water right permits. **DP2.2** New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. A passive bypass system is provided to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.

Table 3-2. Policy Element Alternative Criteria Proposed to Restrict Instream Barriers.

Class II (cont)	**DP2.3** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.
Class III	**DP3.1** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. The on-stream dam will not dewater a Class II stream; and 2. The on-stream dam will cause less than 10% cumulative instantaneous flow impairment at locations where fish are seasonally present. **DP3.2** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; and 3. A gravel and wood augmentation plan or bypass system is implemented. **DP3.3** A water right permit may be considered for an on-stream dam.

3.2.1.1 DFG-NMFS (2002) On-Stream Dam Permitting Alternatives (DP1.1, DP2.1, and DP3.1)

The DFG-NMFS (2002) proposed that the State Water Board avoid additional permitting of small on-stream dams beyond those already legally permitted. An exemption was provided in cases where the following conditions were met: (1) the proposed diversion was located in a stream where aquatic fauna were not historically present, per Class III designation under Cal. Code Regs., tit. 14, section 916.5, Table 1 (i.e., no aquatic life present, water course showing evidence of being capable of sediment transport downstream to fish-bearing waters under normal high water flow conditions); (2) the project would not lead to a cumulative diversion rate exceeding 10% of the natural instantaneous flow in any reach where fish are at least seasonally present ("cumulative" was defined to include all existing water rights); and (3) the project would not lead to dewatering of a fishless stream supporting other aquatic fauna.

3.2.1.2 Modifications to the DFG-NMFS (2002) Alternative (DP1.2, DP2.2, DP2.3, DP3.2, and DP3.3)

Trout Unlimited (MTTU 2000) proposed that new and existing on-stream dams must be individually approved by DFG following a quantitative analysis of; (1) cumulative effects on downstream anadromous salmonid habitat; (2) loss of upstream anadromous habitat; (3) effects on other fish resources as defined by DFG code; (4) effects on off-channel wetlands connected hydraulically to the channel via surface flow; and (5) channel maintenance flow needs. All downstream locations potentially impeding upstream migration of adult and juvenile salmonids must be identified. The analysis would need to consider all existing water rights upstream of potential barriers and the proposed water right application. An exemption would be allowed for on-stream dams on Class III streams where it could be demonstrated quantitatively that (1) the minimum bypass flow and maximum diversion rate guidelines could be met at the upstream limit of potential anadromy, (2) that downstream riparian vegetation and other fishery resources including seasonal wetlands may be sustained, and (3) minimum bypass flow guidelines are met in Class II and III channels and swales. New and existing on-stream dams that meet permitting criteria would need to have an operational plan approved by DFG for annually replacing an equivalent volume of coarse bed material into the downstream channel, so that the supply to salmonid spawning habitat downstream is not interrupted (MTTU 2000).

Alternatives to those proposed in the DFG-NMFS (2002) Guidelines were accordingly developed. The first alternative included protective modifications as suggested by Trout Unlimited and the State Water Board. The second included less restrictive criteria that those proposed by DFG-NMFS. All alternatives are shown in Table 3-2, distinguished by stream class.

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4. EVALUATION OF THE EFFECTS OF POLICY ELEMENT ALTERNATIVE CRITERIA RESTRICTING FLOW DIVERSION ON ANADROMOUS SALMONID HABITAT NEEDS

This chapter presents the methods and results for evaluating the effects of Policy elements restricting flow diversion on the various important anadromous salmonid habitat needs identified in Chapter 2. The assessment of anadromous salmonid habitat needs provided by each alternative criterion included both direct and relative comparisons of specific habitat metrics described in this chapter.

Quantitative analyses focused on the use of daily flow time series. Estimated unimpaired flow time series were compared with different impaired flow time series resulting from implementation of specific combinations of Policy element alternative criteria (diversion season, minimum bypass flow, and maximum cumulative diversion). Each impaired flow time series resulting from implementing a specific set of Policy element alternatives is called henceforth a "Flow Alternative Scenario."

Whether or not a specific Policy element alternative criterion, or combination of alternative criteria (i.e., a Flow Alternative Scenario), could be considered protective depended on the extent to which each habitat need was adversely affected by the reduction in daily flows resulting from the allowed impairment. The relevant habitat metrics were derived from analyses of unimpaired and impaired flow data, using hydraulic and habitat data collected in the late summer of 2006 at a number of sites distributed over the Policy area (henceforth called "validation sites" in this report). Because the overall goal of the analysis was to determine protectiveness at the regional scale, an overall criterion used to evaluate the results for all validation sites was the extent to which Policy element alternative criteria resulted in some streams barely being protected and the rest being over-protected (see Appendix D for a discussion of the rationale). If more than one or two validation sites were adversely affected in some way, the outcome would then not be considered protective at a regional scale.

Of the six habitat needs identified in Chapter 2, upstream passage and spawning habitat metrics were assessed most directly using field data, in part because they were most readily quantifiable. Figure 4-1 depicts the general analysis steps followed for these two habitat needs. The steps are described further below and in greater detail in Appendices F and G. For some habitat needs, it was not possible to define a quantitative metric for establishing the degree of effect, such that a weight of evidence, literature-based approach was necessary instead; such cases are noted below.

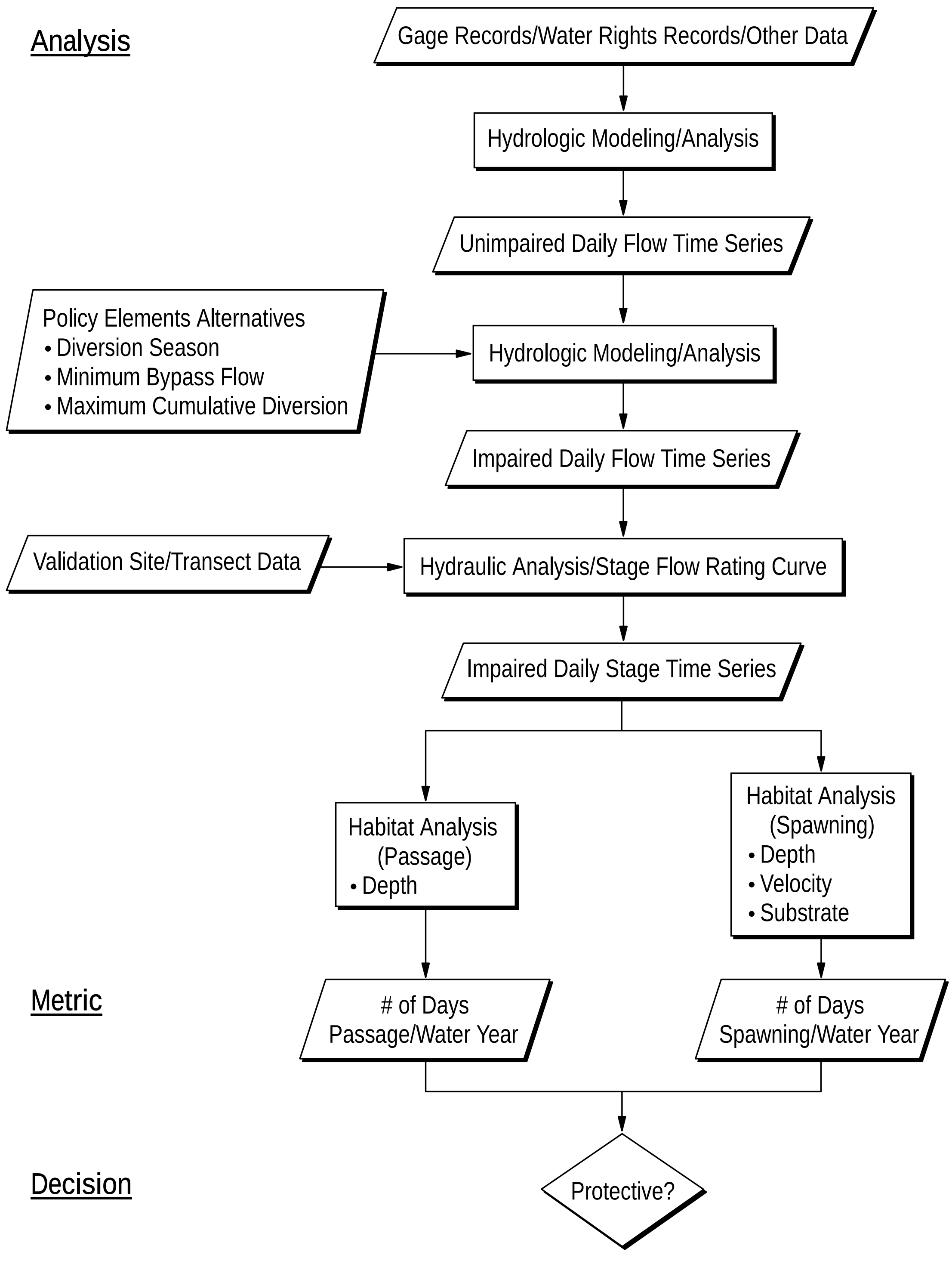


Figure 4-1. Outline of steps taken to analyze the protectiveness of Policy element alternative criteria restricting flow diversion with respect to anadromous salmonid upstream passage and spawning habitat needs.

The methods used to derive flow data for the validation sites are presented first, followed by the methods used to derive the habitat metrics. Results of the habitat analyses are then discussed (specific results are presented in Appendices H and I). The results serve as the basis for the analyses of protectiveness in subsequent chapters.

It should be noted that the analysis of anadromous salmonid habitat needs was restricted to assessing direct protective attributes of each Policy element described in Chapter 3, not indirect attributes or effects due to changes in diversion practices that result from implementation of the Policy. For example, in the case of riparian vegetation, which is an important element of salmonid habitat, the analysis considers how the MCD element may help maintain the level of high flow and how the level of high flow so-maintained could directly maintain and protect the riparian zone. The analysis in this chapter does not consider the indirect effects of shifting water extraction from surface water diversion to alternate sources, such as groundwater pumping and use of riparian water rights, which could lead to loss of the riparian zone by reducing the summer water table elevation. These types of indirect effects will be addressed in the effects analysis of the SED.

4.1 HYDROLOGY AT VALIDATION SITES

Thirteen validation sites were used to evaluate Policy element alternative criteria. Hydrologic data were collected and unimpaired daily flow time series were developed for each site. Policy elements restricting flow were then applied to time series of unimpaired flow in order to develop impaired time series. The hydrologic data and creation of time series at the validation sites is summarized below and is detailed in Appendix F.

4.1.1 Validation Site Locations

The thirteen validation sites were visited in the Policy area between August 28 and September 1, 2006 to collect spawning habitat and upstream passage data. As described in Appendix G, the sites were selected that (1) represented smaller sites (drainage area generally less than 15 mi^2) to supplement more readily available habitat-flow data for larger sites, and to address a critical data gap identified by MTTU (2000), (2) had a gage nearby from which an unimpaired winter daily flow time series could be reasonably estimated for at least two years, and preferably more, (3) would be well distributed across the Policy area, and (4) could be readily accessed to maximize field time efficiency. The major physical and hydrologic characteristics of the sites are summarized in Table 4-1, and their general locations depicted in Figure 4-2.

Table 4-1. Sites Where Transects Were Surveyed to Characterize Passage and Spawning Conditions Associated with Alternative Criteria for Policy Elements Regarding Restrictions on Flow. Streams are Ordered from Smallest to Largest Drainage Area.

Stream	Date Visited	Drainage Area (mi^2)	Reach Slope (%)	Number of Transects		Water Years Analyzed
				Passage	Spawning	
E. Fk. Russian River Trib	8/31/2006	0.25	2.5	1	0	1959-1961
Dry Creek Trib	8/30/2006	1.2	2.04	1	1	1968-1969
Dunn Creek	8/31/2006	1.9	1.58	2	2	1962-1964
Carneros Creek	8/29/2006	2.8	1.10	2	2	2002-2005
Huichica Creek	8/29/2006	4.9	0.79	1	1	2002-2005
Olema Creek	8/28/2006	7.0	0.91	2	2	1987-2003
Pine Gulch Creek	8/28/2006	7.8	1.14	2	2	1999-2003
Warm Springs Creek	8/30/2006	12.2	0.71	2	2	1974-1983
Santa Rosa Creek	9/1/2006	12.5	1.37	1	2	1960-1970
Albion River	8/31/2006	14.4	1.01	2	2	1962-1969
Salmon Creek	8/30/2006	15.7	0.69	2	2	1963-1975
Franz Creek	9/1/2006	15.7	0.29	2	2	1964-1968
Lagunitas Creek	8/28/2006	34	0.53	2	2	1956-1992

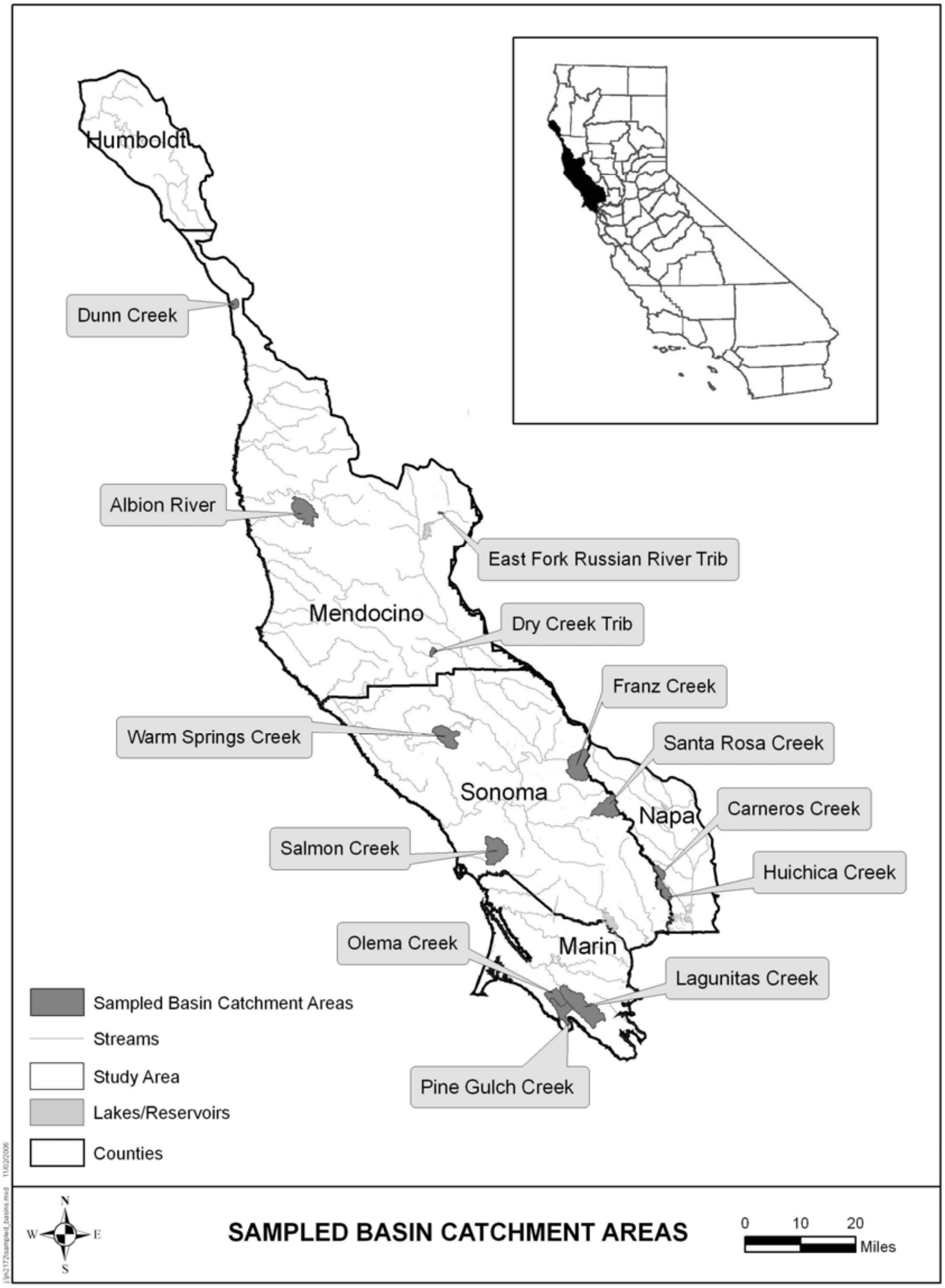


Figure 4-2. Locations of validation sites sampled for passage and spawning transects that were evaluated for protectiveness of Policy element alternative criteria involving restrictions on flow.

4.1.2 Estimation of Unimpaired Flow Time Series

Unimpaired flow is the natural flow in a stream without any human alterations to the hydrology; that is, the flow without any diversions or man-made storage. The unimpaired stream flow was needed particularly to analyze two of the Policy elements, MBF and MCD rate or volume. Accordingly, unimpaired flow time series were developed for each of the validation sites.

For all thirteen validation sites, gaged data were available from one of three sources: the US Geological Survey (USGS), Napa County Resource Conservation District (NCRCD), and the National Park Service (NPS). The gaged data were collected and compared to historical permitted diversions and storage to determine whether they represented unimpaired flows.

Historical permitted diversions and storage were estimated for the validation sites using data from the State Water Board's Water Rights Information Management System (WRIMS) database as of December 20, 2006. In cases where diversions and storage regulation during the gaged period of record were not significant, gaged flows were used as an estimate of unimpaired flow. This was the case for nine of the thirteen sites (Albion River, Dry Creek Trib, Dunn Creek, EF Russian River Trib, Olema Creek, Pine Creek, Salmon Creek, Santa Rosa Creek, and Warm Springs Creek).

For the remaining four validation sites, gaged data were not used to represent unimpaired flows because diversions and storage were determined to have potentially impacted measured daily flow rates significantly. Instead, calculated or modeled flows were used to represent unimpaired flows. For one validation site (Lagunitas Creek), unimpaired flows were obtained from the Marin Municipal Water District (MMWD) which has calculated such flows on a daily basis. For the other three streams with significant diversions and storage, a model (Hydrologic Simulation Program - Fortran, HSPF) was used to simulate unimpaired flows. Streamflow was modeled for the Carneros Creek, Franz Creek, and Huichica Creek validation sites. Details of the model inputs, calibration, and results are in Appendix F, Section F.2.4.

After the unimpaired time series for each validation site were created, hydrologic parameters such as mean annual flow, peak flood magnitude, and flow-duration (exceedance) values were computed. Development of these unimpaired flows and associated hydrologic parameters is described in detail in Appendix F, Section F.2.

4.1.3 Hydrology and Impaired Flow Time Series

Impaired daily flow time series were generated by applying, in concert, specific diversion season, MBF, and MCD rate or volume criteria to the estimated unimpaired flow daily time series. Details of the impairment calculations are given in Section F.3 in Appendix F.

Statistics and hydrologic parameters of the impaired time series were computed in order to assess changes to the hydrology resulting from the application of the Policy elements (see section F.3 in Appendix F). In addition, a sensitivity analysis was performed to specifically assess the effect of the MCD rate or volume criteria on the hydrology (Section F.4 in Appendix F). The sensitivity analysis was used in the assessment of protectiveness for the MCD Policy element. Results of the sensitivity analysis indicate that, in general, diversions occur less frequently but at much higher rates when the MCD volume method is employed. Maximum diversion rates are generally an order of magnitude higher when diversions are limited by the MCD volume method. Also, the MCD volume method reduces peak annual floods more significantly than the MCD rate methods.

As described in the next section, specific combinations of the three Policy elements restricting flow diversion were evaluated by first creating the appropriate impaired flow time series. Effects on anadromous salmonid habitat needs were then evaluated by relating various habitat-flow metrics to the impaired daily flows.

4.2 HABITAT ANALYSIS METHODS

The general approach of the habitat analysis involved evaluating the effects of impaired flows on the various important habitat needs of anadromous salmonids identified in Chapter 2. Negligible effects were interpreted as representing a protective condition in the context of the habitat attribute under consideration. Where possible, the unimpaired and impaired daily flow time series were related as directly as possible to effects on habitat quantity and quality. For habitat needs where a quantity or quality metric could not be identified and readily analyzed, the analysis of protectiveness relied on more general ecological and physical principles established in the literature.

It is important to note that the analyses of effects of flow diversions on habitat were complicated by the fact that the three elements restricting flow diversion must be applied in concert. As indicated in 4.1.3, each impaired daily flow time series is generated through hydrologic analysis, and the analysis requires that a set or combination of alternative criteria be specified for each of the three Policy elements, diversion season, MBF, and MCD. The diversion season controls the dates when instream flows are affected by impairment, and the MBF and MCD elements variously and simultaneously control the level of flow remaining in the stream. Hence, it is difficult to single out the effect of any one element alternative criterion without conducting a detailed sensitivity analysis where two elements are held constant at a given level of impact and the third element is varied. A habitat-flow sensitivity analysis was not feasible in the time frame and budget available.

Instead, a fixed number of impaired flow time series were generated and evaluated for passage, spawning, and channel maintenance habitat-flow needs. As described at the beginning of this chapter, the impaired flow time series corresponded to implementation of specific combinations of Policy element alternatives identified in Chapter 3; these specific combinations are referred to as Flow Alternative Scenarios and are described in Table 4-2. Flow Alternative Scenario 1 and 5 represent the two alternative expressions of the DFG-NMFS (2002) Draft Guidelines, one using a MCD rate (MCD1) and the other the CFII MCD volume (MCD5). Flow Alternative Scenario 2 represents the proposal by Trout Unlimited. Flow Alternative Scenario 3 (Upper Flow Scenario) represents a combination of the most restrictive Policy element alternatives; Flow Alternative Scenario 4 (Lower Flow Scenario) represents a combination of the least restrictive Policy element alternatives excluding those that were likely to not be protective. The number of Flow Alternative Scenarios compared was the minimum that could be analyzed to describe effects associated with the various Policy element alternatives. In the absence of a full sensitivity analysis, however, these five scenarios still described a range of impaired flow scenarios that appeared to have sufficient variation for inferring the relative protectiveness of alternatives for each distinct Policy element.

Of the Flow Alternative Scenarios listed in Table 4-2, Flow Alternative Scenarios 1, 2, 3, and 4 involve specifying a MCD rate as opposed to a volume (Flow Alternative Scenario 5). The corresponding flow rates estimated for MBF and MCD are presented in Table 4-3 (note there is no fixed MCD flow rate for Flow Alternative 5). An example of the effect of each Flow Alternative Scenario on the shape of the impaired hydrograph is depicted in Figure 4-3 for the October 1 – March 31 period of WY 1971 in a representative validation site, Salmon Creek. The MBF is visible as periods of steady flow below the natural, unimpaired hydrograph for the respective Flow Alternative Scenario time series. The point at which the CFII = 10% limit was reached under Flow Alternative Scenario 5 is also visible in the figure as the date when Flow Alternative 5 no longer results in flat-lining the hydrograph at the MBF level.

Table 4-2. Description of Flow Alternative Scenarios Evaluated in the Analysis of Protectiveness.

Flow Alternative Scenario	Description, Policy Element Alternative Criteria Included		
Unimpaired	Flow conditions using the estimated natural hydrology described in the previous section		
Flow Alternative Scenario 1	Flow conditions impaired with the maximum diversions allowed by the following Policy Element Alternatives:		
(DFG-NMFS 2002 Criteria, MCD Rate)	DS1 12/15-3/31	MBF1 February median daily flow	MCD1 Rate 15% of 20% winter exceedance flow
Flow Alternative Scenario 2 *(MTTU 2000 Criteria)*	DS2 Year round	MBF2 10% exceedance flow	MCD4 Rate Calculated for each site following the procedure depicted in Figure 3-2
Flow Alternative Scenario 3 *(Upper Flow Scenario)*	DS1 12/15-3/31	MBF3 Specified as a function of drainage area and mean annual flow	MCD1 Rate 15% of 20% winter exceedance flow
Flow Alternative Scenario 4 *(Lower Flow Scenario)*	DS3 10/1-3/31	MBF4 Specified as a function of drainage area and mean annual flow	MCD2 Rate 5% of 1.5 year flood magnitude
Flow Alternative Scenario 5 *(DFG-NMFS 2002 Criteria, MCD Volume)*	DS1 12/15-3/31	MBF1 February median daily flow	MCD3 Volume CFII = 10% estimated unimpaired runoff (EUR)

Table 4-3. Application of Protectiveness Criteria to the Thirteen Validation Sites, for Flow Alternative Scenarios where MCD is Specified as a Maximum Permissible Rate. Streams are Ordered from Smallest to Largest Drainage Area.

Stream	Mean Annual Flow (cfs)	Flow Alternative Scenario 1			Flow Alternative Scenario 2			Flow Alternative Scenario 3			Flow Alternative Scenario 4		
		Diversion Season	Minimum Bypass Flow (cfs)	Maximum Diversion Rate (cfs)	Diversion Season	Minimum Bypass Flow (cfs)	Maximum Diversion Rate (cfs)	Diversion Season	Minimum Bypass Flow (cfs)	Maximum Diversion Rate (cfs)	Diversion Season	Minimum Bypass Flow (cfs)	Maximum Diversion Rate (cfs)
E. Fk. Russian River Trib	0.13	12/15-3/31	0.3	0.1	1/1-12/31	0.3	0.1	12/15-3/31	2.0	0.1	10/1-3/31	1.8	1.3
Dry Creek Trib	2.2	12/15-3/31	6.8	1.5	1/1-12/31	5.6	3.2	12/15-3/31	16	1.5	10/1-3/31	10	5.5
Dunn Creek	2.5	12/15-3/31	4.3	0.8	1/1-12/31	5.5	0.1	12/15-3/31	15	0.8	10/1-3/31	8.1	4.7
Carneros Creek	3.8	12/15-3/31	2.7	1.6	1/1-12/31	6.6	9	12/15-3/31	18	1.6	10/1-3/31	9.3	13
Huichica Creek	8.9	12/15-3/31	7.4	3.7	1/1-12/31	17	2.2	12/15-3/31	33	3.7	10/1-3/31	15	13
Olema Creek	25	12/15-3/31	36	15	1/1-12/31	52	*na* [1]	12/15-3/31	79	15	10/1-3/31	32	*na* [1]
Pine Gulch Creek	12	12/15-3/31	19	6.2	1/1-12/31	25	1.1	12/15-3/31	36	6.2	10/1-3/31	14	37
Warm Springs Creek	35	12/15-3/31	39	20	1/1-12/31	92	11	12/15-3/31	85	20	10/1-3/31	30	43
Santa Rosa Creek	19	12/15-3/31	25	8.3	1/1-12/31	39	7.2	12/15-3/31	46	8.3	10/1-3/31	16	60
Albion River	20	12/15-3/31	21	11	1/1-12/31	51	10	12/15-3/31	45	11	10/1-3/31	15	37
Salmon Creek	25	12/15-3/31	21	12	1/1-12/31	50	13	12/15-3/31	53	12	10/1-3/31	18	70
Franz Creek	24	12/15-3/31	15	9.1	1/1-12/31	55	7.6	12/15-3/31	52	9.1	10/1-3/31	17	65
Lagunitas Creek	72	12/15-3/31	83	31	1/1-12/31	163	*na* [1]	12/15-3/31	108	31	10/1-3/31	30	*na* [1]

[1] - 1.5 year flood estimate not available from gage data

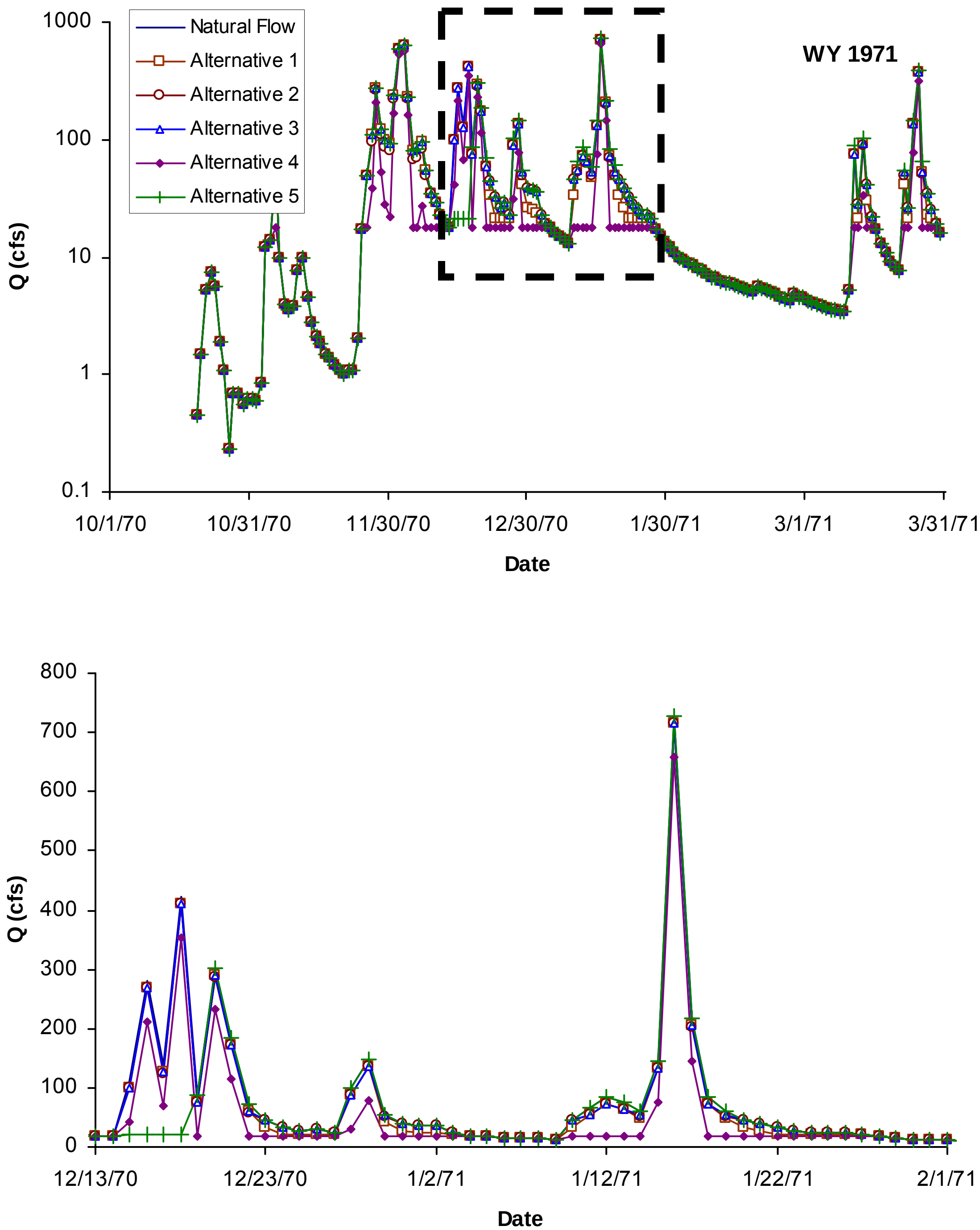


Figure 4-3. Example comparison of impaired hydrographs resulting from implementation of Flow Alternative Scenarios (listed in Table 4-2), for the October 1 – March 31 period of WY 1971 in the Salmon Creek validation site. Lower graph is an expansion of box indicated in upper graph.

4.2.1 Methods for Assessing Effects on Upstream Passage Needs

Methods used to analyze the effects (and conversely protectiveness) of Policy element alternative criteria to upstream passage are presented in detail in Appendix G. As shown in Figure 4-1, the habitat analysis for passage focused on quantifying the number of days that upstream passage was afforded in all 13 validation sites for each Flow Alternative Scenario. Protectiveness was inferred when the Flow Alternative Scenario (i.e., impaired flow time series) did not result in a substantial reduction in the number of days per water year that passage was afforded compared with unimpaired conditions. Two comparisons were made, in terms of (1) absolute and (2) percent difference in number of days from unimpaired flow conditions. A consistent, quantitative, biologically meaningful basis could not be identified for selecting a specific threshold, in terms of a number difference or a percent reduction, that distinguished between protective and non-protective flow conditions. For example, a 25 percent reduction in passage opportunities in a stream with few such occurrences each year could have greater biological significance to the indigenous anadromous salmonid stock than a comparable percent reduction in a stream with many days of passage afforded overall. It was thus necessary to invoke professional judgment when concluding whether a particular Flow Alternative Scenario (i.e., combination of Policy element alternatives) was protective or not.

In performing the analysis, one to two transects were sampled that best represented low flow passage barriers in the site after walking a length of stream and visually assessing low flow passage conditions. The number of transects depended on whether a single transect could be identified clearly as the low flow limiting condition for the length of site walked. Where uncertainty existed, two transects were placed at the two locations in the site that were perceived as being the most limiting to upstream passage at low flow.

The minimum flow providing passage was estimated for each passage transect sampled using a habitat-flow curve, where habitat was represented as a suitable width for passage (e.g., Figure 4-4). Where two transects were analyzed, the one requiring the highest minimum passage flow was used to represent limiting conditions in the site in comparisons between impaired and unimpaired flow conditions. Passage was considered feasible when a minimum 2 ft wide contiguous portion of the cross-section profile had a depth equaling or exceeding minimum depth criteria for each species. The upstream passage depth suitability criteria used in the analysis are presented in Table 2-1. The biological periods over which upstream passage was evaluated for the Flow Alternative Scenarios were, for each species:

a. Steelhead: From 11/1 through 3/31
b. Coho: From 10/1 through 2/28
c. Chinook: From 10/1 through 1/31

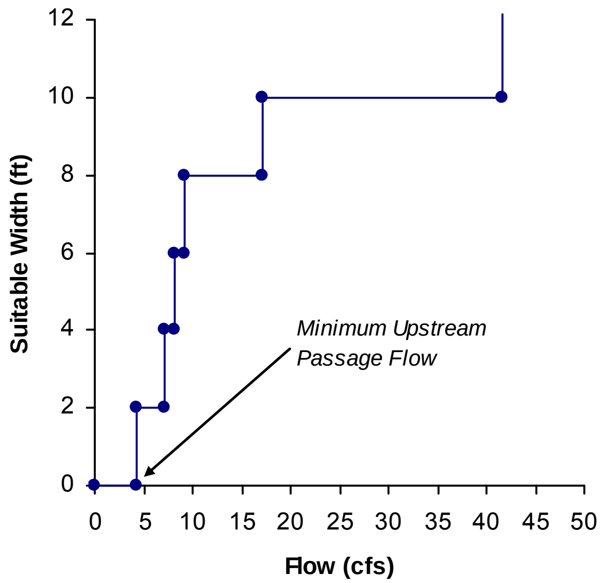


Figure 4-4. Identification of minimum upstream passage flow magnitude using a transect habitat-flow curve, as the lowest flow resulting in a 2 ft wide passage lane in the Dunn Creek validation site.

The protectiveness assessment included evaluating whether the daily flows associated with a Flow Alternative Scenario adversely affected upstream passage opportunities. Without a comprehensive habitat-flow sensitivity analysis for all thirteen sites (which was not possible for the given budget), it was not possible to completely partition out the effect of the MCD element on habitat availability from the effects of the MBF and diversion season elements. Professional judgment was therefore used to infer the protectiveness of the MBF and MCD element alternative criteria tested.

4.2.2 Methods for Assessing Effects on Spawning and Incubation Habitat Needs

Methods used to analyze effects (and conversely protectiveness) of Policy element alternative criteria to spawning and incubation habitat are presented in detail in Appendix G. As shown in Figure 4-1, the habitat analysis for spawning and incubation focused on quantifying the number of days that spawning was afforded across transects measured in 12 validation sites for each Flow Alternative Scenario (potential spawning habitat was not present in the accessible reach of one site). Spawnable substrates were only considered useable for successful reproduction if they remained wetted by 0.1 ft of water or more over the modeled duration of incubation (see Appendix G). Protectiveness was inferred when the impaired flow time series did not result in a substantial reduction in the number of days per water year that reproduction could occur successfully, compared with unimpaired conditions. Two comparisons were made, in terms of (1) absolute and (2) percent difference in number of days from unimpaired flow conditions. As for passage, a consistent, quantitative, biologically meaningful basis could not be identified for selecting a specific threshold in terms of a number difference or a percent reduction that distinguished protective and non-protective flow conditions. For example, a 25 percent reduction in the number of days spawning could occur successfully in a stream with few such occurrences each year could have greater biological significance to the indigenous anadromous salmonid stock than a comparable percent reduction in a stream with many days of spawning afforded overall. Professional judgment was therefore used when concluding whether a particular Flow Alternative Scenario (i.e., combination of Policy element alternatives) was protective or not.

In performing the analysis, one to two transects were sampled that best represented good quality spawning habitat in the site after walking a length of stream and visually assessing geomorphic and flow conditions. Transects were placed in channel locations where spawning was expected to occur based on professional experience. Typically, transects were placed preferentially over the pool edge/riffle crest interface, representing classic salmonid spawning habitat. The number of transects depended on the availability of spawning habitat within the length of site walked.

The minimum flow providing spawning was estimated for each transect based on depth, velocity, and substrate suitability criteria. Where two transects were analyzed, the one requiring the lowest minimum spawning flow was used to represent the site. The spawning habitat suitability criteria used in the analysis are presented in Table 2-2. The durations over which spawning habitat must remained wetted by at least 0.1 ft of water are presented in Table 2-3 for two general incubation periods, corresponding to before and after March 1. The lengths of incubation reflected general temperature trends recorded at USGS gages for the region. Species specific biological periods over which spawning activity was considered possible based on information summarized in Appendix C were:

a. Steelhead: from 12/1 through 3/31
b. Coho: from 11/1 through 2/28
c. Chinook: from 11/1 through 1/31

The protectiveness assessment included evaluating whether daily flows associated with each Flow Alternative Scenario adversely affected spawning habitat availability. As for the passage habitat analysis, it was not possible to completely partition out, or compare the effects of the MCD element on habitat availability from the effects of the MBF and diversion season elements. Professional judgment was therefore used to assess the protectiveness of the MBF and MCD element alternative criteria tested.

4.2.3 Methods for Assessing Effects on Juvenile Winter Rearing Habitat Needs

As discussed in Chapter 2 and Appendix D, juvenile anadromous salmonid winter rearing habitat was assumed to be protected if the flows provided by the MBF protected spawning and incubation habitat. High flow habitats and their accessibility could not be related directly to flow metrics given the high degree of site-specificity of the relationship. Such habitats were assumed to be protected if natural flow variability was preserved through the MCD element.

4.2.4 Methods for Assessing Effects on Outmigration Needs

Given the uncertainty discussed in Chapter 2 and Appendix D regarding clearly defining flow-based criteria protecting outmigration, it was not possible to identify a regional flow criterion that could be used to establish protectiveness. Instead, protectiveness was evaluated indirectly in terms of the effects of changing the end date of the diversion season relative to availability of pulse flows and seasonal increases in water temperature in the spring. The assessment relied primarily on existing literature.

4.2.5 Methods for Assessing Effects on Channel and Riparian Maintenance Needs

The analysis of protectiveness of channel and riparian maintenance flows involved estimating or hypothesizing changes in channel morphology and riparian condition that might occur from the different Policy element alternative criteria and the corresponding effects on anadromous salmonid habitat quantity and quality. The primary metric analyzed was the percent change in bankfull flow and the resulting changes in three fundamental morphologic attributes, bankfull depth, width, and surface grain size characteristics. This analysis was made based on a relationship derived from general gravel bed river data (Figure 2-1; details on derivation and rationale for using bankfull flow are given in Appendix D). However, the scatter of data used to generate the relations was large, resulting in uncertainty in the predictions of channel change. Increasing the level of confidence in such predictions would require extensive site-specific hydrograph and sediment transport analyses. Even then, additional uncertainty exists when attempting to relate morphologic changes to changes in anadromous salmonid habitat quantity and quality.

Therefore, protectiveness of channel and riparian maintenance flows was assumed to be provided by implementing a protective MBF and proposing a MCD that results in a relatively small level of channel morphology change. In the absence of clearly defined alternative criteria, the three cumulative diversion rate alternatives proposed by DFG-NMFS (15% of 20% winter daily exceedance flow; 5% of the 1.5 year flood) and MTTU (the diversion rate resulting in a half-day reduction in the duration of the MBF during the 1.5 year flood event), and the volume based CFII alternative proposed by DFG-NMFS, were evaluated for their effect on bankfull flow in terms of how they would change the 1.5 year flow magnitude in the validation sites. The assessment relied primarily on existing literature for determining direct effects on channel form and riparian condition and in turn anadromous salmonid habitat.

4.2.6 Methods For Assessing Estuary Habitat/Ocean Connectivity

As discussed in Chapter 2 and Appendix D, it was not possible to directly identify a regional flow criterion that could be used to protect estuarine habitat and provide ocean connectivity during the summer. Protectiveness was instead indirectly evaluated by comparing flow characteristics reported in the literature as being required for sand bar breaching, with the general level of base flows occurring during the diversion season associated with impaired Flow Alterative Scenarios.

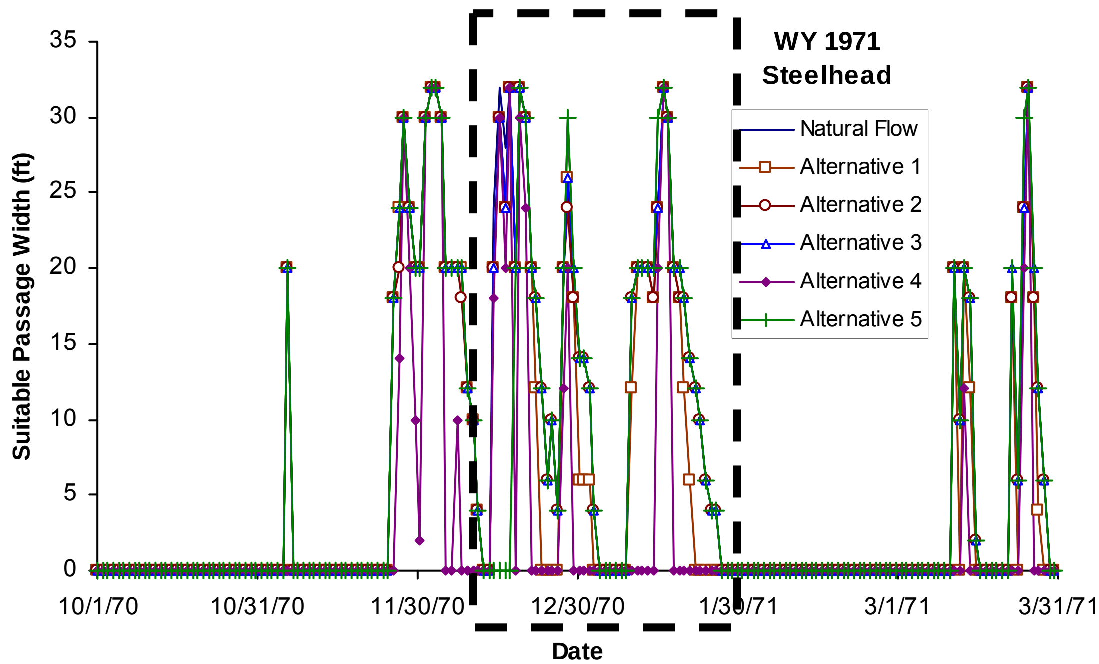
4.3 HABITAT ANALYSIS RESULTS USED TO ASSESS PROTECTIVENESS

The results presented and discussed in this section were used as the basis for conclusions regarding the protectiveness of the three Policy elements restricting diversion on anadromous salmonid habitats.

4.3.1 Upstream Passage

Curves were developed that depicted the width of stream passable as a function of flow for each of the 13 validation sites (see Appendix H). In this case, habitat time series were derived by applying habitat-flow curves in Appendix H to flow time series for each site. An example of the resulting relationship is presented in Figure 4-5 for steelhead in Salmon Creek corresponding to the impaired flow time series depicted in Figure 4-3. The term ‘habitat’ refers to width of stream bed predicted to be passable that day. The data depicted in Figure 4-5 were used to determine the number of days that passage was possible, where for example any non-zero data point depicted in Figure 4-5 corresponded to a day with passage (the minimum passable width was set at 2 feet, where having wider passage lanes does not affect the ability to pass). The analysis focused on assessing changes in the total number of days that passage was predicted to be possible for each Flow Alternative Scenario (i.e., days with potentially successful passage opportunities).

The average number of days per year of potential upstream passage opportunities afforded by the unimpaired flow and each impaired Flow Alternative Scenario for all 13 validation sites are depicted by species in Figures 4-6 to 4-8 (based on data in Appendix I). Also presented in Appendix I are the results for the two water years with the fewest and most days of passage (these may not necessarily equate to wet and dry years, as the length and years of record vary among the gages).



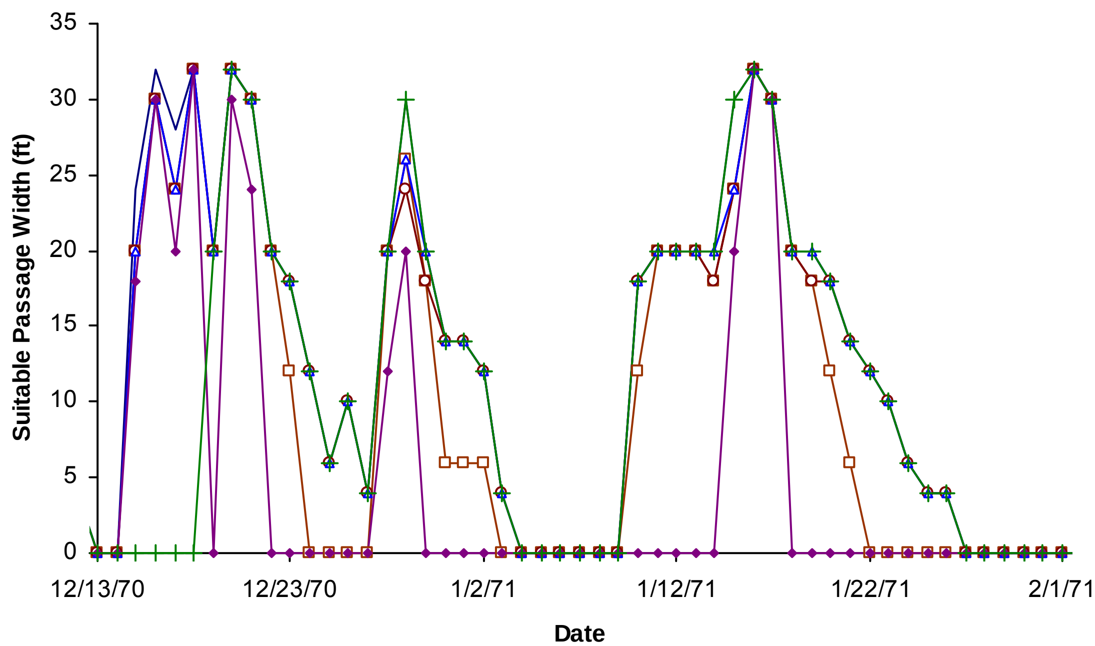


Figure 4-5. Comparisons of habitat time series for steelhead trout upstream passage resulting from implementation of Flow Alternative Scenarios (listed in Table 4-2), for the October 1 – March 31 period of WY 1971 in the Salmon Creek validation site. Lower graph is an expansion of box indicated in upper graph.

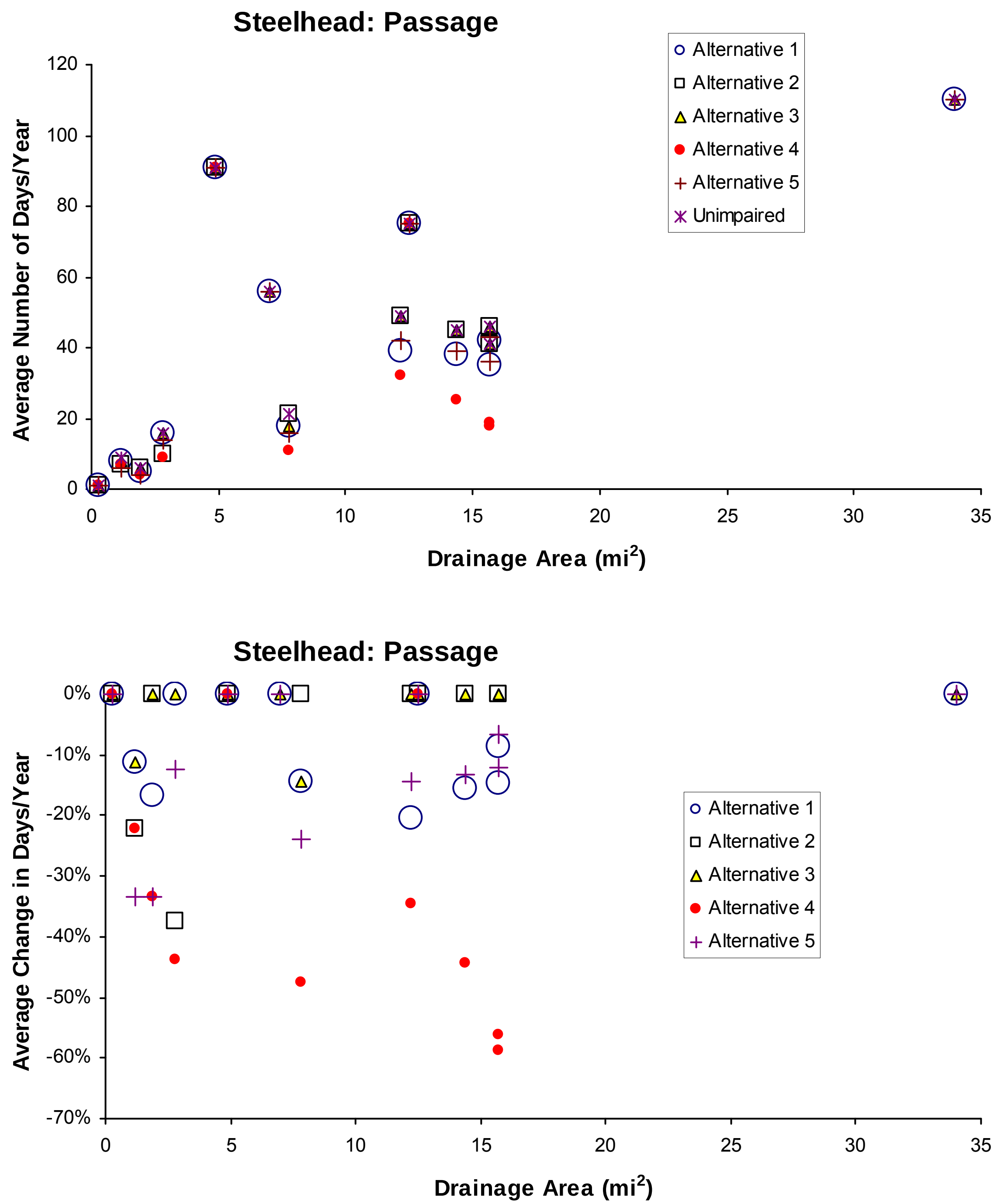


Figure 4-6. Predicted effects of the Flow Alternative Scenarios on upstream passage opportunities for steelhead trout in the validation sites, expressed as average number of days per year (top) and percent change from estimated unimpaired flow conditions (bottom), as a function of drainage area.

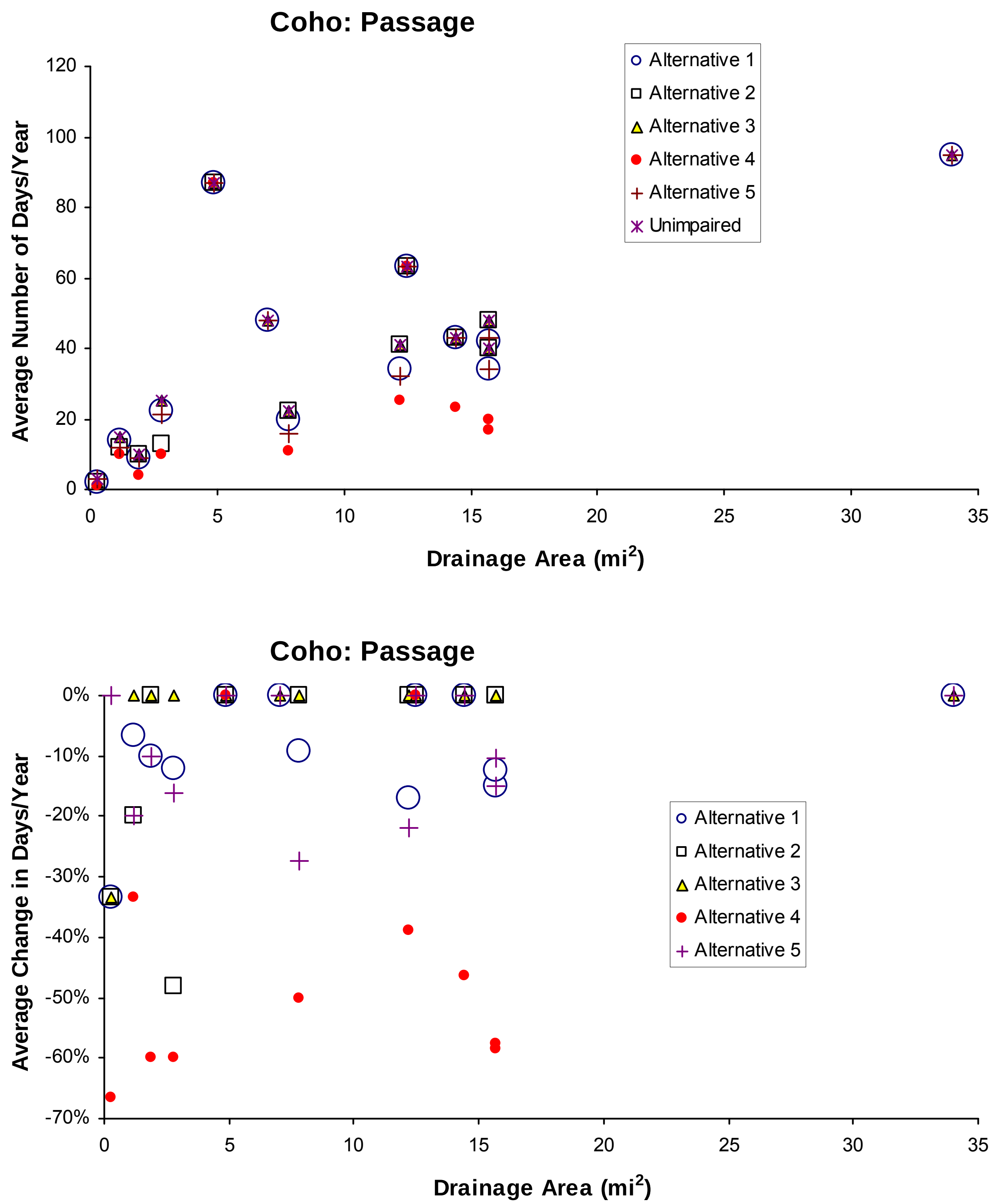
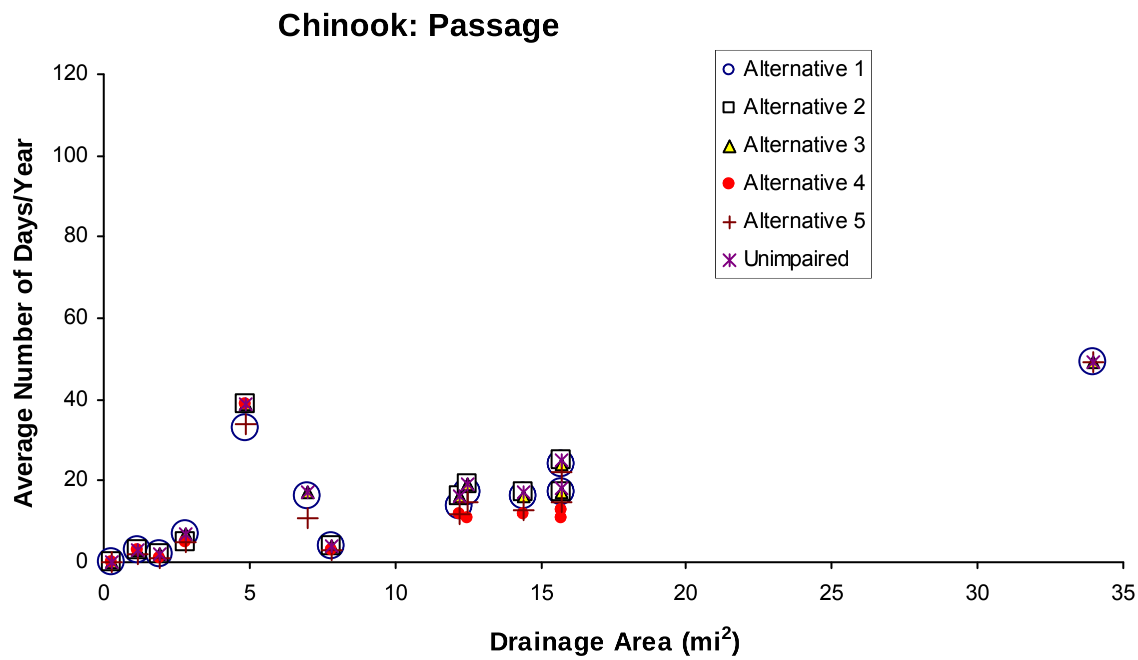


Figure 4-7. Predicted effects of the Flow Alternative Scenarios on upstream passage opportunities for coho salmon in the validation sites, expressed as average number of days per year (top) and percent change from estimated unimpaired flow conditions (bottom), as a function of drainage area.



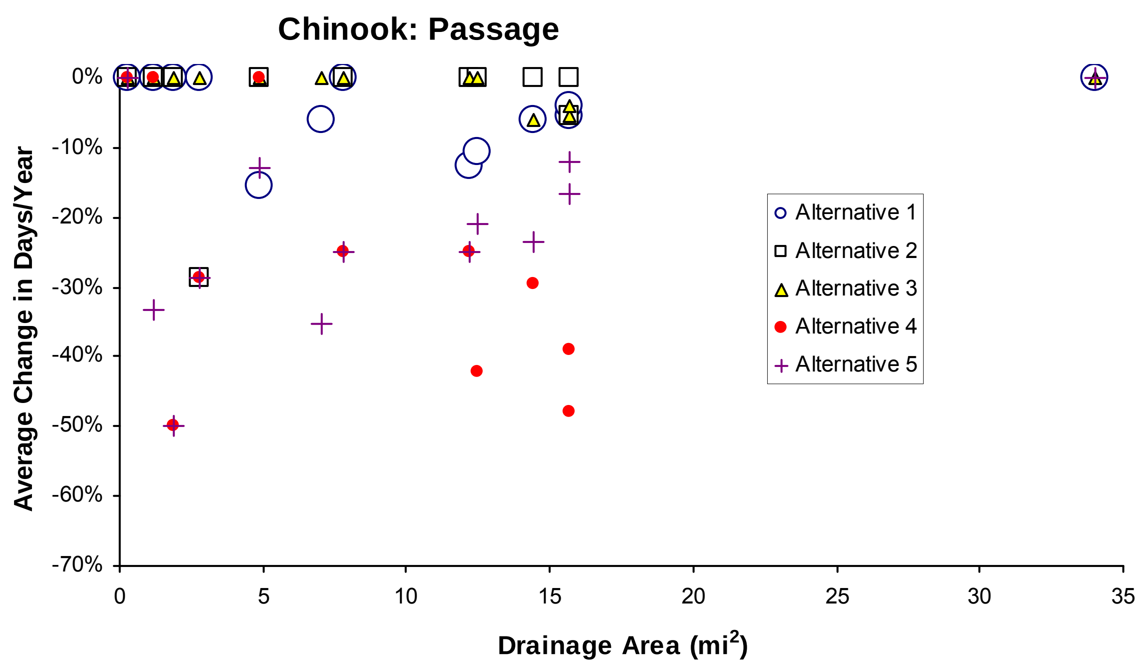


Figure 4-8. Predicted effects of the Flow Alternative Scenarios on upstream passage opportunities for Chinook salmon in the validation sites, expressed as average number of days per year (top) and percent change from estimated unimpaired flow conditions (bottom), as a function of drainage area.

4.3.2 Spawning and Incubation

Curves were also developed of the relationships of the width of stream available for spawning as a function of flow for each of the 13 validation sites (see Appendix H). As for upstream passage, habitat time series were derived by applying spawning habitat-flow curves in Appendix H to flow time series for each site. Figure 4-9 depicts an example of the resulting relationship for steelhead in Salmon Creek corresponding to the impaired flow time series depicted in Figure 4-3. In this case, the term 'habitat' refers to the width of streambed with suitable depths, velocities and substrates available for a given day that stays wetted over the incubation season, thus providing for successful reproduction. The data depicted in Figure 4-9 can be used to assess effects in terms of the number of days that spawning habitat is provided, as well as relative changes in total habitat availability. For example, when unimpaired flows are relatively high, Flow Alternative Scenario 4 can be seen to result in a few days with more spawning habitat available than the other Flow Alternative Scenarios.

This analysis focused primarily on assessing changes in the total number of days that spawning habitat would be provided (i.e., days with potentially successful spawning opportunities; details on how spawning was determined to be successful are given in Appendices G and H), rather than an evaluation of the quantity of spawning habitat which would have required the placement and measurement of several more transects at each site. Accordingly, the total number of days was summed for each water year with complete unimpaired and impaired flow records, for each site. The average number of days per year with potential spawning opportunities afforded by the unimpaired flow and each impaired Flow Alternative Scenario for all 13 validation sites over all water years, are presented in Figures 4-10 to 4-12 (see Appendix I for details). Also presented in Appendix I are the results for the two water years with the fewest and most days with potentially successful spawning opportunities (these may not necessarily equate to wet and dry years, as the length and years of record vary among the gages).

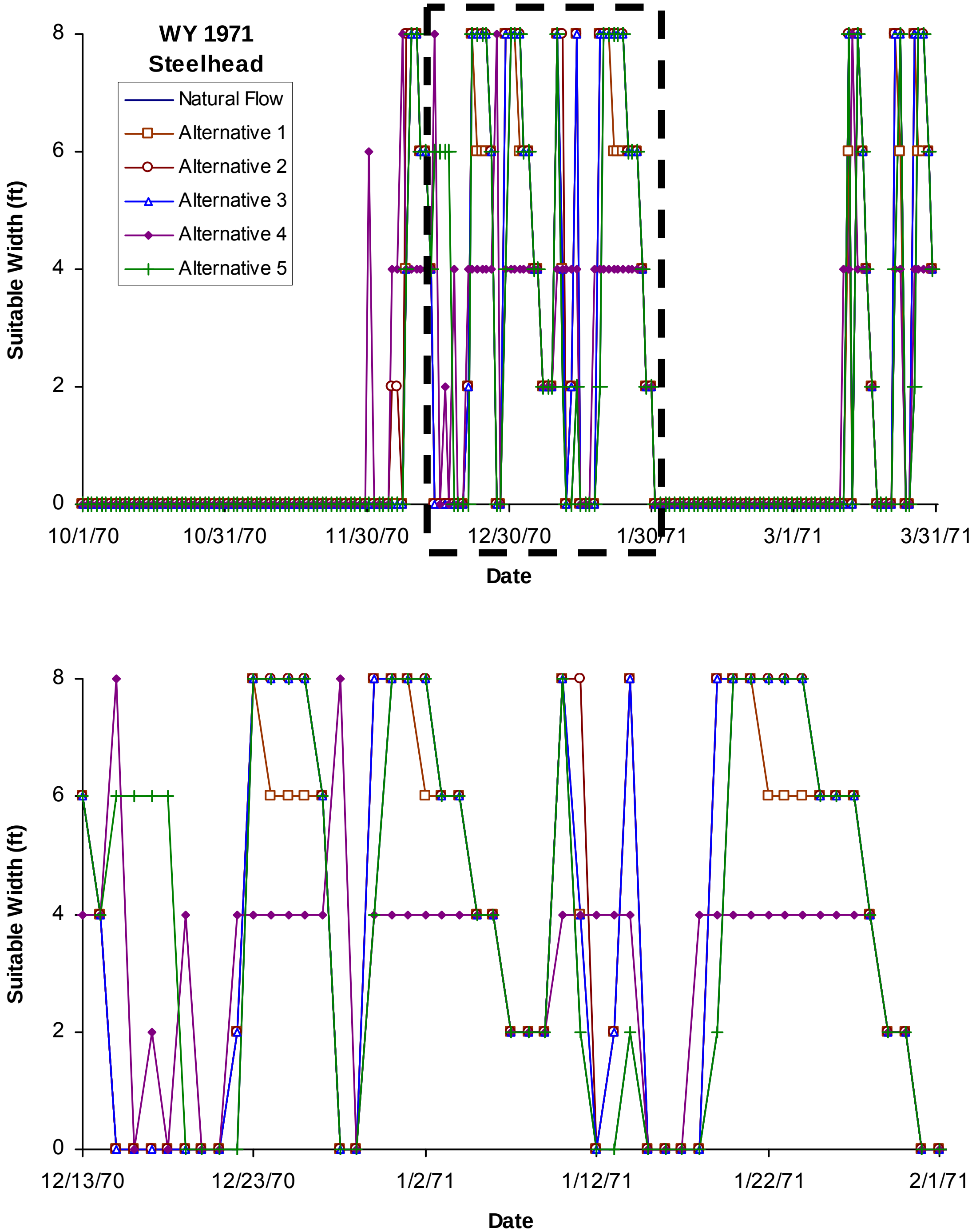


Figure 4-9. Comparisons of habitat time series for steelhead trout spawning and incubation resulting from implementation of Flow Alternative Scenarios involving a MCD rate criterion (listed in Table 4-3), for the October 1 – March 31 period of WY 1971 in the Salmon Creek validation site. Lower graph is an expansion of box indicated in upper graph.

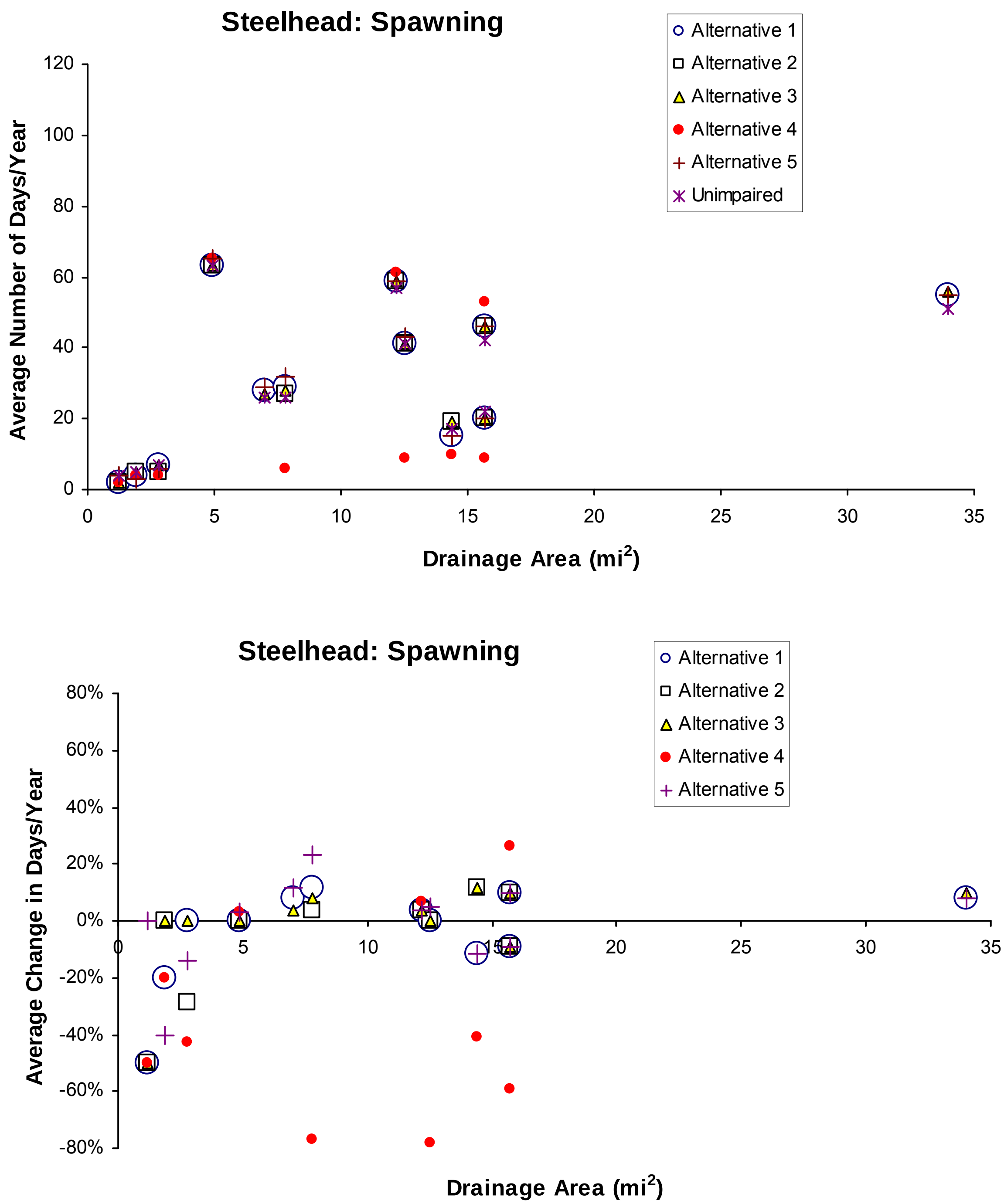


Figure 4-10. Predicted effects of the Flow Alternative Scenarios on spawning opportunities for steelhead trout in the validation sites, expressed as average number of days per year (top) and percent change from estimated unimpaired flow conditions (bottom). Data are plotted against each site's drainage area and are summarized from information presented in Appendix I.

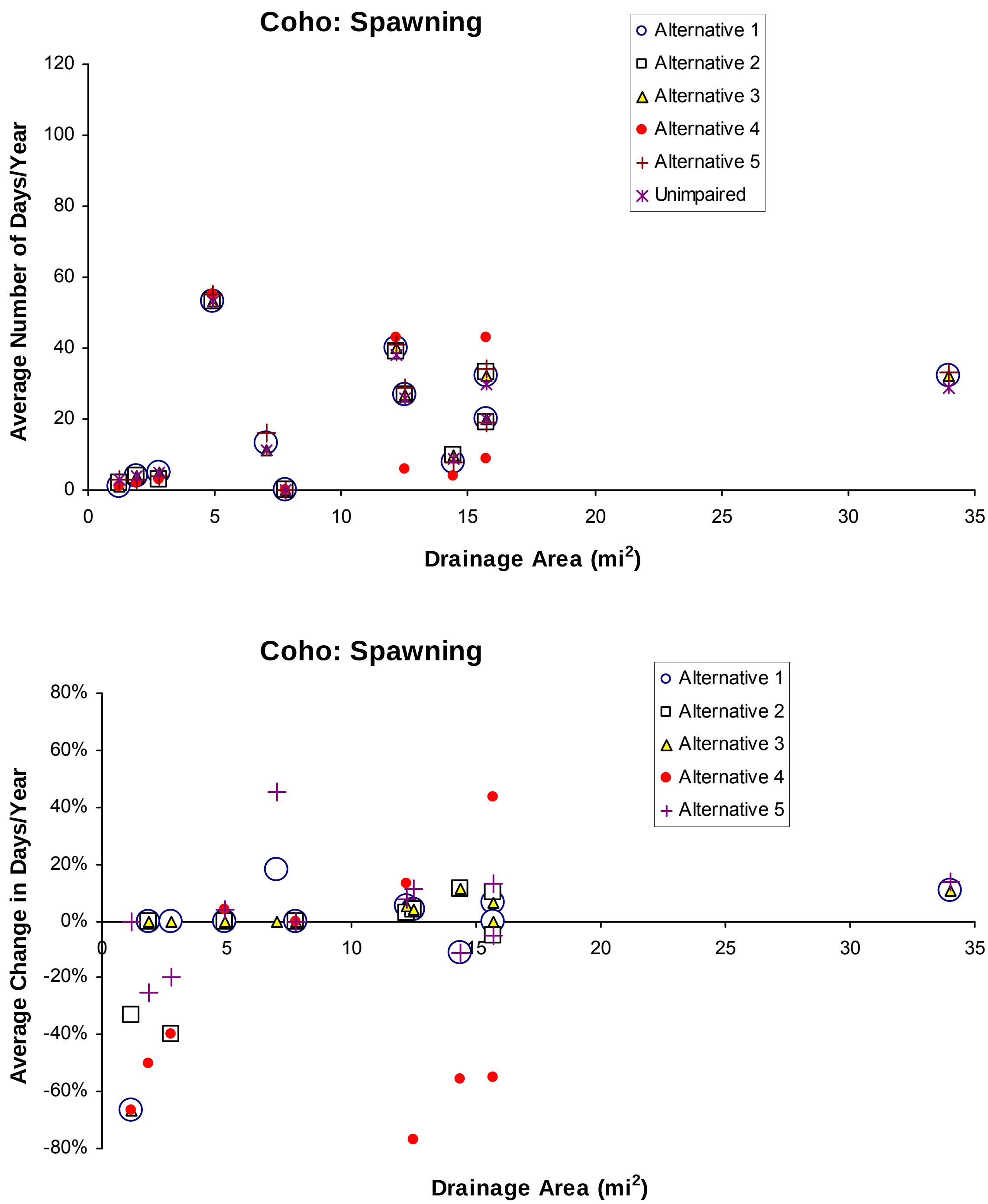


Figure 4-11. Predicted effects of the Flow Alternative Scenarios on spawning opportunities for coho salmon in the validation sites, expressed as average number of days per year (top) and percent change from estimated unimpaired flow conditions (bottom). Data are plotted against each site's drainage area and are summarized from information presented in Appendix I.

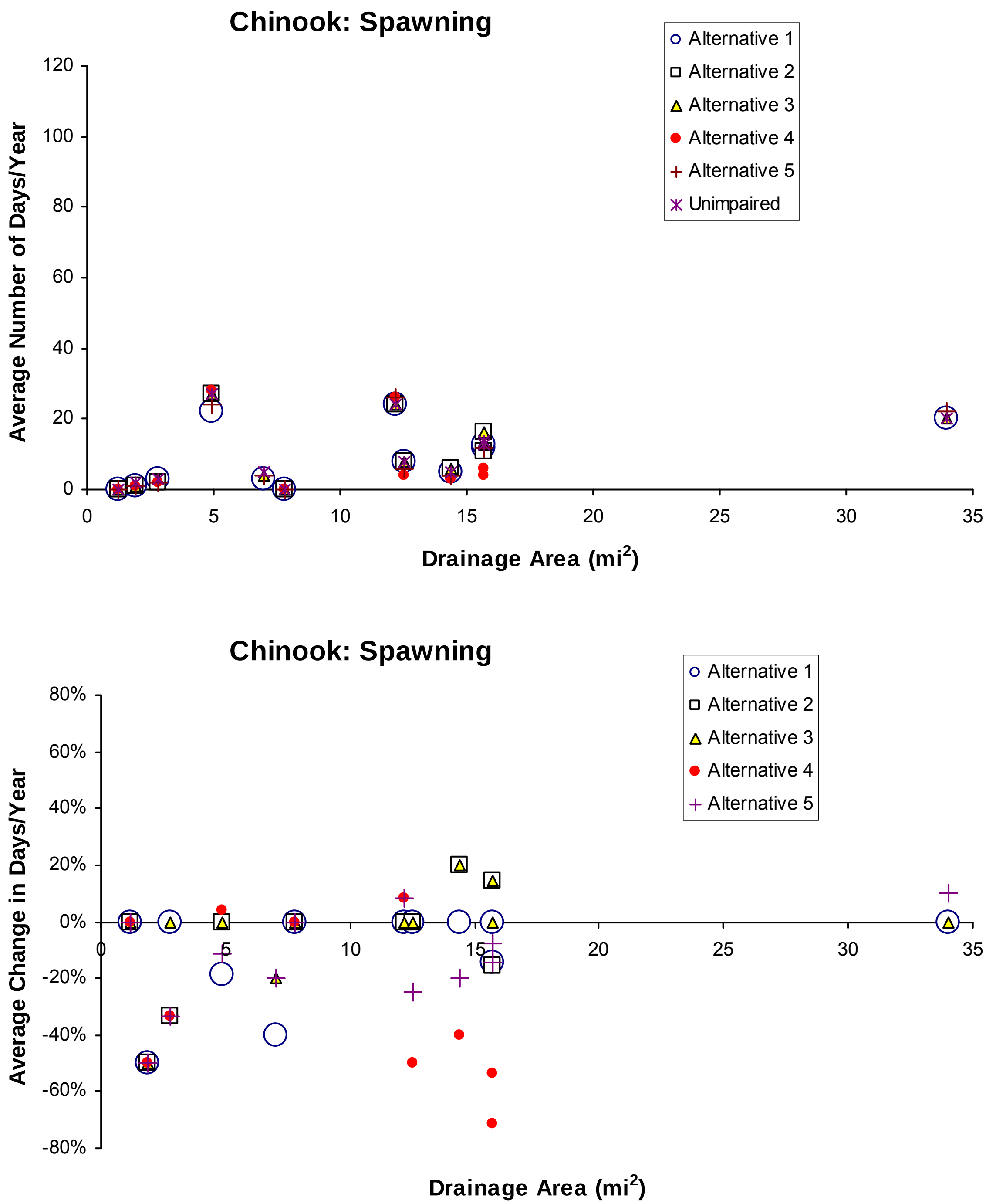


Figure 4-12. Predicted effects of the Flow Alternative Scenarios on spawning opportunities for Chinook salmon in the validation sites, expressed as average number of days per year (top) and percent change from estimated unimpaired flow conditions (bottom). Data are plotted against each site's drainage area and are summarized from information presented in Appendix I.

4.3.3 Juvenile Winter Rearing

There were no specific habitat-flow results for juvenile winter rearing habitat. As discussed in Chapter 2 and Appendix D, this habitat component was assumed protected by provision of spawning habitat through the MBF element and by maintaining natural flow variability through the MCD element.

4.3.4 Outmigration

The results of the literature review indicated that water velocity, temperature, level of smolt development, time of year and possibly turbidity can all influence the downstream migration of juvenile salmonids (Giorgi et al. 1985; Beeman and Rondorf 1992; Berggren and Filardo 1993; Achord et al. 1994; Buettner and Brimmer 1995; Skalski and Townsend 1999). Many of these factors are related to high flow and were considered when assessing protectiveness. There are primarily two ways described below in which diversion in the Policy area could adversely affect outmigration: through the effects of physical changes in flow rate on migration behavior, and through physiological effects of water temperature.

For example, the reduction in flow velocities caused by low to moderate rates of diversion in the Policy area has the potential to directly affect both (1) initiation of migration and (2) travel time of outmigrants as they head downstream to the ocean. The effect of reduced water velocity in the spring can be qualitatively evaluated by assuming that travel time is inversely proportional to water velocity. Average water velocities during spring runoff in Policy area streams may typically be between 3-10 ft/s (cf. Leopold et al. 1995), or 50-160 miles/day. Manning et al. (2005) tracked outmigrating steelhead smolts in the Russian River and observed travel speeds averaging around 9-12 miles/day. These speeds were similar to results from the previous year and for hatchery fish that exhibited speeds ranging from 3.7-12 miles/day, and appeared to be independent of differences in flow across years. Demko et al. (1998) observed travel speeds of Chinook smolts in the Central Valley ranging on the order of 5-7 miles/night. These speeds were generally less than average water particle speeds during high flow. However, Moser et al. (1991) noted faster, short-term travel speeds for coho of up to 36-64 miles/day, and longer duration speeds averaging 18 miles/day. Chinook migration rates have been observed in the Willamette River in Oregon to approximate 70 miles/day (Bradford et al. 1990). These rates are relatively fast, and most Policy area streams are comparatively short in length. Hence, the direct effects of flow reductions in Policy area streams during periods of smolt outmigration would not likely be biologically significant because they are unlikely to affect smolt swimming speeds and rates of downstream movement to an extent where delays in reaching the ocean would result in biologically meaningful consequences.

However, effects could still be indirectly manifest if flow reductions resulted in warming of water temperatures which can increase stress and incidence of disease. Temperatures of 15ºC and

19ºC approximate the limit to optimal juvenile salmon growth, and the approximate onset of feeding inhibition and avoidance during migration, respectively (ODEQ 1995; McCullough 1999). These temperatures are generally reached in Policy area streams between March-May (15ºC) and April-July (19ºC), respectively, depending on the stream and location in the channel network (USGS water quality data). Temperature preference has been correlated with optimal growth temperature, and the general preference of juvenile salmonids appears to be for temperatures 15ºC and lower (McCullough 1999). Water temperatures around 15ºC and higher have been found to cause premature smolting and/or de-smoltification (failure to smolt), which may influence the numbers of fish reaching the estuary and successful transition to saltwater. This phenomenon has been observed for steelhead, Chinook and coho juveniles, with steelhead smolts appearing to undergo reverse smoltification more readily at elevated temperatures than salmon species (Wedemeyer et al. 1980). Elevated water temperatures could thus affect steelhead smolts more strongly than coho and Chinook smolts in Policy area streams, although all three species would likely be susceptible to adverse effects of elevated temperatures beginning in March.

4.3.5 Channel and Riparian Maintenance

As discussed in Appendix D, the literature indicates that the 1.5-year flood magnitude, as derived from an annual maximum flood series, is a hydrologic metric that can be used as an estimate of the bankfull flow or effective discharge magnitude. The bankfull flow metric can be applied throughout a drainage basin, and is a surrogate that effectively integrates the effects of magnitude, frequency and duration of high flows forming the channel and affecting riparian condition.

The clearest conclusion that could be inferred from the analysis of channel and riparian maintenance flow needs is that a greater rate of diversion is less protective than a smaller rate, but it was not possible to identify a clear threshold between protective and non-protective diversion rates or volumes in the context of anadromous habitat needs. The MCD Policy element has the most significant impact on channel and riparian maintenance flows.

Table 4-4 summarizes predicted percent reductions of the 1.5 year flood magnitude caused by implementing each MCD alternative criterion as part of the Flow Alternative Scenarios, as estimated for the four validation sites with the longest stream gage records (see section F.4 in Appendix F for details). The 15% of the winter 20% exceedance flow rate and the comparable magnitude diversion rate proposed by MTTU (2000) are predicted to result in negligible channel change based on a comparison of the percent reductions in Table 4-4 with Figure 2-1. The CFII = 10% alternative criterion proposed in the DFG-NMFS (2002) Draft Guidelines results in the greatest predicted change, at levels that according to Figure 2-1 could result in large changes in channel morphologic characteristics. Therefore, the CFII = 10% level does not appear to be regionally protective of channel maintenance flow needs. Based on professional judgment, the

5% of the 1.5 year flood magnitude appeared to have the potential to result in relatively small channel changes according to Figure 2-1 and be the closest of the MCD element alternative criteria to a protective regional channel maintenance threshold. Smaller diversion rates have a greater potential to be overly protective.

Table 4-4. Estimated Reduction in the 1.5 Year Flood Peak Flow Rate Associated with Implementation of the Five Flow Alternative Scenarios, in Four Validation Sites with at Least Ten Years of Stream Flow Records.

Validation Site	Unimpaired 1.5 Year Flood (cfs)	Percent Reduction in 1.5 Year Flood Magnitude by Flow Alternative Scenario				
		Flow Alternative Scenario 1 (MCD1: 15% of 20% Winter Exceedance Flow)	Flow Alternative Scenario 2 (MCD4: Reduce MBF Duration for 1.5 Year Event by ½ Day)	Flow Alternative Scenario 3 (MCD1: 15% of 20% Winter Exceedance Flow)	Flow Alternative Scenario 4 (MCD2: 5% of 1.5 Year Flood Flow Rate)	Flow Alternative Scenario 5 (MCD3: CFII=10%)
Albion R	1,017	1%	1%	1%	5%	30%
Salmon Cr	1,439	1%	1%	1%	5%	20%
Santa Rosa Cr	1,170	1%	1%	1%	5%	37%
Warm Springs Cr	690	3%	2%	1%	5%	11%

Hence, it was concluded in the analysis that specification of a protective maximum cumulative diversion limitation should involve an element of conservativeness, whereby a level is proposed that is considered by professional judgment to have a low risk of reducing channel size and surface grain size distribution over the long and short terms, respectively. Given the level of uncertainty in specifying a MCD that is protective of channel and riparian maintenance flow needs, it was concluded that effectiveness monitoring would be key to determining protectiveness in this context, particularly with respect to establishing whether additional water may be diverted.

4.3.6 Estuary Habitat/Ocean Connectivity

The literature review indicates that sand bar closing generally occurs during the summer months. The reduction of flows during the fall months could potentially delay sand bar breaching. Presently, sand bar breaching is artificially induced in some systems to meet various management goals and ensure impacts to aquatic fauna are minimized. In the case of the Russian River, management of flows into the estuary involves coordinated flow releases from Warm Springs and Coyote Valley dams during the summer months. Management actions can include mechanical breaching of the sandbar at the mouth to allow adult Chinook and coho access to the river during dry and critical water supply conditions. Artificial breaching has allowed some adult Chinook salmon to enter the Russian River as early as August, although the majority of upstream migration generally occurs in October or November when water temperatures are more favorable. The overall objective of a present multiagency estuary management proposal (Russian River Estuary Flow-Related Habitat Project; Cook 2004, Entrix 2004) is to improve adult passage and juvenile rearing habitat for listed salmonid species, while preventing flooding. Given the extent to which the Russian River and other affected estuaries are managed by artificial breaching, the Policy is unlikely to have direct biological effects in those systems.

In systems not managed by artificial breaching, the literature review indicated that the amount of flow required to breach the blocking sand bar tends to reflect a minimum flow level, not the peak magnitude of a pulse flow event during the fall. There does not appear to be one flow level associated with breaching because of various other physical factors involved. Findings in the literature and gage data suggest that the range of base flows occurring during the winter period typically exceeds the flow at which sand bar blockage occurs. For example, estimates of the flow needed in the Navarro River to keep the mouth open throughout the summer range from around 5 cfs (Cannata 1998) to 25 cfs (Fisk 1955). Mean monthly flow during the winter period at the Navarro River gage generally exceeds 30 cfs from October through June (USGS station 1146800). October flows in some years are less than 5 cfs, but on average the base flow exceeds the flow needed to breach the sand bar. As another example, the Mattole River sand bar was observed to close when flows were between 44-133 cfs at the Petrolia gage (USGS station 1146900; MRC 1995). Mean monthly flow during the winter period at this gage generally exceeds 200 cfs from October through June, although October flows in some years are less than 44 cfs. Specification of a minimum bypass flow that equals or exceeds winter base flow levels would ensure sand bar breaching dates would not differ from unimpaired flow conditions.

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5. PROTECTIVENESS OF DIVERSION SEASON ELEMENT ALTERNATIVE CRITERIA

This chapter analyzes the protectiveness of diversion season element alternative criteria for anadromous salmonids and their habitat in the Policy area. The analysis interprets results identified in Chapter 4, Appendix D, and in other relevant literature. The analysis focused particularly on differences in the five Flow Alternative Scenarios (Tables 4-2 and 5-1) with unimpaired flow conditions.

Table 5-1. Description of Diversion Season Element Alternative Criteria Evaluated in the Analysis of Protectiveness.

Diversion Season Alternatives	Description	Impaired Flow Analysis
DS1 (DFG-NMFS 2002)	12/15-3/31	Flow Alternative Scenario 1, 3, & 5
DS2 (MTTU 2000)	Year Around	Flow Alternative Scenario 2
DS3 (Consulting Engineers 2006 Scoping Comments)	10/1-3/31	Flow Alternative Scenario 4

5.1 ANALYSIS OF PROTECTIVENESS

The times of year when new diversions can be permitted in the Policy area without adversely impacting anadromous salmonids are generally restricted to the winter high flow period, which generally corresponds to the months of December through March, although diversion may also be possible in the late fall months during storm events. During the diversion season, primary instream flow needs are protected by appropriate MBF and MCD element criteria. The winter diversion season specification also reflects the need to prevent permitting further diversion during the critical late spring, summer, and early fall months when low flows may substantially limit juvenile habitat quantity and quality in Policy area streams. Therefore, the protectiveness of the diversion season element hinges on specification of appropriate starting and ending dates that preclude the potential for adverse effects of winter diversion. The year-round alternative (DS2) is therefore not considered a feasible option.

5.1.1 Upstream Passage

Upstream passage needs have the potential to affect the beginning date of the diversion season. Upstream migration of anadromous salmonids in the Policy Area generally begins first with Chinook in September or October depending on the stream. Coho begin migrating upstream in substantial numbers in October, followed by steelhead in November (see Appendix C for details). The upstream migration of each species generally occurs opportunistically as flow conditions allow. Low flow years may be associated with infrequent upstream movement triggered by suboptimal flow increases, whereas wet years with numerous high flow events may allow a more even distribution of fish entry, upstream migration, and spawning (e.g., Tetzlaff et al. 2005). With protective MBF and MCD elements in place, the effect of the diversion season element should be minor on hydraulic conditions affecting upstream passage.

Water temperatures can influence upstream migration behavior during the October-December period when stream flows are increasing, and air and river temperatures are falling (NCRWQCB 2000). Adults generally do not migrate upstream until water temperatures are suitable, typically below 21ºC (McCullough 1999). Water temperatures in Policy area streams are generally near or above this level in September and below this level in October (USGS data). Thus, although stream flow reductions can increase periods of warmer water temperatures, diversions made after October 1 have a lower probability of interfering with upstream passage ability than diversions occurring earlier. As such, there does not appear to be a distinguishable difference in terms of protectiveness between the DS1 and DS3 alternative criterion start dates to the winter diversion season. Comparison of the results of the different Flow Alternative Scenarios in Appendix I indicates that the diversion season length has less influence on passage opportunities than the MBF and MCD. This suggests that the earlier diversion date (October 1) should be equally protective compared with the December 15 date, as long as protective MBF and MCD criteria are met. For example in Franz Creek (Figure I-12), it was predicted that the combined effect of lower MBF and higher MCD under Flow Alternative Scenario 4 would consist of substantial reductions in passage opportunities compared with Flow Alternative Scenario 2. At the same time, Flow Alternative Scenario 3, which involved the most protective combination of diversion season, MBF and MCD (see Table 3-1), does not substantially reduce passage opportunities compared with unimpaired flow conditions, in terms of number of days per year.

5.1.2 Spawning and Incubation Habitat

The major spawning activity in Policy area streams generally begins around October 1 and continues through the end of March (Chapter 4; Appendix C). Base flows are highest during the December-March period and provide the greatest opportunity for spawning.

With respect to the DS1 and DS3 alternative criteria diversion start dates (October 1, or December 15), redds that are created during early fall freshets in October and November could be constructed in any portion of the channel containing suitable depth, velocity and substrate characteristics, including channel margins as well as deeper channel segments (e.g., thalweg). Absent appropriate MCD and MDF criteria during these periods, redds constructed along the margins could be susceptible to dewatering if flows decrease after spawning is completed. Conversely, redds constructed near the thalweg could be more prone to scour during winter high flows (MTTU 2000). However, allowing a diversion start date of October 1 could benefit redds constructed near channel margins as well as deeper areas, provided appropriate MBF and MCD rate elements are met during this time. Indeed, comparison of results for the different Flow Alternative Scenarios (see Appendix I) indicated that diversion season length has less influence on spawning habitat availability for all three anadromous salmonid species than the MBF and MCD. For example in Franz Creek (Figure I-12), it was predicted that the combined effect of lower MBF and higher MCD under Flow Alternative Scenario 4 would consist of substantial reductions in spawning habitat availability compared with Flow Alternative Scenario 2. At the same time, Flow Alternative Scenario 3, which involves the most protective combination of diversion season, MBF and MCD, does not substantially reduce spawning opportunities compared with unimpaired flow conditions in terms of number of days per year. This suggests it should be possible to divert prior to December 15 as long as protective MBF and MCD criteria are met.

Chinook salmon are a special case and warrant a separate discussion. Because Chinook salmon migrate and spawn earlier than the other anadromous salmonid species, they would be most vulnerable to effects of diversion prior to December 15 due in part to their larger size and higher flow requirements. However, Chinook in the Policy area tend to spawn in larger channels, which require proportionally less water than smaller channels relative to mean annual flow. Therefore, maintaining base flows in upstream channels that are protective of steelhead spawning habitat needs after October 1 should also be moderately to fully protective of Chinook spawning needs downstream depending on the stream (see Appendix E). Also, because major spawning activity of Chinook and coho generally occurs in November and later, water temperatures should not be adversely affected by the earlier alternative criterion diversion start date.

5.1.3 Juvenile Winter Rearing Habitat

As long as an MBF element protective of spawning habitat is implemented, the start and end dates of the diversion season should not influence the protectiveness of juvenile rearing habitat. In general, upper water temperature thresholds for juvenile salmonid rearing tend to be higher than for adult upstream migration and smolt outmigration (cf. McCullough 1999). Hence, diversion season start and end dates that are protective of these habitat needs should also be protective of juvenile winter rearing habitat needs in terms of physical living space and water temperature.

5.1.4 Outmigration

Since the difference in diversion period between alternatives DS1 and DS3 only involves the start date, and most juvenile outmigration occurs in the spring, the effects of an earlier start date (October 1) should not reduce the overall protectiveness of the Policy relative to smolt outmigration. High flow events can still occur in April and later, thus it is necessary to assess the protectiveness of the March 31 end date proposed. The literature and available data indicated that March 31 is approximately the latest ending date of the diversion season that may be considered protective, as discussed below. Considerations other than physical habitat space influence protectiveness of the end date of the diversion period. Downstream water velocity and water quality are two important factors potentially influencing migration timing/rate and smolting processes, as described below.

Flows tend to drop off markedly in Policy area streams in April. Considerable numbers of salmon and steelhead smolts that depend on high flows complete their downstream migration through June. However, as indicated in Chapter 4, the effect of flow reduction on travel time is unlikely to be a critical determinant of outmigration success. Diversions during the post March 31 period may influence downstream migration success, by reducing the flow needed to stimulate and facilitate downstream migration.

The protectiveness of the Policy diversion season ending date is thus influenced predominantly by the relation between flow and water temperature. Increased water temperatures may interfere with smolting and fish health. Most coho salmon, steelhead, and Chinook salmon migrate downstream before highly stressful temperatures occur. Coho and steelhead tend to outmigrate as yearlings or older individuals in the Policy area, whereas Chinook emigrate primarily as young of year, including in the larger Russian River (Entrix 2004). Because older smolts tend to outmigrate first, high flows later in the outmigration season may be most important for later migrating, younger fish (Quinn 2005). Chase et al. (2003) noted downstream migration of Chinook smolts in the Russian River to peak through the first half of May and then slowly decline through June in 2002, and steelhead smolts to migrate primarily in mid-March through April. As discussed in Chapter 4, water temperatures have the potential to adversely affect smolt outmigration success in April and later, depending on the year and location. Late migrating steelhead and Chinook salmon can encounter stressful temperatures with adverse results, with later migrating Chinook being at greatest risk to decreases in spring flows (Entrix 2002). For all species, allowing additional diversion could lead to smolts being increasingly vulnerable to adverse water temperature conditions if new permits are approved for April or later.

The net conclusion based on the information reviewed is that extending the diversion past March 31 would not be protective of downstream migrant steelhead and salmon. Consequently, the year-round diversion season proposed by MTTU (2000) could also be considered as non-protective for outmigration in addition to summer rearing habitat.

5.1.5 Channel and Riparian Maintenance

The majority of channel and riparian maintenance flows occur after the first few fall storms, usually after October 1 and before March 31. As long as a protective MCD element is implemented, the start and end dates of the diversion season should not influence the protectiveness of the Policy towards ensuring suitable channel and riparian maintenance flows.

5.1.6 Estuary Habitat/Ocean Connectivity

Base flows after October 1 appear to be generally sufficient to promote sand bar breaching. Base flows in September may not be sufficient. Hence, an October 1 diversion season start date should be protective of freshwater entry by Chinook salmon, which is the earliest species to return to spawn. The end date of the Policy would need to extend into the summer before sand bar blockages would be promoted. Consequently, other factors than estuary habitat and ocean connectivity would be expected to control specification of a protective diversion season end date.

5.2 SUMMARY OF PROTECTIVENESS

Table 5-2 summarizes the protectiveness attributes of Policy diversion season element alternative criteria. Key habitat needs influencing the protectiveness assessment of the diversion season element are adult upstream passage, steelhead incubation during the late spring, and smolt outmigration, in terms of starting and ending dates of diversion.

A diversion season start date of October 1 would not be expected to be any less protective of upstream migration needs of anadromous salmonids than a December 15 start date, as long as protective MBF and MCD elements of the policy are also in place that protect upstream passage, spawning, winter rearing, and channel and riparian maintenance needs. Prior to October 1, water temperatures could be adversely affected by diversion leading to delay in upstream migration, and diversion may also potentially lead to delay in sand bar breaching dates. Permitting of new diversions should thus be avoided prior to about October 1. After March 31, water temperature increases may exacerbate adverse effects of diversion on incubation and smolting processes and survival, and thus permitting of new diversions should be avoided later in the spring.

Table 5-2. Summary of Protectiveness of Instream Flow Policy Diversion Season Element Alternative Criteria.

Policy Element: Diversion Season		
Alternative	**Regionally Protective?**	**Basis**
DS1: 12/15 – 3/31	Yes	Start date does not contribute to adverse water quality conditions, and flows must be protected by appropriate MBF and MCD element alternative criteria. End date avoids adverse water temperature effects on steelhead incubation and smolt outmigration.
DS2: Year Round	No	New diversions cannot be permitted during the late spring, summer, and early fall because instream flows during this period are generally limiting anadromous salmonid rearing habitat quantity and quality in the Policy area.
DS3: 10/1 – 3/31	Yes	Start date does not contribute to adverse water quality conditions, and flows must be protected by appropriate MBF and MCD element alternative criteria. End date avoids adverse water temperature effects on steelhead incubation and smolt outmigration.
Recommendation:	**Apply the 10/1 – 3/31 DS3 alternative criterion**	

6. PROTECTIVENESS OF MINIMUM BYPASS FLOW ELEMENT ALTERNATIVE CRITERIA

This chapter analyzes the protectiveness of the Minimum Bypass Flow (MBF) element alternative criteria identified in Chapter 3 for anadromous salmonids and their habitat in the Policy area. The analysis interprets results identified in Chapter 4, Appendix D, and in other relevant literature. The analysis focused particularly on differences between unimpaired flow conditions and impaired flow conditions under each of the five Flow Alternative Scenarios (Table 6-1). The analysis indicates that the MBF has the potential to impact primarily upstream migration, spawning success, and winter rearing habitat availability of anadromous salmonids.

Table 6-1. Description of Minimum Bypass Flow Element Alternative Criteria Evaluated in the Analysis of Protectiveness.

Minimum Bypass Flow Alternatives	Description	Impaired Flow Analysis
MBF1 (DFG-NMFS 2002)	February median daily flow	Flow Alternative Scenario 1, 5
MBF2 (MTTU 2000)	10% exceedance flow	Flow Alternative Scenario 2
MBF3 (Upper MBF)	Varies with drainage area and mean annual flow, protective of best spawning habitat conditions in all streams	Flow Alternative Scenario 3
MBF4 (Lower MBF)	Varies with drainage area and mean annual flow, lowest possible limit of protectiveness	Flow Alternative Scenario 4

6.1 ANALYSIS OF PROTECTIVENESS

The analysis below indicates that the MBF has the potential to impact primarily upstream migration, spawning success, and winter rearing habitat availability of anadromous salmonids.

6.1.1 Upstream Passage

Based on data described in Chapter 4 and Appendix E, the provision of spawning habitat appears to require more flow than passage on a regional basis, and therefore protection of the former should protect the latter. For example, steelhead and coho passage opportunities are generally provided more frequently in the validation sites than spawning opportunities (see graphs in Appendix I). Indeed, suitable passage conditions were afforded for steelhead on more days than suitable spawning habitat in ten out of twelve validation sites for unimpaired flow conditions (one site was not assessed for spawning habitat).

The data analysis also suggests that on a daily basis, suitable passage conditions in most Policy area streams are more limited for Chinook than for steelhead and coho (Figures 4-6 to

4-8 and Appendix I). The analysis indicates that passage conditions for Chinook are suboptimal under unimpaired flows in the validation sites, where passage depths are below the minimum depth criterion in Table 2-1 but still provide for limited passage under more stressful conditions (see range of alternate criteria in Appendix G). These results appear consistent with the existing distribution of Chinook in the Policy area, where the species is generally restricted to larger mainstem channels compared with the broader historical distributions of steelhead and coho.

As a related consideration, anadromous salmonids require holding habitat while they migrate upstream to spawn. Adult salmon and steelhead may enter spawning streams several weeks prior to spawning and seek out pools and cover to hold until flow conditions are suitable and/or they have matured sexually. For example, Bratovich and Kelley (1988) noted that most spawning in the Lagunitas Creek system occurred from 3 weeks to a month after adult fish had entered freshwater. Importantly, the provision of suitable passage conditions by the MBF element will allow access to important holding areas.

Comparisons of the reduction in average number of days per year with suitable passage conditions against those provided under unimpaired flow conditions suggest that Flow Alternative Scenarios 1 and 4 (described in Table 4-2) are least protective for upstream passage and that Flow Alternative Scenario 3 is most protective (Figures 4-6 to 4-8). Flow Alternative Scenario 4 typically resulted in an approximate 30-60% reduction in the number of suitable upstream passage days in most validation sites for all three species. Flow Alternative Scenario 2 appeared to be less protective than Flow Alternative Scenarios 1 and 3 in two of the smallest streams (i.e., drainage areas < about 4 mi^2).

Because results for the upstream passage analysis are based on Flow Alternative Scenarios that combine different Policy element alternatives to generate a flow time series (see Table 4-2), it is not possible to attribute the above results solely to the effects of the MBF. However, some inferences can be made from the results depicted in Figures 4-6 to 4-8 based on sites where the MCD levels of two Flow Alternative Scenarios are of comparable magnitude (see Table 4-3) but MBF levels are different. For example, Flow Alternative Scenarios 1 and 3 have the same MCD rate and diversion season for all sites, but different MBF levels, thereby allowing an evaluation of relative protectiveness of the MBFs with unimpaired flow conditions. In this case, the upper MBF in Flow Alternative Scenario 3 appears more protective as indicated by the greater number of sites afforded suitable passage conditions than in Flow Alternative Scenario 1 (Figures 4-6 to 4-8). As a second example based on site comparisons in Table 4-3, the Salmon Creek, Franz Creek, Albion River, and Santa Rosa Creek sites have similar MCD rates for Flow Alternative Scenarios 1 and 2, but the DFG-NMFS (2002) MBF in Flow Alternative Scenario 1 is about half that of the MTTU (2000) MFB in Flow Alternative Scenario 2 and is correspondingly less protective of upstream passage.

Flow Alternative Scenario 4, which includes the lower MBF4 alternative criterion for the MBF, resulted in substantial reductions in passage opportunities (Figures 4-6 to 4-8). While Flow Alternative Scenario 4 also includes a MCD rate that allows the greatest cumulative diversion of the four flow rate based element alternatives, it appears that the lower MBF4 level likely contributes to the overall reduction in suitable passage conditions. The MBF4 element alternative appears to result in suboptimal passage depth conditions for both Chinook and steelhead in most basins (see Appendix E, and the comparison of upstream passage requirements with criteria listed in Table G-3 in Appendix G).

The observations above suggest that the upper MBF (MBF3) alternative criterion contained in Flow Alternative Scenario 3 appears to be most protective of upstream passage needs in all size basins.

6.1.2 Spawning Habitat and Incubation

Protectiveness of the MBF for spawning and incubation habitat is, to a certain extent, facilitated by spawning behavior of anadromous salmonids. In general, steelhead and coho choose redd locations that are rarely exposed by falling stream levels in California coastal streams (Shapovalov and Taft 1954; Bratovich and Kelley 1988; Trush 1991). This phenomenon likely reflects fish waiting to begin spawning until the storm hydrograph is in recession. Water levels typically fall rapidly following the peak flow and then fall off more gradually as the source of water switches to groundwater storage within the basin (Linsley et al. 1982). Spawning activity seems to begin nearer the inflection point of the descending limb than the peak (Shapovalov and Taft 1954), and thus likely represents an adaptation to characteristics of groundwater input, rather than the more variable surface runoff. Spawners that use areas that are inundated and suitable at higher flows and become exposed at lower flows, would likely experience a selective pressure against that trait. Moreover, steelhead and coho spawning sites are frequently near riffle heads, in pool or run tails (Shapovalov and Taft 1954; Bratovich and Kelley 1988; Trush 1991). These sites are less prone to dewatering during flow reductions because the riffle crest downstream prevents the water level from decreasing to levels where redds become exposed (i.e., depth is greater than zero when there is no flow).

Higher MBFs, in addition to providing more suitable spawning habitat, should also be more protective against redd scour than lower flows. In general, under low flow conditions, redd construction may be concentrated closer to the channel thalweg and in deeper water areas closer to the upstream edge of a pool tail (i.e., closer to a pool). Redds constructed near the channel thalweg and near the upstream edge of the pool tail would likely be most susceptible to scour during high flows (Bratovich and Kelley 1988; MTTU 2000; DeVries 2000). Thus, if MBFs are too low during the spawning period, many redds may be constructed in the deepest regions of the channel where the stream bed may be more prone to scour (although not all thalweg locations are prone to deep scour depending on stream-wise position of the redd in the spawning bed; DeVries 2000). MTTU (2000) noted that a minimum bypass flow would be more protective if it allowed for some spawning to occur in locations other than the deepest spawning habitat available. A higher MBF would therefore be more protective from this perspective.

The validation site analysis indicated that Flow Alternative Scenarios 1, 2 and 3 provide comparable frequencies of spawning day opportunities for steelhead and coho in streams draining more than about 4 mi^2, and for Chinook in streams draining more than about 8 mi^2 (Figures 4-10 to 4-12). In these cases, the three Flow Alternative Scenarios do not appreciably reduce the availability of days that spawning is possible compared with unimpaired flows. The greatest differences in spawning day opportunities were observed for Flow Alternative Scenario 4 over all sites. For drainage areas less than about 4 mi^2, the analysis indicated that Flow Alternative Scenarios 1 and 2 had large reductions in successful spawning opportunities compared with unimpaired flow conditions.

The reductions in spawning opportunities observed above can be attributed in large part to the magnitude of the MBF calculated for the four MBF alternatives. The reason can be seen in Figure 6-1. This figure compares the four MBF alternatives against minimum spawning flow needs at the validation sites. The minimum spawning flow needs derived from field measurements are indicated by the diamonds. Predicted minimum bypass flows using MBF1 and MBF2 are shown by the squares and open circles, respectively. Predicted minimum bypass flows using MBF3 and MBF4 are indicated by the solid lines.

Figure 6-1 shows that MBF2, part of Flow Alternative Scenario 2, and MBF1, part of Flow Alternative Scenario 1, fall below minimum spawning flow needs for drainage areas less than about 4 mi^2 and 5 mi^2, respectively. Thus, these two hydrologic MBF metrics would not likely be protective of spawning habitat availability in streams with smaller drainage areas. They do appear to be protective in larger streams.

In contrast, the MBF3 alternative criterion (part of Flow Alternative Scenario 3) is associated with the smallest change in the number of spawning days compared with unimpaired flows, around +/- 10% (Figures 4-10 to 4-12), and also envelopes most of the spawning habitat-flow needs determined for the validation sites (Figure 6-1). This demonstrates the overall protectiveness of the MBF3 criterion. In addition, Flow Alternative Scenarios 1 and 3 have the same MCD criteria, but Flow Alternative Scenario 1 was less effective in estimating minimum flow needs. This indicates that the MBF has a strong influence on spawning habitat availability, particularly in streams draining less than about 4-5 mi^2 (Figure 6-1).

Figure 6-1 shows the MBF4 criterion (part of Flow Alternative Scenario 4) can be protective of spawning conditions in some but not all streams. The habitat analysis indicated that in many of the larger streams, the MBF4 criterion is associated with a decreased frequency of predicted

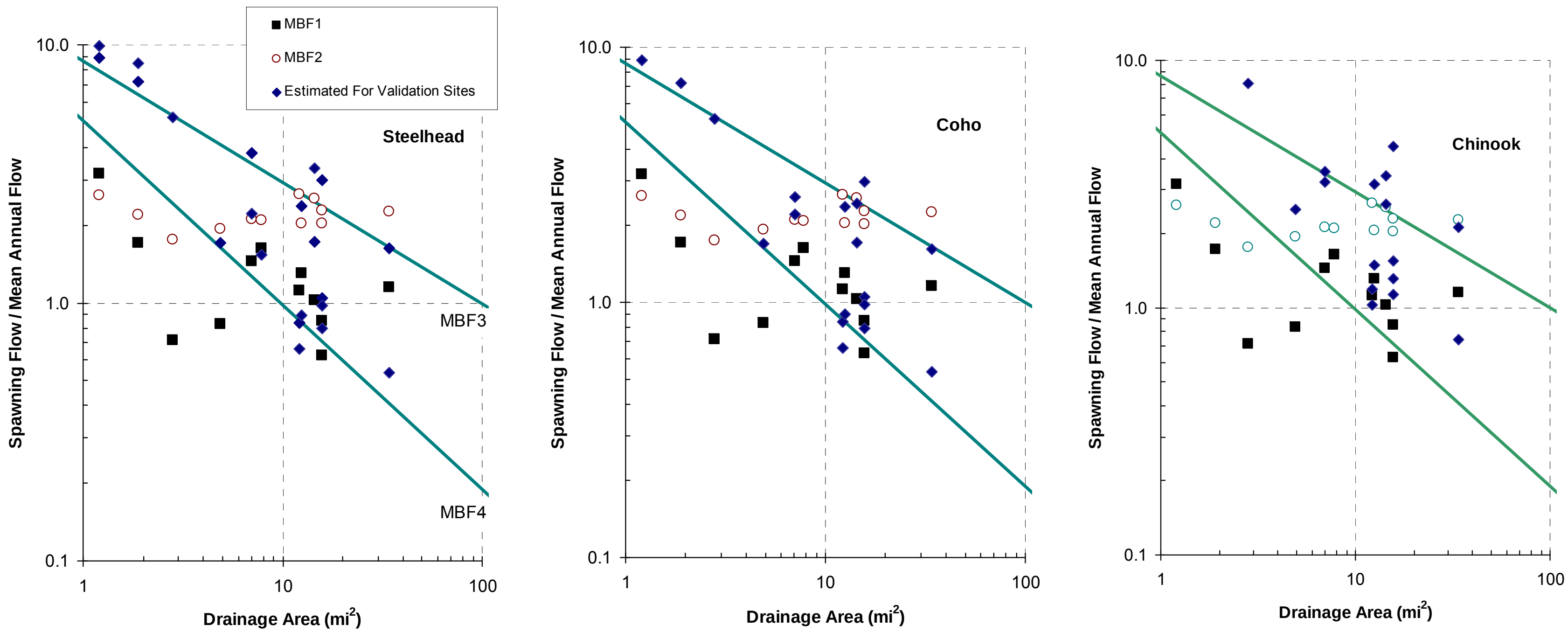

Figure 6-1. Comparisons of minimum bypass flow alternative criteria with protective spawning habitat-flow needs determined for the validation sites for steelhead, coho, and Chinook spawning, distinguished by drainage area. The spawning flow is scaled by the approximate unimpaired mean annual flow.

depths and velocities over steelhead and coho spawning substrates that meet suitability criteria (see Table 2-2), compared with other alternative criteria. Of the three species, the MBF4 criterion appears to be well below the flow needed for Chinook salmon spawning habitat (i.e., the diamonds) in more validation sites than for steelhead or coho (Figure 6-1).

6.1.3 Winter Rearing Habitat

As discussed in Chapter 4 and Appendix D, this habitat need is assumed to be protected by a MBF element that also protects spawning habitat.

6.1.4 Outmigration

The MBF element generally does not affect outmigration flow needs. As discussed in Chapter 5, the diversion season Policy element protects outmigrating smolts from the potential of adverse effects related to flow and water temperature during base flows resulting from Policy implementation. The need for pulse flows to stimulate and facilitate outmigration is affected by the MCD element.

6.1.5 Channel and Riparian Maintenance

The MBF element does not affect channel and riparian maintenance flow needs, which are affected by the MCD element.

6.1.6 Estuary Habitat/Ocean Connectivity

All of the MBF alternatives are generally protective of estuary habitat and ocean connectivity. As described in Chapter 4, the flow required to breach sand bars blocking river mouths is generally less than the winter base flow. All MBF alternatives appear to result in preserving winter base flows based on hydrologic analysis of the validation sites. Estuarine habitat conditions for juveniles generally do not become adverse until the summer. However, all of the MBF alternative criteria are protective of this anadromous salmonid habitat flow need if a protective winter diversion season alternative is used.

6.2 SUMMARY OF PROTECTIVENESS

Table 6-2 summarizes the protectiveness attributes of each MBF element alternative criterion considered. The results indicate that it is more protective on a regional basis to apply a conservative MBF threshold for administering water right permit applications under the Policy, and require site specific studies to determine if lower bypass flows might still be protective. Because a regionally protective Policy inherently results in over-protecting some streams (e.g., see Figure D-5 in Appendix D), application of the MBF3 alternative criterion would likely result in many cases where additional study could indicate that lower bypass flows might still be protective.

Table 6-2. Summary of Protectiveness of Minimum Bypass Flow (MBF) Alternatives.

Policy Element: Minimum Bypass Flow		
Alternative	**Regionally Protective?**	**Basis**
MBF1: February Median Daily Flow	Partially	Protective of upstream passage and spawning habitat flow needs in streams draining more than about 5 mi^2. Under-protective in smaller streams.
MBF2: 10% Exceedance Flow	Partially	Protective of upstream passage and spawning habitat flow needs in streams draining more than about 4 mi^2. Under-protective in smaller streams.
MBF3: Drainage Area (DA[1]) < 290 mi^2: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ Drainage Area > 290 mi^2: $Q_{MBF} = 0.6\ Q_m$ Q_m = unimpaired mean annual flow (cfs); For streams above anadromous habitat, DA is determined at the upstream limit of anadromy	Yes	Generally protective of upstream passage and spawning habitat flow needs across a wide variety of stream sizes in the region. Protects winter rearing habitat as well. Does not affect outmigration, channel and riparian maintenance, and estuarine habitat flow needs.
MBF4: Drainage Area < 0.11 mi^2: $Q_{MBF} = 8.7\ Q_m\ (DA)^{-0.47}$ Drainage Area = 0.11-500 mi^2: $Q_{MBF} = 5.1\ Q_m\ (DA)^{-0.71}$ Drainage Area ≥ 500 mi^2: $Q_{MBF} = 0.06\ Q_m$ For streams above anadromous habitat, DA is determined at the upstream limit of anadromy	No	Protective of upstream passage and spawning habitat flow needs in some streams, but a majority of streams in the region are under-protected with respect to upstream passage and spawning habitat flow needs for steelhead and coho. Appears to under-protect Chinook upstream passage and spawning habitat flow needs in nearly all streams. In all cases, the MBF is sufficiently low that adverse effects could occur to upstream passage and spawning opportunities even with small diversion rates.
Biological Recommendation:	**Apply Alternative MBF3**	

[1] Drainage area (DA) is evaluated in square miles.

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7. PROTECTIVENESS OF MAXIMUM CUMULATIVE DIVERSION ELEMENT ALTERNATIVE CRITERIA

This chapter analyzes the protectiveness of the maximum cumulative diversion (MCD) element alternative criteria identified in Chapter 3 for anadromous salmonids and their habitat in the Policy area. The analysis interprets results identified in Chapter 4, Appendix D, and in other relevant literature. The analysis focused particularly on differences between unimpaired flow conditions and impaired flow conditions under each of the five Flow Alternative Scenarios (Table 7-1).

Table 7-1. Description of Maximum Cumulative Diversion Element Alternative Criteria Evaluated in the Analysis of Protectiveness.

Maximum Cumulative Diversion Alternatives	Description	Impaired Flow Analysis
MCD1 (DFG-NMFS 2002)	MCD Rate = 15% of 20% winter (12/15-3/31) exceedance flow	Flow Alternative Scenario 1, 3
MCD2 (DFG-NMFS 2002)	MCD Rate = 5% of 1.5 year flood peak flow	Flow Alternative Scenario 4
MCD3 (DFG-NMFS 2002)	MCD Volume = CFII = 10% of estimated unimpaired runoff (no restriction on diversion rate)	Flow Alternative Scenario 5
MCD4 (MTTU 2000)	MCD Rate = calculated from site-specific hydrograph for a reduction in duration of MBF rate by ½ day during 1.5 year event	Flow Alternative Scenario 2

7.1 ANALYSIS OF PROTECTIVENESS

Depending on the timing and magnitude of the extraction relative to the instantaneous instream flow, individual diversions can have local effects on anadromous salmonids and their habitat in the downstream vicinity of the POD. The combined effect of multiple diversions upstream also influences the cumulative amount of water that flows at downstream locations, referred to in the DFG-NMFS (2002) Draft Guidelines as POI. Diversions can therefore have cumulative impacts on downstream resources as well as local impacts. The primary anadromous salmonid habitat needs potentially affected are addressed below. The analyses below and in Chapters 4 and 6 indicate that the MCD element has the potential to impact primarily channel and riparian maintenance flows, although upstream migration, spawning success, and winter rearing habitat availability of anadromous salmonids could be further adversely affected if an unprotective MBF element is applied.

7.1.1 Upstream Passage

Upstream passage of anadromous salmonids tend to be more restricted by low flows in smaller channels, where suitable passage depths are hydrologically less frequent, than in larger channels (MTTU 2000; R2 2004; Lang et al. 2004). The analysis in Chapter 6 and Appendix E indicates, however, that the MCD element should not appreciably affect upstream passage opportunities for steelhead and coho in most smaller channels when an MBF element is used that is protective of upstream passage flow needs based on the conservative depth criteria in Table 2-1. The validation site analysis results suggest that the primary way diversions could influence upstream passage under the Policy would be if the MCD element allows substantial reduction in peak flood magnitude earlier in the late fall/winter diversion season in some small streams if the MBF used is less than that truly needed for good passage conditions. In the extreme case, when flows greater than the MBF are completely diverted as is assumed for the worst case application under Flow Alternative Scenario 5, the impaired hydrograph would be essentially ‘flat-lined’ nearer the MBF level, akin to ‘lopping off the top.’ If this mode of diversion occurs for long enough (e.g., in dry and possibly average flow years), upstream passage opportunities of earlier migrating Chinook in particular could be reduced in frequency compared with unimpaired flow conditions.

The adverse effect of flat-lining the peak hydrograph, in the manner proposed for the worst case application of the CFII metric, can be seen in the validation site analysis results depicted in Figures 4-7 and 4-8 for Flow Alternative Scenarios 1 and 5. Flow Alternative Scenario 5 results in more reductions in coho and Chinook salmon passage opportunities compared with unimpaired and Flow Alternative Scenario 1 instream flows. It should be noted that the only difference between Flow Alternative Scenarios 1 and 5 is the use of different maximum cumulative diversion alternatives. They have the same MBFs and diversion seasons. Flow Alternative Scenario 1 applies a maximum diversion rate, whereas Flow Alternative Scenario 5 involves the worst case, unlimited diversion rate starting at the beginning of the diversion season until the CFII = 10% limit is reached. Since these two Flow Alternative Scenarios have a common diversion season start date of December 15, it is likely that applying an earlier start date (e.g., October 1) to Flow Alternative Scenario 5 could result in an even greater reduction in passage opportunities for coho and Chinook salmon because stream flows are generally higher for the month or so after December 15 than for the equivalent length period after October 1. A significant fraction of each species’ run migrates upstream between October 1 and December 15. Effects would be expected to be most pronounced in dry and average years when it can take up to 60 days or more after December 15 for the CFII to reach 10%. Hence, of the alternative criteria for the MCD element, the worst case, flat-lining method of diversion used when applying the CFII alternative criterion appears to have the greatest potential to reduce upstream passage opportunities for coho and Chinook in smaller stream channels, particularly when a regionally unprotective MBF element is implemented.

Other inferences can be made from the results depicted in Figures 4-6 to 4-8 based on sites where the MBF levels of two Flow Alternative Scenarios are comparable in magnitude in Table 4-3 and the MCD rates are different. For example, in the Dunn Creek and Dry Creek Tributary sites, the MBF levels for Flow Alternative Scenarios 1 and 2 are similar, but the MCD rate differs, where for Flow Alternative Scenario 1 it is higher in Dunn Creek and lower in Dry Creek than for Flow Alternative Scenario 2. In both cases, the higher MCD rate results in fewer passage opportunities in the respective streams for steelhead and coho (the streams are generally too small to support Chinook). In addition, the MCD rates in Pine Gulch Creek and Warm Springs Creek are generally higher for Flow Alternative Scenario 3 than Flow Alternative Scenario 1. Steelhead passage opportunities are fewer for Flow Alternative Scenario 3 in Pine Gulch Creek and comparable in Warm Springs Creek. Coho passage opportunities are comparable in both streams. These results suggest that upstream passage opportunities are less vulnerable to effects of diversions allowed by the MCD when the most protective MBF alternative criterion is applied (MBF3, part of Flow Alternative Scenario 3) than for the other MBF alternative criteria with which increased diversion rates are more likely to result in reduced passage opportunities.

7.1.2 Spawning and Incubation Habitat

The validation site analysis results for the MBF element in Chapter 6 indicated that diversion can adversely affect the availability of anadromous salmonid spawning habitat primarily when the MBF element is not protective. Use of a protective MBF criterion for spawning according to the conservative habitat suitability criteria in Table 2-2 should ensure that spawning habitat would remain available at some locations in a stream even at maximum cumulative diversions that are higher than the MCD1 alternative.

Figures 4-10 and 4-11 show that in a few cases, a less restrictive MCD which allows more diversion leads to lower peak flows that are predicted to provide more favorable conditions for steelhead and coho spawning. These cases are indicated by the points in the lower graphs of Figures 4-10 and 4-11 that plot as positive changes, where the number of days with spawning opportunities increase over unimpaired flow conditions. The result reflects additional time during the rising and descending limbs of event hydrographs in which the diversion of flow provides more spawning habitat (via provision of suitable depths and velocities over spawning gravels) than would otherwise exist.

7.1.3 Winter Rearing Habitat

As discussed in Chapter 4 and Appendix D, this habitat need is assumed to be protected by an MBF element that also protects spawning habitat.

7.1.4 Outmigration

The importance of flow for downstream passage was concluded in Chapters 4 and 5 and Appendix D to be minor for initiating and facilitating outmigration, as long as the diversion season ends before increasing water temperatures become an issue and, as well, there are still freshets. All of the MCD element alternative criteria result in the maintenance of flow pulses later in the diversion season and thus, would not be expected to adversely affect outmigration. By maintaining natural hydrograph variability and the associated stimulus for migration, flows that serve a channel maintenance function would also be generally sufficient for downstream passage at any point in the drainage network system. Prior to March 31, delays in migration and temperature effects do not appear to be significant, and thus downstream passage is not likely an important factor on which to base the MCD criterion. Consequently, all of the MCD alternative criteria can be considered to be protective of outmigration flow needs subject to the constraint of also having a protective diversion season element.

7.1.5 Channel and Riparian Maintenance

There are two approaches embodied in the MCD alternative criteria in which diversions may be managed to protect natural hydrograph functions, with varying effects on channel maintenance processes. In both approaches, water may be extracted when instream flows exceed the MBF. In the first approach, a fixed MCD rate may be permitted once instream flows exceed the threshold MBF (analyzed as Flow Alternative Scenarios 1-4). In the second approach, water may be extracted above the MBF threshold at any rate but total extractions are limited by the MCD volume (analyzed as Flow Alternative Scenario 5). As seen in Appendices F and J, the second approach allows more water to be diverted than the first, in terms of both volume and rate, and can thus have greater effects on channel processes and habitat availability. The second approach can result in a reduction of peak stream flows to the MBF, or “flat-lining,” which can adversely affect channel and riparian conditions. The first approach better preserves hydrograph variability in terms of frequency of channel modifying events, and thus would likely be more protective of anadromous salmonid habitat. However, what the levels of MCD rate and volume criteria should be to ensure protectiveness of channel and riparian maintenance flow needs are uncertain, as discussed in Appendix D.

7.1.5.1 Channel Maintenance Flows

Changes in Channel Size

The MCD element alternative criteria generally limit diversions in a manner such that bedload transporting flows still occur. However, the results described in Appendices D and F, and presented in Figure 2-1 and Table 4-4, suggest that specification of a relatively low magnitude MCD rate or volume will over the long term result in channel adjustments toward establishment of a smaller channel for a given basin size and available runoff volumes, and thus reduced habitat area. This long term outcome may not necessarily have negative impacts on anadromous salmonids. If the size adjustment is relatively small, then the change in channel size would not likely adversely affect production of anadromous salmonids. For example, if a 30 ft wide channel eventually becomes 5% narrower according to Figure 2-1, it may still provide all the habitat elements needed and used by anadromous salmonids. While the net effect may be reduced habitat area, there is no clear threshold defining when habitat loss related to channel size would impart a population level effect. Indeed, when coupled with MBFs based on current channel sizes, such channel narrowing may actually tend to increase the number of upstream passage and spawning opportunities as a function of increased water depths. If so, caution is needed to avoid a situation where additional diversions become considered subsequently feasible under the rationale of meeting MBF requirements reflecting a smaller channel. By setting a conservative diversion rate, effectiveness monitoring can later indicate if additional water is available for diversion without adversely affecting anadromous salmonid habitat (see Chapter 10).

Comparison of the flow magnitudes in Table 4-3 suggests that the 15% of 20% winter exceedance flow, and the MTTU (2000) alternative criteria for the MCD element (contained in Flow Alternative Scenarios 1 and 2, respectively) result in comparable maximum diversion rates. Table 4-4 shows that stream flows using these two alternatives correspond to roughly 1% of the 1.5 year flood peak flow rate for four validation sites. Based on Figure 2-1 and results in Appendix F, the two alternative criteria would therefore not be expected to result in significant channel change.

The analyses and literature reviewed in Appendix D and above suggest that a greater reduction in peak flow magnitudes associated with the MCD alternative criterion of the DFG-NMFS (2002) Draft Guidelines (i.e., 5% of the 1.5 year flood magnitude; contained in Flow Alternative Scenario 4) should still be protective; changes in channel size and spawning and rearing habitat should be relatively small. The 5% of the 1.5 year flood magnitude MCD alternative criterion has an advantage over the other MCD element alternative criteria in that it most directly accounts for the variation in channel maintenance needs throughout a channel network. This makes the criterion more attractive from the perspective of protecting against the effects of cumulative diversions upstream of a POI. As noted above, whether to allow an increase in diversion rates above this level should be assessed through monitoring and/or site specific studies.

The results in Table 4-4 indicate that the CFII=10% alternative (MCD3) criterion has the potential to adversely affect channel maintenance flow needs through relatively large reductions in channel size over the long term (greater than 10 years). The MCD3 criterion is thus likely not protective of channel maintenance flow needs at the regional level.

Changes in Grain Size Distribution

As suggested by the analysis in Appendix D, reductions in high flows are also expected to result in an increase in fine sediments (“fining”) within the bed surface armor layer in Policy area streams, and possibly some loss in morphologic complexity associated with the substrate over the short term. Parker et al. (2003) conducted experiments of the effects of extracting various amounts of water when flows were around bankfull and lower. A variable flood hydrograph was found to be associated with reduced fine sedimentation the bed, and greater variation in bed elevation compared with conditions under a constant bankfull flow. The surface fines content progressively increased, and bed irregularity decreased, as the degree of diversion increased. Parker et al. (2003) inferred from the results that variable flows may be associated with a greater diversity in habitat than flows affected by diversion.

Fining of the streambed can fill-in the interstitial spaces of the substrate thereby reducing invertebrate production, and the quality of spawning gravels. However, changes in the subsurface layer composition primarily reflect changes in the prevailing sediment load (Dietrich et al. 1989) while changes in the armor layer more reflect changes in the hydrograph. Changes in sediment load should, in principle, not substantially change in response to small changes in bankfull flow regime. Given that salmonid embryos are generally buried well below the surface armor layer (Montgomery et al. 1996; DeVries 2000), it is unlikely that small reductions in channel maintenance flow magnitudes associated with the MCD alternatives would have large effects on intragravel survival of anadromous salmonid embryos.

7.1.5.2 Riparian Maintenance Flows

Implementation of the MCD under the Policy may affect riparian vegetation directly through reduction of winter peak flows. As described in Chapter 2 and Appendix D, riparian vegetation may be affected primarily through three mechanisms: (1) reduction in groundwater recharge through the stream banks, (2) reduction of scouring flows that create new surfaces that allow growth of riparian vegetation, and (3) reduction in growth rates during the early spring. The question for analyzing protectiveness concerns the amount of water that may be diverted without adversely affecting the health, diversity, and future potential of the riparian zone as affected by high flows in terms of each of these three factors.

Each factor is addressed below, although assessing the potential impacts of high-flow diversion on the riparian zone is complicated. Prediction of diversion impacts and mitigation needs must generally be based on site-specific information and analyses, reflecting a number of sources of variability not directly related to diversion rate (Risser and Harris 1989). Local geology, microclimate, and floodplain physiography determine the relative impact of diversion on scouring or availability of water to riparian plants. Lower gradient reaches with significant groundwater recharge primarily by streamflow may be associated with loss of riparian vegetation depending on the extent to which water is diverted relative to recharge rate. Steeper reaches may experience increased plant height or riparian encroachment due to reduction in frequency and severity of scouring flows, depending on the availability of adequate substrate. Species-specific adaptations can also influence the nature of effect of diversion on a riparian community (Risser and Harris 1989). Factors that may lead to shifts in dominant riparian forest species include frequency of disturbance, air temperature, root zone aeration, and depth to groundwater. For example, willow species prevail in high disturbance environments, cool growing seasons favor black cottonwood, and white alder can dominate when turbulent, well aerated water is close to the surface (Holstein 1984).

Stream Bank Groundwater Recharge

None of the instantaneous MCD rate alternative criteria would be expected to prevent or substantially reduce the frequency of large magnitude flows, and given the transient nature of streambank groundwater recharge, would not be expected to adversely affect the riparian zone in this manner. Additionally, given the relatively small changes in channel form expected in association with the largest magnitude MCD rate alternative criterion (i.e., the 5% of 1.5 year flood level), the riparian zone should be able to adjust to changes in the high flow regime. The unlimited diversion rate embodied in the CFII alternative criterion would not be expected to affect spring and summer streambank groundwater levels because in most years the CFII = 10% limit would be reached within the first month or two of the diversion season. Therefore, additional high flow events could still occur during the remainder of the winter. The CFII alternative criterion would be expected to have the greatest effects of all MCD alternative criteria in dry years.

Scouring Flows

Regional flood frequency regressions in DFG (2003a) indicate that a 5% reduction in the 2-year flood peak flow rate in the Policy area corresponds approximately to a 3% reduction in the 5-year flood peak flow rate. The highest MCD rate alternative criterion analyzed as part of Flow Alternative Scenario 3, i.e., a 5% reduction in the 1.5 year flood, would correspond to a smaller reduction in the magnitude of the 5 year flood and other recurrence interval events. Using the same regressions and plotting the results on log-probability paper suggests that the corresponding pre-diversion recurrence interval for the 3% reduction in the 5-year event flow rate is around 4.3 to 4.6 years for a range of drainage areas and precipitation values. Higher flood levels remain possible when the MCD element is based on an instantaneous rate, hence the highest MCD proposed as part of the Flow Alternative Scenario 4 is not predicted to result in a substantial reduction in the availability of scouring flows, especially in wet years when scouring activity is greatest under unimpaired flow conditions. Likewise, the CFII = 10% alternative criterion embodied in Flow Alternative Scenario 5, where all flow above the MBF is extracted until the 10% limit is reached, would not be expected to adversely affect scouring flows because the criterion would be reached relatively soon after the diversion season begins in wetter years.

Reduced Vegetation Growth

Riparian communities contain some of the most productive vegetation in the Policy area, largely because they receive the most water. Most of the growth of riparian vegetation occurs in the spring when water is still sufficiently available in the soil and temperatures are favorable. Red alder is frequently the dominant riparian tree in coastal forests within the Policy area. White alder forms gallery forests south and east of the range of red alder, but is much more restricted to channel margins and is thus a reliable indicator of permanent water table levels. Its roots need constant saturation by cool, well aerated water (Holstein 1984). Reduction in the streambank water table level by diversions in March could impact initial spring growth of these and other riparian species by reducing water availability to the roots. By restricting diversions to maintain natural variability in flood hydrographs, by not permitting additional diversion after March 31 during the peak of the growing season, and by specifying a relatively conservative MCD, all subject to site specific study if less restrictions are desired, the MCD element of the Policy should inherently protect riparian growth.

7.1.6 Estuary Habitat/Ocean Connectivity

The results and literature reviewed in Chapters 4 and 6 indicate that a protective MBF for spawning should also protect estuarine sand bar breaching processes. The MCD element is therefore generally protective for all Flow Alternative Scenarios that involve a MCD rate criterion. It is possible that the MCD alternative criterion of Flow Alternative Scenario 5 might not be protective in some cases if the diversion season started on October 1 instead of December 15, where higher flows would be prevented in the fall until the CFII = 10% limit is met. Depending on the stream, it is possible that Flow Alternative Scenario 5 could delay sand bar breaching in October or early November if flow increases up to the MBF level are attenuated downstream by channel storage, and base flows are still low. The uncertainty regarding the potential level of effect would need to be addressed through effectiveness monitoring and/or site specific study.

7.2 SUMMARY OF PROTECTIVENESS

Table 7-2 summarizes the protectiveness attributes of each MCD element alternative criterion considered. The analysis and literature indicate that overall, the 5% of the 1.5 year flood magnitude MCD alternative criterion would likely be as protective of anadromous salmonid habitat as the other alternative flow rate criteria, provided it is accompanied by a protective MBF criterion. For all MCD alternatives, effectiveness monitoring and site-specific studies would be needed to determine if additional water could be made available for use without decreasing protectiveness. Importantly, the CFII = 10% volume alternative criterion proposed in the DFG-NMFS (2002) Draft Guidelines does not appear to be protective of coho and Chinook upstream passage or spawning in many streams, and of channel maintenance flow needs in general. In addition, because the calculated magnitude of the CFII for a given date varies with specification of diversion season and MBF and the type of year, it would be difficult to establish a consistently protective volume.

Table 7-2. Summary of Protectiveness of Maximum Cumulative Diversion (MCD) Alternatives.

Policy Element: Maximum Cumulative Diversion		
Alternative	**Regionally Protective?**	**Basis**
MCD1 (Rate): MCD Rate = 15% of 20% Winter (12/15-3/31) Exceedance Flow	Yes	Generally allows the lowest instantaneous rate of diversion. Likely results in negligible channel change over the long term.
MCD2 (Rate): MCD Rate = 5% of 1.5 yr flood peak flow (annualized series)	Yes	Allows a higher instantaneous rate of cumulative diversion than MCD1 and MCD4. This alternative will likely result in long term adjustment and reduction in channel size, but the potential change is thought to be minor in terms of bankfull width, depth, and surface grain size distribution. Basing a MCD rate on the 1.5 year flood peak flow rate more directly accounts for the relation between channel size and instream flow need.
MCD3 (Volume): MCD Volume = No restriction on diversion rate, stop diversion after the ratio of total cumulative diverted volume to unimpaired runoff volume = 10%	Partially	May not be protective of coho and Chinook upstream passage and spawning habitat flow needs during the first month of the diversion season (for DS1 or DS3) in dry and average years. May not be protective of channel maintenance flow needs. Protectiveness is related more defensibly to flow rate rather than volume.
MCD4 (Rate): MCD Rate = Diversion rate that corresponds to a half day reduction in the duration of time that flow is above the MBF during a 1.5 year flood event	Yes, but impractical to apply	Provides a comparable level of instantaneous diversion rate to MCD1 (15% of 20% winter exceedance flow). Likely results in negligible channel change over the long term. Impractical because its implementation requires detailed hourly hydrograph information for each stream.
Biological Recommendation:	**Apply Alternative MCD2.** There is uncertainty in defining the maximum amount of change in channel maintenance flows that could occur that would still be protective of anadromous salmonid habitat. Regardless of which MCD alternative is chosen for the Policy, effectiveness monitoring data collected over a period of 10 to 20 years would be needed to assess whether the Policy could be reopened in the future to include a less restrictive MCD that would still be protective of channel maintenance flows while offering the opportunity for higher diversion rates.	

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8. PROTECTIVENESS OF ON-STREAM DAM/RESERVOIR RESTRICTIONS

This chapter analyzes the protectiveness of the DFG-NMFS (2002) Draft Guidelines and alternatives (see Section 3.2.1) regarding the permitting of on-stream dams and water storage for streams within the Policy area (herein collectively, on-stream dams). The analysis interprets results identified in Chapter 4 and in other relevant literature, and focuses primarily on the periods of diversion.

8.1 ANALYSIS OF PROTECTIVENESS

The extent to which permitting an on-stream dam may adversely affect anadromous salmonids depends on, among other things, the size of the on-stream dam and area of stream inundated, whether upstream and downstream passage facilities are provided and the condition of such, the extent of anadromous salmonid habitat upstream and downstream from the on-stream dam, and whether flow releases from the on-stream dam are provided. In general, on-stream dams can directly impact salmonids if they: (1) prevent fish passage and block access to upstream spawning and rearing habitats; (2) intercept and retain spring and summer flows without providing continuous flow releases below the on-stream dam (i.e., bypass flows); (3) intercept and retain sediments/gravels that would otherwise replenish downstream spawning gravels; (4) intercept and retain large wood that would otherwise provide downstream habitat structure; and/or (5) create slow moving, lentic (lake-like) habitats that favor non-native species that may either prey on anadromous salmonids or compete for food and shelter.

8.1.1 Upstream Passage, Spawning, and Rearing Habitat

On-stream dams that are constructed without properly designed fishways can block upstream passage of adult and juvenile anadromous salmonids, thereby reducing the quantity of available habitat within the stream and its overall production potential (see Chapter 1). From the federal regulatory perspective, on-stream dams constructed in “critical habitat” remove stream habitat that is needed to ensure the conservation of anadromous salmonid species listed under the ESA (50 CFR 424.12(e)). In addition to preventing adult salmonids from reaching upstream spawning habitats, on-stream dams/reservoirs can prevent juveniles from moving upstream to find suitable rearing areas. In many stream systems within the Policy area, summer water temperatures exceed criteria for juvenile salmonids throughout most of the lower accessible reaches, and the only over-summering rearing habitat exists in isolated, stratified pools with groundwater input (e.g., Nielsen et al. 1994) or upstream in smaller, shaded channels.

Depending on their size and configuration, on-stream dams can retain most or all stream flow during certain times of the year. For example, many small dams with on-stream storage within the Policy area employ a “fill-and-spill” operational pattern in which the entire flow within the stream is retained by the dam until the reservoir is filled, before any downstream releases (“spill”) are provided. This pattern typically occurs during the late fall-early winter period when reservoir levels are low, and can result in lost spawning and rearing habitat for anadromous salmonids. Steiner (1996) noted that on-stream dams in tributaries within the Russian River basin have resulted in decreased habitat availability and increased water temperatures downstream.

On-stream dams that retain water year-round can create lentic habitats that are more suited to non-native, non-salmonid fish species such as bluegill and bass, as well as other exotic species such as the bullfrog. Impacts of non-native fish predation on anadromous salmonids in streams in the project area are well documented (e.g., Steiner 1996; Beach 1996), while the potential effects of other species introductions on salmonids are less understood. While bullfrogs have become a well established predator of sensitive amphibian species including red-legged frogs and salamanders (USFWS 2002), their impacts to salmonids are largely unknown.

8.1.2 Outmigration

On-stream dams that do not contain suitable fish bypass structures can delay the downstream migration of salmonid smolts and juveniles that seek to find a way past a structure (e.g., Manning et al. 2005). The potential impact of such delay becomes greatest during late spring when water temperature increases may lead to stress, disease, reverse smolting, and possibly death.

8.1.3 Channel and Riparian Maintenance

In addition to direct impacts related to fish passage and habitat loss, the regulation of flows by on-stream dams can disrupt sediment and wood transport processes that can impact the quality and quantity of downstream salmonid habitats. From a flow and sediment perspective, the filling of on-stream dams/reservoirs (particularly the fill-and-spill type) can reduce downstream peak flows (especially during dry years) resulting in an overall reduction in sediment transport and corresponding increase in sediment deposition. This can lead to sedimentation of spawning gravels or compaction of streambeds (Fisk 1955), and ultimately a reduction in egg and fry survival (Chapman 1988; Kondolf 2000). A second sediment related effect of on-stream dams relates to the trapping of bedload, which would otherwise be transported downstream (Benda et al. 2005). Trapping reduces the downstream supply of gravel, and may lead to a reduction in spawning habitat quality and quantity, streambed armoring, channel incision, and/or increased scour probability in spawning beds (Ligon et al. 1995; DeVries 2000). The degree of impact depends on the location of the on-stream dam and the balance between gravel supply and transport capacity within the spawning reaches (Montgomery and Buffington 1993, 1997; Montgomery et al. 1999; Kondolf et al. 1991; Moir et al. 2004).

On-stream dams can also intercept wood that would otherwise be transported downstream. Large woody debris represents an important habitat component in anadromous salmonid streams in the Policy area (Opperman 2002). Functionally, large woody debris provides velocity refuge and overhead cover for both adult and juvenile salmonids (e.g., Nickelson et al. 1992; Gregory et al. 2003; Opperman and Merenlender 2004). It also plays a role in shaping the morphology of a channel by contributing to pool formation, channel meandering, and channel stability. In general, the size of wood transported by water is dependent on the width of the channel. Pieces with lengths similar to or longer than the channel width are more likely to form habitat near where they entered the channel. Hence, on-stream dams located in Class III and possibly Class II streams are likely to trap mostly small pieces (on the order of 10 ft length or smaller) that would likely be flushed downstream eventually, or removed by the on-stream dam owner. In contrast, on-stream dams located in Class I channels are likely to trap larger pieces of wood, that may not become available to downstream reaches if they are not allowed to pass below the on-stream dam.

Depending on on-stream dam size and reservoir capacity, on-stream dams have the potential to regulate the quantity of water released downstream. In addition to directly affecting anadromous salmonid habitats, the regulation and reduction of flows can alter the vegetative communities (density, diversity, species composition) within the riparian zone, in some cases resulting in the complete collapse of native riparian plant communities (Rood et al. 1995; Scott et al. 1997). In general, the long term health of native riparian communities depends on flood flows to recharge alluvial aquifers, provide sites for seedling establishment, transport and deposit seeds on the floodplain, and replenish nutrients in floodplain soils. In addition, sufficient in-channel flows are needed for maintaining the alluvial aquifer within or near the rooting zone of riparian plants through the growing season.

8.2 SUMMARY OF PROTECTIVENESS

Table 8-1 summarizes the protectiveness of the alternatives that pertain to permitting of on-stream dams. The analysis indicates that the restrictions imposed by the DFG-NMFS (2002) Draft Guidelines (DP1.1, DP2.1, and DP3.1) would be protective of anadromous salmonids within the Policy area. The guidelines prohibit construction of on-stream dams/reservoirs on Class I and II streams, and conditionally allow such on Class III streams. The analysis also considered two sets of alternatives to the DFG-NMFS (2002) Draft Guidelines. One alternative (DP2.2) provides a mechanism from the State Water Board to address and evaluate situations where unauthorized on-stream dams exist on Class II streams, and a proposal from MTTU (2000) that includes more stringent criteria when considering on-stream dams for Class III streams. Other alternatives provide less stringent criteria than those proposed by DFG-NMFS. For example, alternatives DP2.3 and DP3.3 would increase the potential for adverse effects on downstream anadromous salmonid spawning and rearing habitat through the cumulative effect of permitting many dams.

Table 8-1. Summary of Protectiveness of the On-Stream Dam Permitting Restrictions (DP) Alternatives.

Policy Element: Restriction of On-Stream Dams/Reservoirs			
Stream Class	**Alternative**	**Regionally Protective?**	**Basis**
Class I	**DP1.1**		
	On-stream dams may not be issued water right permits.	Yes	DFG-NMFS (2002) Guidelines
	DP1.2		
	New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. Fish passage and screening is provided; 2. A passive bypass system is provided to bypass the minimum instream flow requirements; 3. An exotic species eradication plan is implemented; 4. A gravel and wood augmentation plan or bypass system is implemented; and 5. Disturbed riparian habitat will be mitigated.	Partially – dependent on success of mitigation measures	Although this alternative allows some existing on-stream dams on Class I streams to receive water right permits, it contains criteria to mitigate existing adverse impacts to anadromous salmonids and protect and/or restore important ecosystem functions to those streams.
Class II	**DP2.1**		
	On-stream dams may not be issued water right permits.	Yes	DFG-NMFS (2002) Guidelines
	DP2.2		
	New on-stream dams may not be issued water right permits. A water right permit may be considered for an existing, unauthorized on-stream dam that was built prior to 7/19/2006 if the following criteria are met: 1. A passive bypass system is provided to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.	Yes	Although this alternative allows some existing on-stream dams on Class II streams to receive water right permits, it contains criteria design to protect and/or restore important ecosystem functions to those streams and still afford a high level of protectiveness.

Table 8-1. Summary of Protectiveness of the On-Stream Dam Permitting Restrictions (DP) Alternatives.

Class II (cont)	**DP2.3** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; 3. A gravel and wood augmentation plan or bypass system is implemented; and 4. Disturbed riparian habitat will be mitigated.	Partially	Multiple on-stream dams on Class II streams have potential to cause adverse cumulative effects on downstream spawning and rearing habitat quantity and quality in Class I streams.
Class III	**DP3.1** A water right permit may be considered for an on-stream dam if the following criteria are met: 1. The on-stream dam will not dewater a Class II stream; and 2. The on-stream dam will cause less than 10% cumulative instantaneous flow impairment at locations where fish are seasonally present.	Partially	DFG-NMFS (2002) Guidelines Protectiveness could be increased via inclusion of additional fish protection measures as provided in DP 3.2.
	DP3.2 A water right permit may be considered for an on-stream dam if the following criteria are met: 1. A passive bypass system is used to bypass the minimum instream flow requirements; 2. An exotic species eradication plan is implemented; and 3. A gravel and wood augmentation plan or bypass system is implemented.	Yes	This alternative contains criteria that must be met before on-stream dams would be allowed on Class III streams. The criteria are designed to protect and/or restore important ecosystem functions, and provide an additional level of protectiveness not provided by the DFG-NMFS (2002) Guidelines.
	DP3.3 A water right permit may be considered for an on-stream dam.	Partially	With no restrictions imposed, cases would likely occur where protectiveness would not be assured. Multiple on-stream dams built without restrictions on Class III streams are likely to cause adverse cumulative effects on downstream spawning and rearing habitat quantity and quality in Class I and II streams.
Biological Recommendation:		**Apply DP1.1, DP2.2 and DP3.2**	

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9. IMPORTANCE OF FISH PASSAGE AND SCREENING MEASURES

This chapter reviews recommendations in the DFG-NMFS (2002) Draft Guidelines regarding following DFG and NMFS fish passage and screening requirements for on-stream dams and diversions in Policy area streams. Diversion structures may block or seasonally/periodically restrict upstream and downstream movements of adult and juvenile anadromous salmonids. Applicable Fish and Game Code sections concerning dams and diversions (Fish and Game Code section 5931) serve to protect anadromous salmonids from adverse effects, thereby potentially increasing production levels and survival. The DFG-NMFS (2002) Draft Guidelines are thus generally protective, although exemptions in the DFG code based on practicality for the dam or diversion owner could adversely affect anadromous salmonids depending on circumstance. To be fully protective, fish passage and screening should be required at any diversion located within the currently accessible range of anadromous salmonid habitat, as per the recommended passage (NMFS 2001; DFG 2003a) and screening (NMFS 1997) requirements. In addition, there should not be exemptions to passage or screening requirements for any diversion affecting Class I streams. Furthermore, fish passage and protection measures should be considered and evaluated in streams that are not currently accessible, but were used historically, if and when watershed restoration actions lead to correction of artificial barrier(s) downstream.

9.1 ASSESSING PROTECTIVENESS

Protectiveness may be assessed in the context of evaluating impacts in the absence of protective measures (i.e., what are the potential effects of on-stream dams and diversions that do not include fish passage and screening measures), and in terms of sufficiency for fully protecting anadromous salmonids within the Policy area.

9.1.1 Effects of On-Stream Dams and Diversions without Fish Passage and Screening Measures

On-stream dams and diversions constructed without properly designed fishways can block upstream passage of adult and juvenile anadromous salmonids, thereby reducing the quantity of available habitat within the stream. Inclusion of fishways into these structures may remedy the issue of upstream passage, but will not, in most cases, address the needs of downstream migrating juveniles and smolts. Protection and safe passage of smolts requires inclusion of properly designed bypass structures and/or diversion screens that will safely transport/guide downstream migrating fish below the on-stream dam, and prevent fish from entering diversion canals.

In addition to the effects associated with potential blockage and delay, structures associated with on-stream dams or diversions such as debris racks, intake screens, pumps, weir crests, bypass pipes, etc. may physically injure and/or kill (e.g., abrasion, impingement) fish moving near, over, or through such features. In addition, fish, especially juvenile salmonids, can become entrained into unscreened diversion canals where they would be more susceptible to predation and subjected to stress. Unless a fish return or bypass system is provided, any fish entering the canals would be lost from the population.

Minimizing or eliminating these impacts by requiring, in streams that support anadromous salmonids, measures that provide for unrestricted, volitional fish passage (upstream and downstream) at all diversions, and that prevent the loss of juvenile salmonids into diversions via screening would be protective of anadromous salmonids.

9.1.2 Protectiveness of Upstream Fish Passage Measures

The DFG-NMFS (2002) requirements regarding fish passage state that fish passage must be met for any diversion structure permitted where "anadromous salmonids have the likely potential to ascend the stream to the point of diversion." Both the DFG (2003a) and NMFS (2001) have published guidelines for salmonid passage at stream crossings with technical considerations that are also relevant to fishway design. In all cases involving anadromous salmonids, fishway designs must consider upstream passage of both adults and juveniles. Depth, velocity, energy dissipation, and other criteria comprising the passage guidelines have been based on extensive research into passage needs and ensure that no fish would be blocked or seriously delayed.

California Fish and Game Code sections 5930-5948 address the issue of on-stream dams and avoiding their adverse effects on fish passage in all rivers and streams naturally frequented by fish. DFG Code Section 5931 provides that the department shall cause plans to be furnished for a suitable fishway if it is determined by the Fish and Game Commission that there is not free passage over or around any on-stream dam. The DFG can consequently order the owner of the on-stream dam to provide a durable and efficient fishway. Upon construction, sections 5935 and 5936 require that the on-stream dam owner shall keep the fishway in repair and open and free from obstructions to the passage of fish at all times. In the case of a dam without a fishway, however, the owner should allow sufficient water to pass over, around, or through the dam to keep fish in good condition downstream of the dam. (section 5937). Therefore, in the context of providing protective fish passage facilities at dams, Policy language that refers to DFG requirements for passage would be protective of anadromous salmonids.

9.1.3 Protectiveness of Fish Screening Measures

The DFG-NMFS (2002) Draft Guidelines state that screening requirements must be met for any diversion structure permitted where "anadromous salmonids have the likely potential to ascend the stream to the point of diversion," and that screening must be done in accordance with NMFS and DFG's screening criteria. The DFG adopted NMFS (1997) screening criteria in 2000 as described in its screening policy (*www.dfg.ca.gov/nafwb/fishscreenpolicy.html*). The owner of the diversion must pay for construction, operation, or maintenance costs of any screen required pursuant to section 6100. The owner of the diversion is also required to supply sufficient water for a bypass to carry fish stopped by the screen or device back to the channel from which they were diverted. The magnitude of the bypass flow depends on the diversion amount, but is generally a small fraction as outlined in Section 6022 (generally less than 1 percent of the diversion flow rate).

Further, as part of its screening policy, the DFG shall make every effort to require the modernization of fish screens which do not meet present fish screening criteria. This effort shall include the Streambed Alteration process (Section 1600 et seq. of the Fish and Game Code). The DFG requires in its screening policy that variances from screening requirements shall be supported by a report, prepared by the diverter, which includes data from onsite monitoring and a review of historical entrainment and diversion data. The scope of the report and the sampling effort shall be approved by the Department of Fish and Game prior to the initiation of work.

When anadromous fish are not present in the stream, DFG has the responsibility per Section 6021 to determine the need for a screen and to install, operate, and maintain it. DFG's screening policy includes making every effort to require the installation of fish screens on all unscreened diversions where other measures cannot reasonably prevent entrainment of fish.

Compliance with DFG and NMFS screening criteria as described above and specified in the DFG-NMFS (2002) Draft Guidelines should be protective of anadromous salmonids when screens are constructed, operated, and maintained properly.

9.2 SUMMARY OF PROTECTIVENESS

Compliance with DFG fish passage facility design requirements and fish screening facility design requirements of DFG or NMFS should be protective of anadromous salmonids in streams within the Policy area.

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10. EFFECTIVENESS MONITORING PROGRAM

The preceding chapters presented information and analyses evaluating the protectiveness of the proposed Policy element alternatives for the North Coast Instream Flow Policy. The assessment was based on existing information and data, supplemented by field data collected on 13 streams within the Policy area. These latter data were used for evaluating passage and spawning habitat flow needs in smaller basins. The analyses identified certain levels or attributes of each element that were deemed protective of anadromous salmonids and their habitats based on reasonable assumptions of biological criteria and channel response.

Implementation of a Policy that includes the recommended elements noted in Sections 5 through 8 (see Tables 5-2, 6-2, 7-2, and 8-1) should provide a sufficiently conservative level of protection of anadromous salmonids to meet both state mandated trust responsibilities as well as ESA objectives. However, questions remain as to (1) how implementation of the Policy would actually affect anadromous salmonids over longer time scales, say, in the range of 10 to 20 year time horizons that would correspond to 3 to 6 generations of anadromous salmonids, and (2) whether the currently proposed regionally protective criteria may be relaxed if they are indeed found to be overly conservative. The 10 to 20 year time frame should also be sufficiently long to allow detection of changes in channel morphology and composition of riparian vegetation. Such a determination requires development and implementation of a long-term monitoring program (herein, Monitoring Program). The framework for such a program is described in this chapter; detailed information pertaining to categories of monitoring, specific hypothesis to be tested, metrics to be used, and components of the program are provided in Appendix K.

10.1 MONITORING TYPES

In general, monitoring programs can be assigned into one of three types, depending on the objectives and questions to be addressed. These include: (1) compliance/implementation monitoring; (2) effectiveness monitoring; and (3) validation monitoring (see Appendix K for descriptions of each). Of these, effectiveness monitoring is the most appropriate for assessing the protectiveness of the Policy elements over the long term. Effectiveness monitoring can also provide insight on several aspects of the Policy including uncertainty and accountability. Uncertainty can include assumptions made or data gaps identified during policy development. Effectiveness monitoring also provides for accountability and ensures that potentially conflicting beneficial uses of a resource are balanced according to the values both explicit and implicit within policy goals.

In addition to effectiveness monitoring, certain aspects of the Policy would also be subject to compliance monitoring, which is used to determine if an intended action was implemented as planned. Installation of a stream gage below a diversion point to ensure required instream flow releases is an example of compliance monitoring. Compliance monitoring should be implemented under the enforcement program of the policy.

10.2 EFFECTIVENESS MONITORING PROGRAM GOALS AND OBJECTIVES

The primary goals of the Effectiveness Monitoring Program are to assess the effectiveness of the overall Policy to protect anadromous salmonid populations and their habitats in area streams and rivers. Specific objectives of the Monitoring Program would focus on evaluating individual Policy elements including those aimed at providing protective minimum bypass flows, protecting natural flow variability, avoiding cumulative impacts due to multiple diversions, and providing suitable fish passage and screens at diversions and on-stream reservoirs. Importantly, due to the wide range of geographical and temporal scales exhibited in the Policy area streams, the Monitoring Program is, of necessity, relatively general in nature and should be viewed as the starting point from which more detailed, site-specific monitoring plans can be derived. To be most effective, the Monitoring Program should be developed within an adaptive management framework (Lee 1993) as a means to provide a feedback loop linked to management actions. Thus, once the Policy is implemented, results of the Monitoring Program would be used to test whether goals and objectives are being met, and whether modifications to the Policy are warranted. Related to this, because the recommended level of protection afforded by the Policy is conservative to account for regional variation in instream flow needs across variable stream types and sizes, it is more likely that monitoring results would suggest some relaxation in the diversion restrictions could occur and still be protective of anadromous salmonids, rather than the need for more stringent restrictions.

10.3 EFFECTIVENESS MONITORING PROGRAM

There are a number of action items and components, some institutional and some technical that should be addressed and/or incorporated as part of the Monitoring Program (Figure 10-1). These are briefly described below, with more information, including an outline that describes selected metrics deemed suitable for evaluating specific Policy objectives, provided in Appendix K.

10.3.1 Establishment of Monitoring Oversight Committee

As a first step in the process of developing a coordinated Monitoring Program, it is recommended that the State Water Board form a nine member Monitoring Oversight Committee (MOC). A State Water Board senior staff member possessing a high level of experience in water resources management and a good understanding of hydrology, fluvial geomorphology, and salmonid biology should chair the MOC. Other members should include a second representative from the State Water Board, and one representative from each of the following agencies/academic institutions: DFG, NMFS, U.S. Fish and Wildlife Service, USGS, California Department of Water Resources (DWR), and two independent scientists from academic institutions. The MOC may also solicit input from other entities (e.g., US Forest Service, CDF, county water and flood

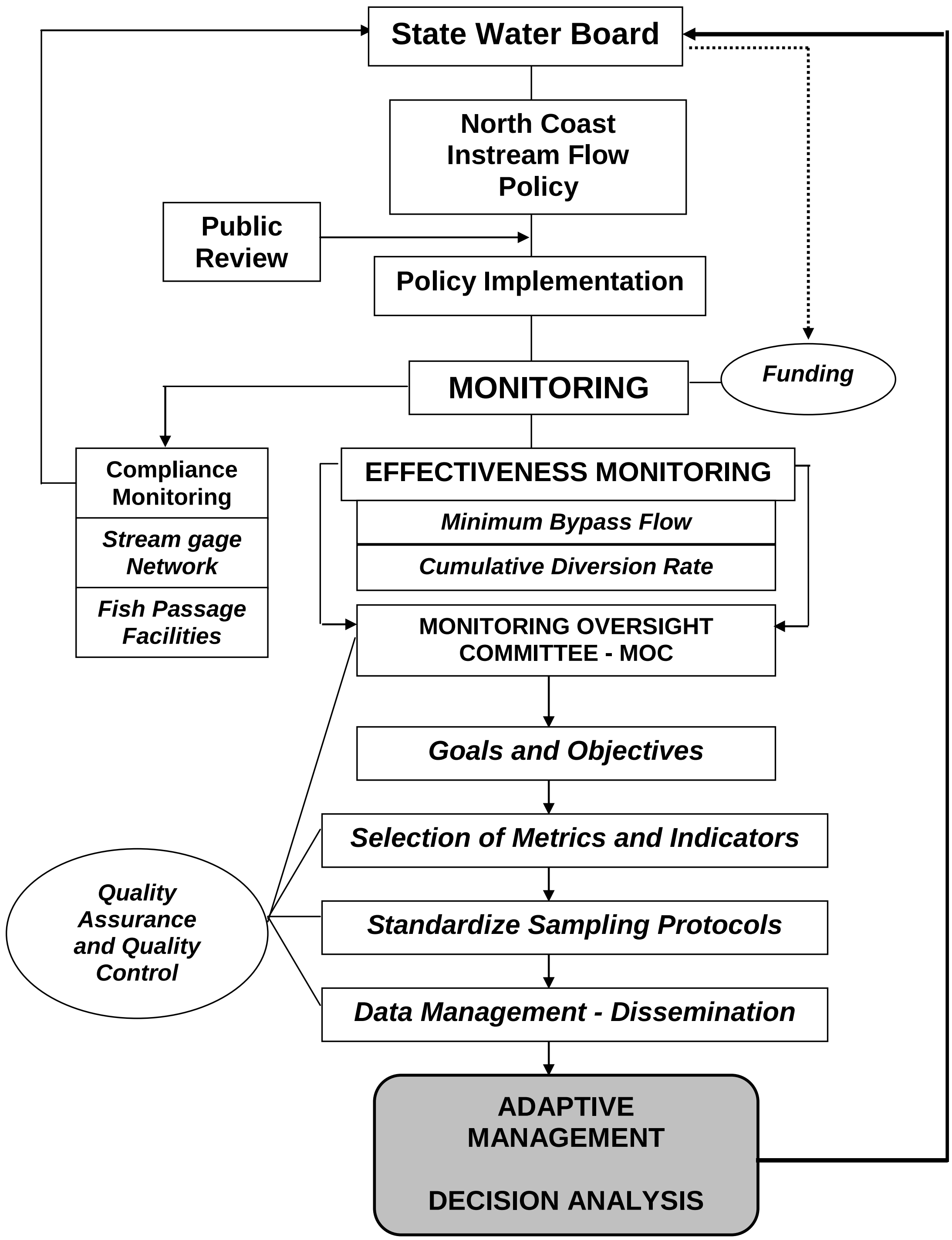

Figure 10-1. General components and actions associated with monitoring the protectiveness of North Coast Instream Flow Policy elements.

control districts and other water resource management agencies) and stakeholders involved in ongoing monitoring programs on certain streams and rivers, and who therefore possess stream-specific information. Also, the MOC may engage the services of certain technical specialists (e.g., statisticians; aquatic ecologists, geomorphologists, fish biologists, and others) to assist in preparing parts of the Monitoring Program. The MOC would be tasked with the overall preparation, implementation, and management of the Monitoring Program. An independent Science Review Panel appointed by the State Water Board would review key work products (including the Monitoring Program) developed by the MOC before being released to the public and prior to implementation. Specific activities of the MOC are described in Appendix K.

10.3.2 Selection of Appropriate Sampling Designs

As noted in Section 1.2 and Appendix B, the Policy area is large and contains over 3,400 classified stream segments of varying drainage area. Thus, the Monitoring Program should include sampling at a variety of spatial and temporal scales and, moreover, be founded on a strong, statistically derived sampling design (see Appendix K). This is important since regardless of whether the Monitoring Program evolves from existing programs or consists of an entirely new program, monitoring of all systems is simply not practical from a funding perspective.

10.3.3 Selecting and Monitoring Appropriate Indicators and Metrics

Choice of indicators and metrics to be measured will depend on specific Policy objectives. In terms of the Monitoring Program, two types of indicators will be important; (1) Effectiveness monitoring indicators that serve to detect potential changes in physical, geomorphological, and biological characteristics of streams attributable to Policy actions; and (2) compliance monitoring indicators, which address compliance activities associated with implementation of the Policy (can be done by the Division under the enforcement program established in the Policy).

10.3.3.1 Effectiveness Monitoring Indicators

There are three Policy elements for which effectiveness monitoring could be applied. These include the elements related to the diversion season, minimum bypass flows, and the maximum diversion rate. For each of these, there are a number of metrics/indicators that could be monitored, some of which are listed in Table 10-1, and discussed in more detail in Appendix K. It must be emphasized that there is no single set of metrics that will address all of the objectives and hypotheses raised regarding effects of Policy activities. Rather, there will likely be a suite of metrics, some standardized across geographic areas, and some that are scale-specific.

Table 10-1. Policy elements and potential effectiveness monitoring metrics useful for assessing protectiveness of the North Coast Instream Flow Policy on anadromous salmonids.

Policy Element	Potential Monitoring Metrics
Diversion Season	• Monitoring of this element captured in metrics specified under "minimum bypass flow" below.
Minimum Bypass Flow	• Derive spawning habitat vs. flow relationships from sites selected within a stratified subset of streams representative of Policy area streams; compare with Policy-imposed bypass flows. • Complete passage corridor analysis within the same subset of streams; compare with Policy-imposed bypass flows. • Spawning surveys within same subset of streams; monitoring for trends post-implementation of Policy; if possible – compare with trends in similar streams not subjected to Policy. • Redd marking and monitoring to evaluate "watering" duration from creation to projected fry emergence. • Biological monitoring (e.g., fry/smolt production – via outmigrant traps, screw traps, snorkeling, etc.) of anadromous salmonid populations within subset of streams; if possible – compare with trends in similar streams not subjected to Policy.
Maximum Cumulative Diversion	• Substrate quality monitoring – within subset of streams representative of Policy area streams; - Core sampling (bulk, grab, freeze-core) - Pebble counts - Ocular – embeddedness - Intragravel sediment monitoring • Cross-sectional profiles – subset of streams • Riparian corridor mapping/ vegetation species composition – subset of streams • Benthic macroinvertebrate (BMI) monitoring – subset of streams

10.3.3.2 Compliance Monitoring Indicators

With respect to the Policy, the major compliance factor relates to having an accurate and reliable means of monitoring and/or determining streamflows, both above and below diversions. Since existing stream gages are typically located in the lower reaches of streams, there is a risk that hydrologic models calibrated to distant downstream flow gages, or generalized relationships (e.g., to drainage area) may result in uncertain conclusions regarding the available unallocated surface flow in headwater streams. Therefore, consideration should be given to installation and monitoring of a stream gage network at selected watershed elevations, as a means to refine the discharge relationships, and also as a means to more accurately monitor/regulate the amount of surface flow being withdrawn by both unauthorized and authorized diversions.

10.3.4 Standardization of Sampling Protocols

Replication and repeatability are fundamental precepts in the design and conduct of statistically rigorous monitoring programs. Unless standards are implemented it will be more difficult to compare data sets collected at different times and places in the Policy area and draw appropriate conclusions. To the extent possible, the monitoring of all metrics should be completed using standardized sampling protocols and data analysis techniques. The MOC should ensure that detailed sampling protocols are drafted, reviewed and approved for each of the metrics selected for inclusion in the Monitoring Program (see Appendix K).

10.3.5 Quality Assurance/Quality Control Program

Since the data collected as part of the Monitoring Program would be used by the State Water Board in a decision-analysis framework, the validity of those data is critical. The MOC should therefore establish a rigorous Quality Assurance/Quality Control (QA/QC) Program designed to ensure that all data to be relied on have been collected and compiled in accordance with QA/QC protocols, and hence have been validated for use in the decision analysis process (see Appendix K).

10.3.6 Data Dissemination

It is envisioned that many agencies and entities would be involved in the implementation of various components of the Monitoring Program. It is also anticipated that the data so collected would be of interest to a wide range of personnel, including agency representatives, scientists, and the general public. The MOC should explore ways to facilitate the dissemination of these data, while at the same time preserving data integrity.

10.3.7 Funding Support

It is recommended that the State Water Board commit sufficient funding support to allow implementation and continuance of an approved Monitoring Program. When possible, the State Water Board should seek to retain existing and create new collaborative partnerships with other agencies and stakeholders as a means to increase monitoring efficiency while at the same time reducing costs.

10.3.8 Adaptive Management – Decision Analysis

The Monitoring Program described above was framed within an adaptive management construct that embodies decision analysis. Thus, it is recommended that the State Water Board develop a formal decision-analysis process to address questions related to which (if any) Policy elements warrant modification; what type of modification is needed (i.e., is the element over- or under-protective); and whether changes in the Monitoring Program are warranted. Monitoring describes what is biologically possible under a given set of Policy conditions. From this, scientists can estimate the probability of different biological conditions evolving, such as suitable spawning habitats, population increases etc. These estimates can prove useful in helping to formulate decisions regarding the extent to which the Policy elements should be modified. However, the degree of adjustment to be implemented is largely a policy decision that must be addressed specifically by the State Water Board.

10.4 MONITORING PROGRAM: PRELIMINARY STUDY DESIGN

This section provides suggestions relative to study design development and the selection of study sites and metrics for evaluation, and is intended to assist the State Water Board in planning the overall scope and budget for the Monitoring Program. It is anticipated that the implementation of the Monitoring Program as described above will occur in phases, with initial efforts focused on (1) establishing the MOC and (2) identifying the overall goals and objectives (Figure 10-1) that will form the basis for selecting study sites and the specific metrics to be monitored. To the extent possible, monitoring sites should be established that can be used to assess both the effectiveness of specific Policy elements, and from an enforcement standpoint, compliance with specified instream flows, diversion rates, and passage requirements. Clearly, efficiencies are gained and overall monitoring costs reduced when sites can be selected that serve more than one purpose.

The Monitoring Program study design should focus on answering the null hypotheses identified at the beginning of Appendix K. In addition to measurements of flow, a variety of other metrics may be monitored for each hypothesis, with the final list dependent on specific questions to be addressed. Of the four hypothesis noted in Appendix K Table K-2, the third, pertaining to the MCD, has the greatest uncertainty associated with it in terms of what maximum level of change equates with protectiveness. Monitoring will thus be a critical part of the Policy for establishing protectiveness of the MCD Policy element. In addition, data collection and analysis related to this hypothesis may be useful in the future if the State Water Board chooses to modify the requirements of the Policy by formally reopening it.

While there is no firm guide on the number of streams to sample and study sites to establish, the large geographic area encompassed by the Policy and the diversity of streams within it suggests the need to stratify the area based on drainage area classes and hydrologic sub-regions, and then selecting a subset of sites from each for detailed monitoring. This approach is intended to ensure some representative sampling within different basin size classes and hydrologic sub-regions, and thus, would lend itself to statistical analysis.

At a minimum, the list of streams should include the 13 evaluated in Chapter 4 (see Figure 4-2), which were used to assess protectiveness. The list would need to be expanded, however, as the 13 evaluated were selected, in part, because of their easy accessibility. Sites that were considered for the protectiveness analysis but not sampled because of access, time, and/or water availability limitations included: Redwood Creek near Muir Beach (National Park Service gage), San Geronimo Creek (Marin Municipal Water District gage), Morses Creek near Bolinas (USGS gage 11460160), Pudding Creek near Fort Bragg (Soda Creek near Boonville (USGS gage 11467850), Russian River near Redwood Valley (USGS gage 11460940), and Big Sulphur Creek (two sites near USGS gages 11463160 and 11463170). With suitable planning and discussion with biologists from various institutions, additional sites can likely be identified for sampling.

For purposes of statistical replication, it is necessary to sample a number of streams with similar characteristics forming a group often called a class or stratum. Similarity may be established any number of ways, ranging from the use of formal stream classification schemes that are different than the system used in the Policy (e.g., Montgomery and Buffington 1997), to statistical stratification and multivariate analyses (e.g., cluster analysis of various physical attributes of the stream). The number of streams necessary to represent each class will reflect in part, inherent variability within a class; that is, the greater the variability within a class, the greater the number of sites required for a specified level of statistical power. In addition, replication is necessary within a given stream. At least three samples of a given metric would be required per stream to be able to describe variability. A greater number of samples is desirable but may not be practicable depending on budget.

As an example of the above, assuming that: (1) the Policy area is stratified into six drainage area classes including <1 mi^2, 1-3 mi^2, 3-5 mi^2, 5-10 mi^2, 10-30 mi^2, and >30 mi^2; (2) the Policy area contains a minimum of three basic hydrologic sub-regions (coastal north, coastal south, and inland); and (3) a minimum of three sites are established per stream-hydrologic class combination, a total of 6 x 3 x 3 = 54 sites would be established for monitoring (Table K-2). This number would vary depending on the final number of drainage area and hydrologic classes selected. The actual number of sites would also need to be adjusted to account for existing stream gaging stations as well as other sites that may be part of other biological monitoring programs that are already collecting data relevant to assessing the Policy effectiveness. These latter sites could include those used by DFG or other agencies and stakeholders as part of long-term biological monitoring programs.

Given the importance of flow quantification to the Policy, most/all of the active and inactive stream gage sites should be considered for incorporation (either from an effectiveness or compliance standpoint) into the Monitoring Program. Given that there are currently 88 USGS stream gages within the Policy area, 31of which are active (Figure K-2), and assuming that the above 54 sites could be represented by a subset of the gaging stations, an additional 34 sites (represented by gage sites – i.e., 34 sites + 54 = 88) should be considered for inclusion into the Monitoring Program (Table K-2). However, the final number of sites and overall scope of the program will clearly need to be based on additional considerations including costs and funding support. It is in this matter that the MOC can be instrumental in achieving consensus on an acceptable Monitoring Program.

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