NORTH COAST INSTREAM FLOW POLICY

WATER DIVERSION - PASSAGE AND SPAWNING HABITAT SENSITIVITY STUDY

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EXECUTIVE SUMMARY

The Policy for Maintaining Instream Flows in Northern California Coastal Streams (Draft Policy, State Water Board, March 2008) provides regional instream flow criteria for use when site-specific data are not available. These criteria include minimum bypass flow (MBF), maximum cumulative diversion (MCD) and diversion season.

Peer review comments and comments from the public on the Draft Policy noted that the State Water Board had not evaluated the relative protectiveness of the proposed regional criteria against other possible permutations using the same regression approach. In response to these comments, this report describes the methods and results of a water diversion - passage and spawning habitat sensitivity study. Public comments noted there were discrepancies in the spreadsheet analysis that was used to develop the proposed MBF criteria in the Draft Policy. The errors and the corrected MBF are presented and utilized in this report.

The study determined the volume of water potentially available (potential diversion volume) for diversion under each of the MBF and MCD alternatives (water diversion analysis) and the number of days of useable spawning and passage habitat for selected MBF alternatives (passage and spawning habitat availability analysis). Given numerous public comments expressing concern regarding the protectiveness of an October 1 start date for the diversion season, a diversion season of December 15 to March 31 was used for the study. The study was performed for the 2006 validation sites that were used to develop recommendations for the Draft Policy alternatives (R2 Resource Consultants, March 2008).

Table ES.1 compares the potential effects of the MCD alternatives. The average potential diversion volume for each MCD was calculated from the results of the water diversion analysis, expressed as percent of mean annual flow averaged over all validation sites and all MBF alternatives (MBF A1 - MBF A9). The channel size reduction was predicted based on the relationship between reduction in bankfull flow and size reduction/change.

Table ES.1. Comparison of Potential Effects of MCD Alternatives at Validation Sites

Alternative	Description	Average Potential Diversion[1] (% mean annual flow)	Channel Size Reduction (% change width, depth, D_{50})
MCD A1	1% of 1.5-year peak flow	2.6%	-0.4%
MCD A2	5% of 1.5-year peak flow	9.9%	-2.0%
MCD A3	10% of 1.5-year peak flow	15.6%	-4.0%
MCD A4	12% of 1.5-year peak flow	17.3%	-4.8%
MCD A5	15% of 1.5-year peak flow	19.5%	-6.0%

[1] Averaged over all validation sites and MBF alternatives.

Table ES.2 compares the potential effects of the MBF alternatives. The average potential diversion volume for each MBF was calculated from the results of the water diversion analysis, expressed as percent of mean annual flow averaged over all validation sites and all MCD alternatives (MCD A1 - MCD A5). The results of the passage and spawning habitat availability analysis are summarized for each of the selected MBF alternatives combined with MCD A2 (Draft Policy regionally protective MCD), expressed as the average change in passage opportunities in terms of percent change from opportunities under unimpaired flow condition and the amount of steelhead spawning opportunities relative to the spawning opportunities for MBF A4 (Draft Policy regionally protective MBF).

Table ES.2. Comparison of Potential Effects of MBF Alternatives at Validation Sites

Alternative	Description	Average Potential Diversion[1] (% mean annual flow)	Steelhead Passage Opportunities[2] (% unimpaired)	Steelhead Spawning Opportunities[3] (relative to MBF A4)
MBF A1	0.8 ft mean regression line	15.2%	not analyzed	not analyzed
MBF A2	0.8 ft mean regression line + 1 SE	13.7%	not analyzed	not analyzed
MBF A3	0.8 ft mean regression line + 2 SE	12.5%	not analyzed	not analyzed
MBF A4	0.8 ft mean regression line + 3 SE	11.0%	-6%	baseline
MBF A5	0.7 ft mean regression line	16.2%	-15%	reduced
MBF A6	0.7 ft regression line + 1 SE	14.7%	-11%	reduced
MBF A7	0.7 ft regression line + 2 SE	13.2%	-6%	reduced
MBF A8	0.7 ft regression line + 3 SE	11.8%	-6%	similar
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	8.7%	0%	increased

[1] Averaged over all validation sites and MCD alternatives.
[2] Assessed in combination with MCD A2 and averaged over all validation sites.
[3] Assessed in combination with MCD A2 and compared at all validation sites.

The sensitivity study results suggest that MBF A8 (0.7 ft regression line plus 3 standard errors) would provide a similar level of steelhead passage and spawning opportunities and slightly higher potential diversion volume (+0.8%) as compared to MBF A4 (the Draft Policy MBF corrected for the spreadsheet calculation error).

1 Introduction

The Policy for Maintaining Instream Flows in Northern California Coastal Streams (Draft Policy, State Water Board, March 2008) provides regional instream flow criteria for use when site-specific data are not available. These criteria include minimum bypass flow (MBF), maximum cumulative diversion (MCD) and diversion season.

1.1 Purpose

The purpose of this report is to provide information to the State Water Board to assist in the selection of the regional MBF and MCD criteria to be used in the final Policy.

1.2 Scope

The water diversion - passage and spawning habitat sensitivity study determined the volume of water available for diversion under each of the MBF and MCD alternatives (water diversion analysis) and the number of days of spawning and passage opportunities for selected MBF alternatives (passage and spawning habitat availability analysis). The study used a diversion season of December 15 to March 31. The study was performed for the eleven 2006 validation sites previously used to develop recommendations for the Draft Policy alternatives (Task 3 Report, R2 Resource Consultants, March 2008).

This report describes the water diversion - passage and spawning habitat sensitivity study, presents the results of the water diversion analysis and the passage and spawning habitat availability analysis, and provides an evaluation of the water available for diversion under each of the MBF and MCD alternatives and the relative protectiveness of selected MBF alternatives.

In the Task 3 Report's assessment of protectiveness, a MBF alternative was considered regionally protective if, when combined with the MCD and diversion season, it would limit diversions so that adequate flows would be available for spawning and passage at all validation sites, including those with the most restrictive instream flow needs. For locations that have less restrictive flow needs, regionally protective criteria might provide more than adequate flows for fish. Habitat-flow needs are highly site-specific, thus if site-specific data are available or can be obtained, they can be used to more precisely determine the local flow needs rather than using regionally protective criteria. Although this sensitivity analysis report contains an evaluation of the relative protectiveness of potential Draft Policy regional MBF and MCD criteria, its results do not outweigh any site specific analysis of habitat conditions that might be submitted to the State Water Board in accordance with adopted policy provisions.

The water diversion analysis and the passage and spawning habitat availability analysis assessed each MBF and MCD alternative by calculating the water potentially available for diversion and the number of days of passage and spawning opportunities under hypothetical impaired flow conditions. The impaired flow was determined by assuming that the cumulative water diversions above and at the validation site are made to the full extent possible while complying with the limitations imposed by the MBF and MCD regional criteria. These water diversions could be made at the validation site transect or at multiple upstream locations. The study did not consider the existing (i.e., real world) level of impairment in the Policy area streams. The study did not consider the impacts of water diversions that do not meet the regional criteria, for example on-stream storage reservoirs that store all flow (perhaps in excess of the MBF criteria) until full and then spill.

2 MBF and MCD Sensitivity Analysis Alternatives

2.1 Minimum Bypass Flow

The Draft Policy regionally protective minimum bypass flow (MBF) is based on the “0.8 foot regression line”. This is a linear regression that fitted the log of the ratio of spawning flow divided by mean annual flow to the log of the drainage area for both the Swift (1976) steelhead spawning data and the data points from the 2006 validation sites. The Swift (1976) flows were determined using a minimum suitable spawning depth criterion of 0.7 foot, whereas the validation site flows were determined using a more conservative 0.8 foot criterion for reasons discussed in the Task 3 Report. Section E.3.2 in Appendix E of the Task 3 Report describes the regression method and the 2006 validation site and Swift (1976) data in more detail.

The Draft Policy regionally protective MBF was calculated using the 0.8 foot regression line with the intercept coefficient increased by 3 standard errors to generate an approximate 99% prediction interval for the intercept.

The MBF alternatives used for the water diversion - passage and spawning habitat sensitivity study were formulated using the same regression methods used to develop the Draft Policy regionally protective MBF but using datasets based on varied depth criteria for the regression and increasing the intercept coefficient of the regression lines by different multiples of the standard error. These alternatives were selected to provide results that could be used to assess an alternative minimum depth criterion and the method of adjusting the intercept coefficient when formulating the regional criteria.

Figure 1 shows the nine MBF alternatives considered in the water diversion - passage and spawning habitat sensitivity study. The basis for each alternative is described in the sections that follow.

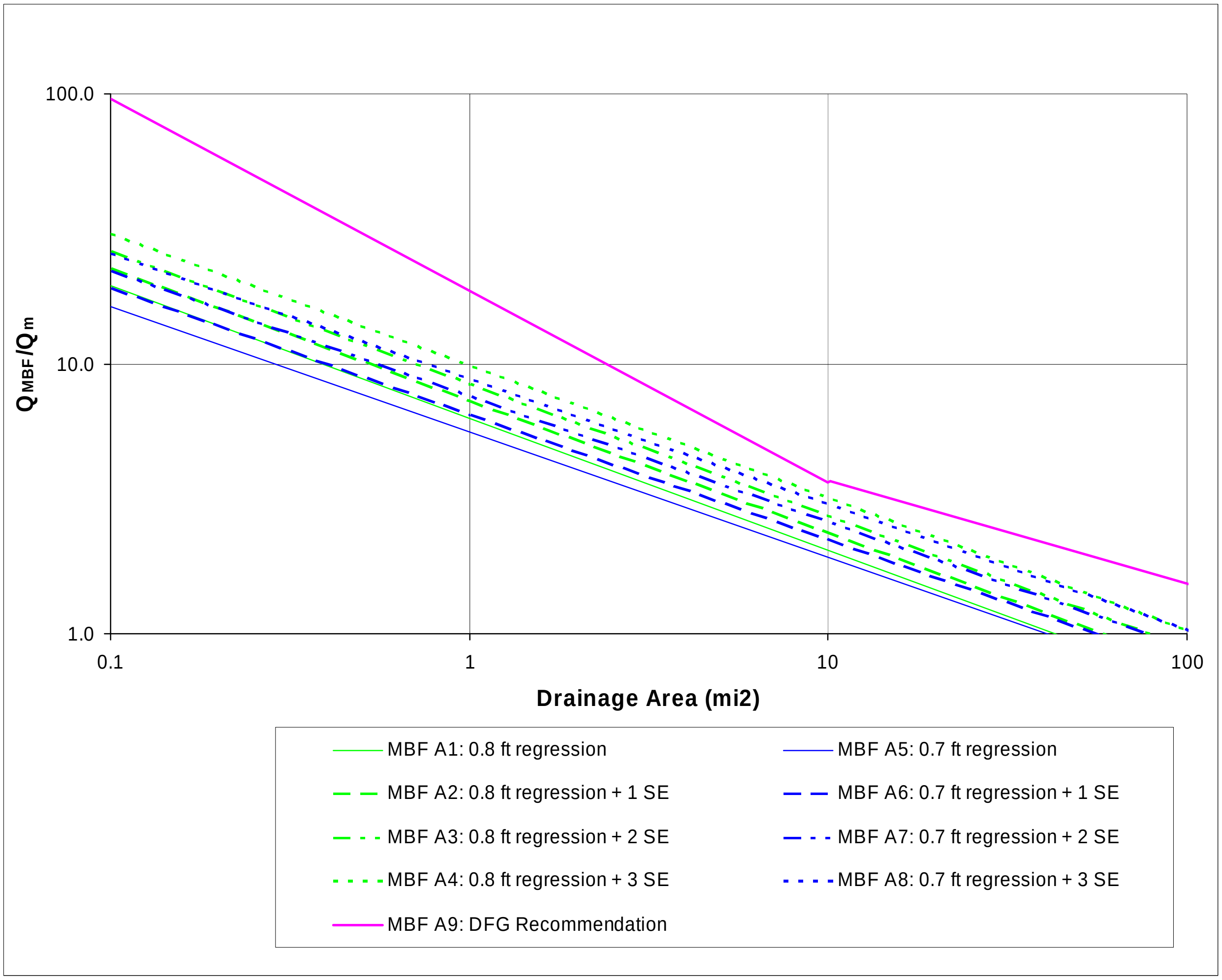

Figure 1. MBF Alternatives, A1–A9

2.1.1 0.8 foot regression line

Four MBF alternatives were selected for the water diversion - passage and spawning habitat sensitivity study using the 0.8 foot regression line developed for the Draft Policy with the intercept increased by 0, 1, 2 and 3 standard errors. The 0.8 ft mean regression line + 3 SE used for MBF A4 was also the basis for the Draft Policy's proposed regionally protective minimum bypass flow (MBF3). The MBF A4 equation differs from MBF3 (Draft Policy, March 2008) due to changes made to selected habitat-flow curves and a typographical spreadsheet error. These corrections address comments provided by Wagner and Bonsignore Consulting Engineers in a comment letter dated April 30, 2008[1]. In the revisions, the data points were changed for the MBF 0.8 foot regression at the following validation site transects: Olema Cr Sp1; Huichica Cr Sp1;

[1] Wagner & Bonsignore Consulting Engineers. A critical review of the December 2007 State Water Resources Control Board Draft Policy for maintaining instream flows in Northern California coastal streams and supporting documents. April 30, 2008.

Carneros Cr Sp2; Dunn Cr Sp1; and Franz Cr Sp1. The typographical errors involved switching of cell values, where Carneros Cr Sp1 was omitted in the regression data and Dry Cr Sp1 was copied twice. The net effect was a small change in the 0.8 foot regression equation, which resulted in a 0.1-2 cfs increase in minimum bypass flow needs compared to MBF3 at the validation sites. The four MBF alternatives shown below incorporate these corrections.

These MBF alternatives were:

MBF A1 (0.8 ft mean regression line):	$Q_{MBF} = 6.3\ Q_m\ (DA)^{-0.49}$, DA <=122 mi^2
MBF A2 (0.8 ft mean regression line + 1 SE):	$Q_{MBF} = 7.3\ Q_m\ (DA)^{-0.49}$, DA <=165 mi^2
MBF A3 (0.8 ft mean regression line + 2 SE):	$Q_{MBF} = 8.4\ Q_m\ (DA)^{-0.49}$, DA <=223 mi^2
MBF A4 (0.8 ft mean regression line + 3 SE):	$Q_{MBF} = 9.8\ Q_m\ (DA)^{-0.49}$, DA <=302 mi^2

where:

Q_{MBF}	=minimum bypass flow in cubic feet per second;
Q_m	=mean annual unimpaired flow in cubic feet per second; and
DA	=the watershed drainage area in square miles.

For all MBF alternatives, if the drainage area (DA) is greater than the stated limit, the minimum bypass flow is set to 60% of the mean annual unimpaired flow:

$$Q_{MBF} = 0.6\ Q_m$$

Figure 2 shows the 0.8 foot regression line (MBF A1), MBF alternatives A2 - A4, the Swift (1976) steelhead data, and the 2006 validation site 0.8 foot data points.

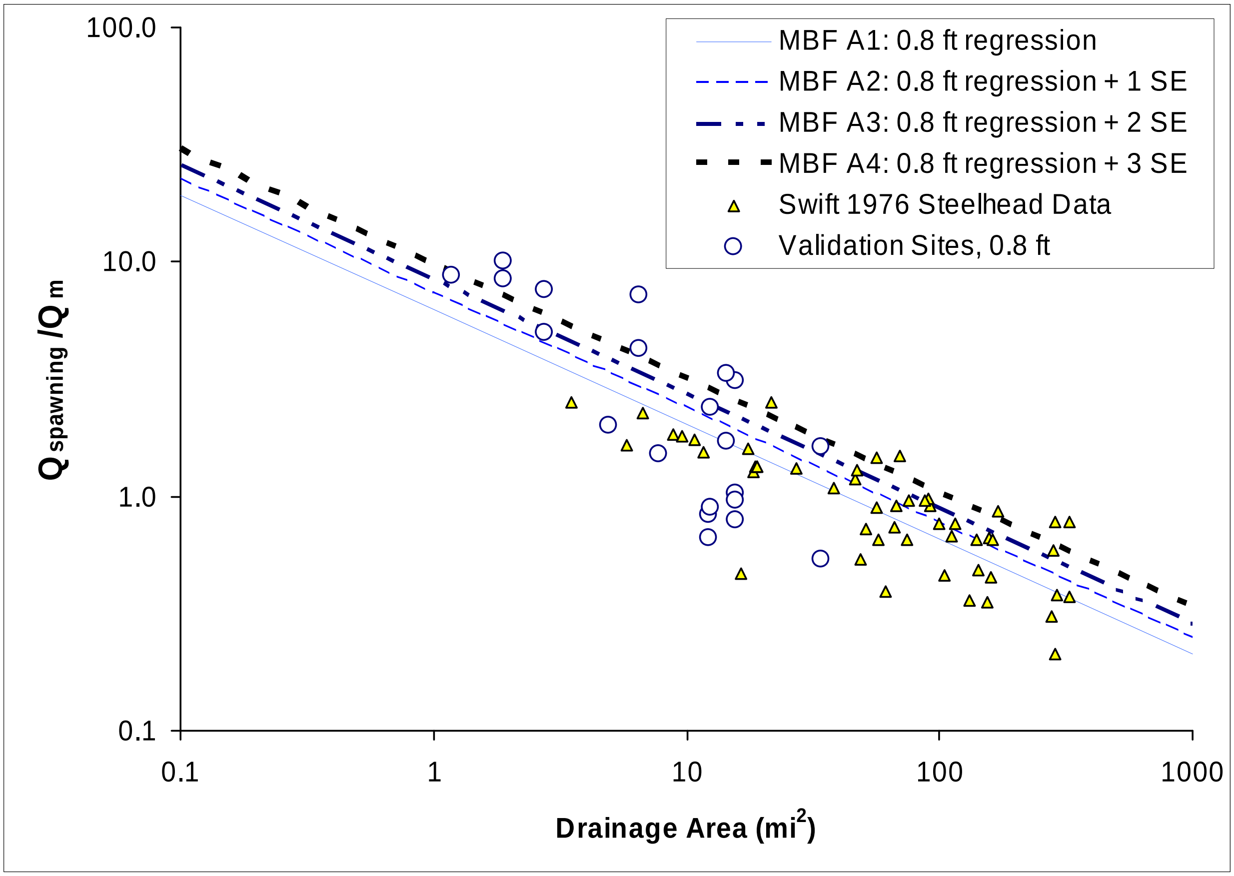

Figure 2. 0.8 ft regression line and MBF alternatives A1-A4

2.1.2 0.7 foot regression line

To evaluate the effect of using a 0.7 foot minimum depth criterion for the validation site habitat-flow relationships, optimal spawning flows were also derived using the 0.7 foot criterion. Appendix A shows the habitat-flow relationships for steelhead spawning using a minimum suitable depth criterion of 0.7 foot in comparison with the 0.8 foot relationships.

A "0.7 foot regression line" was generated by fitting the log of the ratio of spawning flow divided by mean annual flow to the log of the drainage area for both the Swift (1976) steelhead spawning data and the data points from the 2006 validation sites. Both the 2006 validation site data points and the Swift data points correspond to the lowest flow at which maximum spawning habitat occurred using the 0.7 foot minimum depth criterion habitat-flow relationships for steelhead spawning. The 2006 validation sites are different from the flows used for the 0.8 regression line (0.7 foot minimum depth criterion instead of 0.8 foot). The Swift data points are the same flows used for the 0.8 foot regression line.

Four MBF alternatives were selected for the water diversion - passage and spawning habitat sensitivity study using the 0.7 foot regression line with the intercept increased by 0, 1, 2 and 3 standard errors. These MBF alternatives were:

MBF A5 (0.7 ft mean regression line):	$Q_{MBF} = 5.6\ Q_m\ (DA)^{-0.47}$, DA <=121 mi^2
MBF A6 (0.7 ft regression line + 1 SE):	$Q_{MBF} = 6.5\ Q_m\ (DA)^{-0.47}$, DA <=167 mi^2
MBF A7 (0.7 ft regression line + 2 SE):	$Q_{MBF} = 7.6\ Q_m\ (DA)^{-0.47}$, DA <=234 mi^2
MBF A8 (0.7 ft regression line + 3 SE):	$Q_{MBF} = 8.8\ Q_m\ (DA)^{-0.47}$, DA <=321 mi^2

where:

Q_{MBF}	=minimum bypass flow in cubic feet per second;
Q_m	=mean annual unimpaired flow in cubic feet per second; and
DA	=the watershed drainage area in square miles.

Figure 3 shows the 0.7 foot regression line (MBF A5), MBF alternatives A6 - A8, the Swift (1976) steelhead data, and the 2006 validation site 0.7 foot data points.

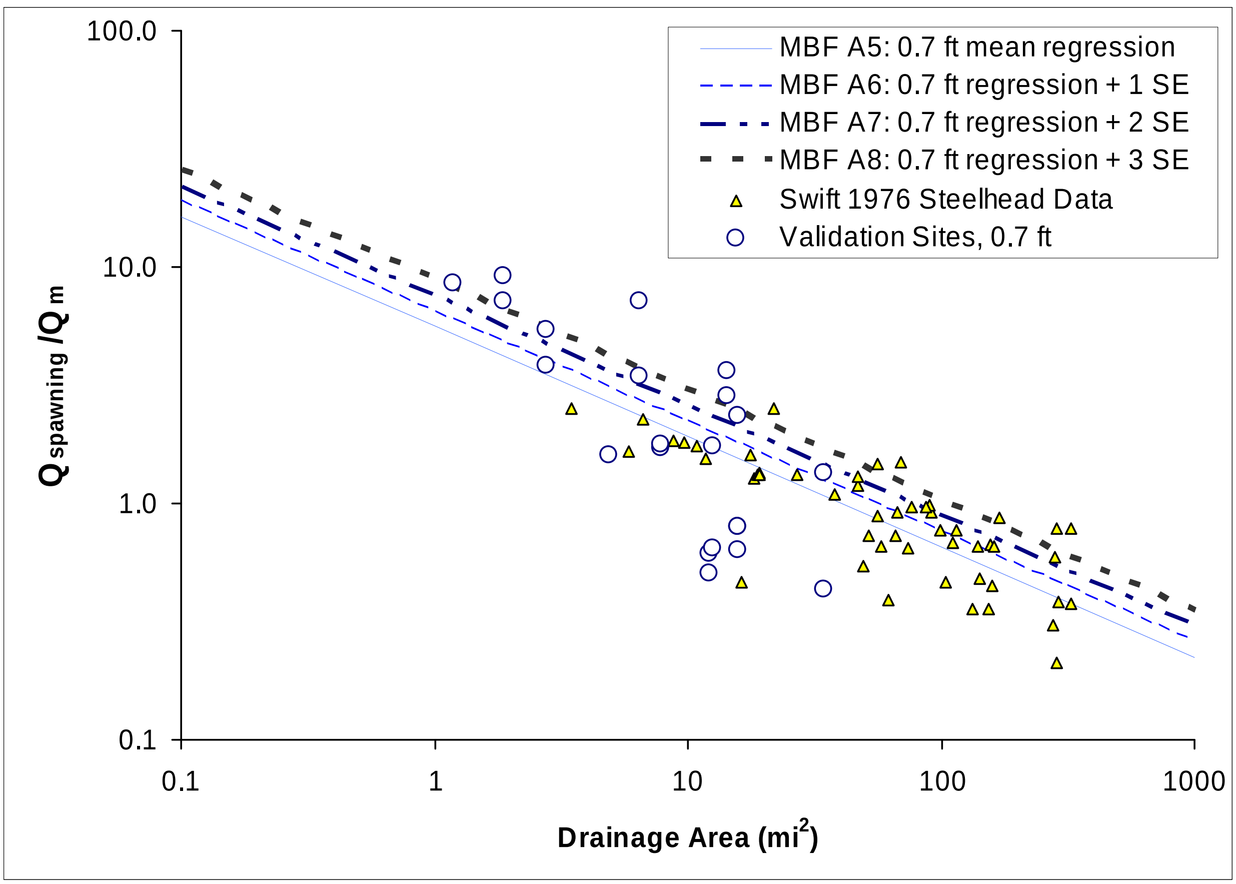

Figure 3. 0.7 ft regression line and MBF alternatives A5–A8

2.1.3 DFG recommendation

In a letter commenting on the Draft Policy, Donald Koch of the DFG[2] recommended use of an alternative MBF based on the Chinook spawning and passage criteria using a minimum depth of 1.0 foot. This recommendation was used to develop the final MBF alternative, MBF A9.

2.1.3.1 Chinook passage regression

In the Task 3 Report (Appendix E), R2 developed a relationship to estimate minimum fish passage flow as a function of mean annual flow, drainage area, and minimum depth criterion. The fish passage regression line was updated from the equation reported in the Task 3 Report (March 2008) due to changes made to selected habitat-flow curves and a typographical spreadsheet error. These corrections address comments provided by Wagner and Bonsignore Consulting Engineers in a comment letter dated April 30, 2008. In the revisions, the data points were changed for the fish passage regression at the following validation site transects: Olema Cr Sp1; Huichica Cr Sp1; Carneros Cr Sp2; Dunn Cr Sp1; and Franz Cr Sp1. The typographical errors involved switching of cell values, where Carneros Cr Sp1 was omitted in the regression data and Dry Cr Sp1 was copied twice. The net effect was a small change in the fish passage regression equation, which resulted in a 0.1-2 cfs decrease in the fish passage minimum flow needs for the validation sites with drainage areas less than 10 square miles.

The regression line fit the log of the ratio of minimum passage flow divided by mean annual flow to the log of the drainage area for various minimum depth criteria, using all data points from Idaho (R2 2004), Deitch (2006) and the 2006 validation sites. The 2006 validation site data points correspond to the lowest flow at which passage occurred for the selected minimum suitable depth criterion. The intercept coefficient of the regression line was increased by 3 standard errors.

The resulting minimum fish passage relationship is:

Chinook passage regression + 3SE: $Q_{fp} = 18.6\, Q_m\, (D_{min})^{2.2} (DA)^{-0.71}$

where:

Q_{fp} =minimum fish passage flow in cubic feet per second;
Q_m =mean annual unimpaired flow in cubic feet per second;
D_{min} =minimum passage depth criterion in feet; and
DA =the watershed drainage area in square miles.

Koch recommended using a 1.0 foot minimum passage depth consistent with the DFG Culvert Criteria for Fish Passage requirements for minimum passage depth for adult anadromous salmonids.

[2] Comment letter from Donald Koch, Department of Fish and Game, dated 4/25/2008, page 6.

Substituting 1.0 foot for the minimum passage depth in the minimum fish passage relationship gives:

DGF 1.0 ft Chinook passage: $Q_{p1} = 18.6\, Q_m\, (DA)^{-0.71}$

where:

Q_{p1} =minimum fish passage flow in cubic feet per second, using a 1.0 foot minimum passage depth;
Q_m =mean annual unimpaired flow in cubic feet per second;
DA =the watershed drainage area in square miles.

2.1.3.2 Chinook spawning regression

Koch indicated that DFG's recommendation for the minimum bypass flow might change depending on a new analysis of Chinook spawning requirements at the validation sites. R2 developed a "1.0 foot Chinook spawning regression line" for the water diversion - passage and spawning habitat sensitivity study. This regression line fitted the log of the ratio of spawning flow divided by mean annual flow to the log of the drainage area for both the Swift (1979) Chinook spawning data and the data points from the 2006 validation sites.

The Swift (1979) data points are the flows that provide maximum spawning habitat availability above which no further increase of habitat is provided based on a minimum suitable depth criterion of 1.0 foot.

The 2006 validation site data points correspond to the lowest flow at which maximum spawning habitat occurred using the habitat-flow relationships for Chinook spawning based on a minimum suitable depth criterion of 1.0 foot. Appendix H of the Task 3 Report provides the habitat-flow relationships for Chinook spawning using a minimum suitable depth criterion of 1.0 foot.

The "1.0 foot Chinook passage regression line + 3SE" is the regression line with the intercept coefficient increased by 3 standard errors:

1.0 ft Chinook spawning regression + 3SE: $Q_{s1} = 8.8\, Q_m\, (DA)^{-0.38}$

where:

Q_{s1} =minimum spawning flow in cubic feet per second, using a 1.0 foot minimum suitable depth;
Q_m =mean annual unimpaired flow in cubic feet per second; and
DA =the watershed drainage area in square miles.

2.1.3.3 1.0 foot Chinook passage and spawning MBF alternative

The DFG reviewed the 1.0 foot Chinook spawning regression line and recommended[3] combining the following equations for an MBF alternative, MBF A9:

MBF A9 (DGF 1.0 ft Chinook passage):	$Q_{MBF} = 18.6\ Q_m\ (DA)^{-0.71}$, DA <=10 mi^2
MBF A9 (1.0 ft Chinook spawning regression + 3SE):	$Q_{MBF} = 8.8\ Q_m\ (DA)^{-0.38}$, DA >10 mi^2 and DA <=1,150 mi^2
MBF A9 (60% of mean annual unimpaired flow):	$Q_{MBF} = 0.6\ Q_m$, DA > 1,150 mi^2

where:

Q_{MBF}	=minimum bypass flow in cubic feet per second;
Q_m	=mean annual unimpaired flow in cubic feet per second; and
DA	=the watershed drainage area in square miles.

Figure 4 shows MBF alternative A9, the 1.0 foot Chinook passage regression line + 3SE , 1.0 foot Chinook spawning regression line + 3SE, the 1.0 foot Chinook spawning regression line, MBF alternative A9, the Swift (1979) Chinook data, and the 2006 validation site 1.0 foot data points.

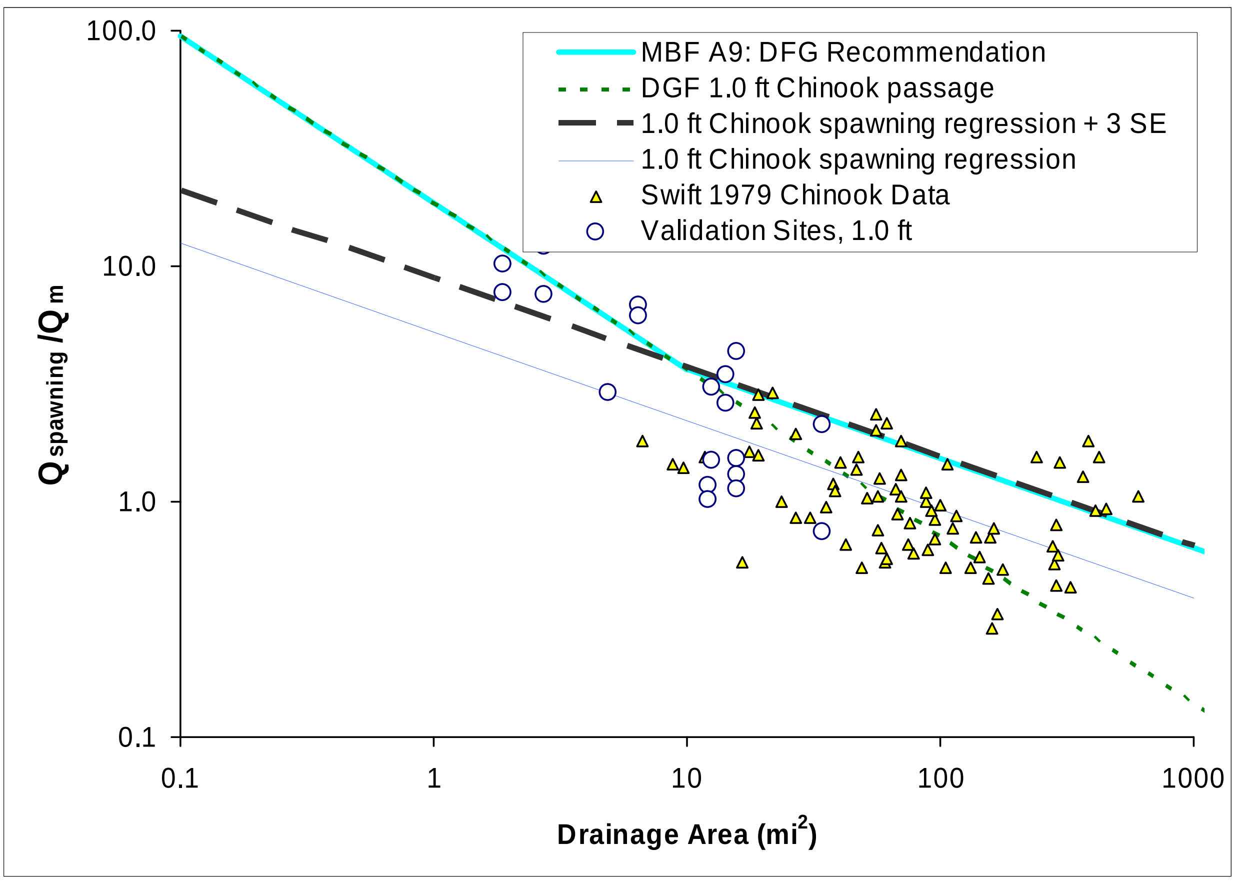

Figure 4. Chinook spawning and passage regression lines and MBF alternative A9

[3] Email correspondence from Chad Dibble, DFG to Steve Herrera, State Water Board, 2/17/2009.

2.2 Maximum Cumulative Diversion

In Section D.3.1.2 of the Task 3 Report, a relationship was developed to predict the long-term potential changes in channel width, depth and grain size distribution resulting from a reduction in bankfull flow. It was predicted that a reduction of 5% in the bankfull flow would give rise to a roughly 2% reduction in channel width, depth and median grain size. Figure 5 shows this relationship (same as Figure 2-1 in the Task 3 Report).

Section D.3.1.1 of the Task 3 Report discussed use of the 1.5-year peak flow, derived from an annual maximum flood series using methods described by USGS Bulletin 17B (IACWD, 1982), as a hydrologic metric to estimate the magnitude of bank full flow and effective discharge.

The Draft Policy regionally protective maximum cumulative diversion (MCD) is 5% of the 1.5-year peak flow based on the recommendations of the Task 3 Report.

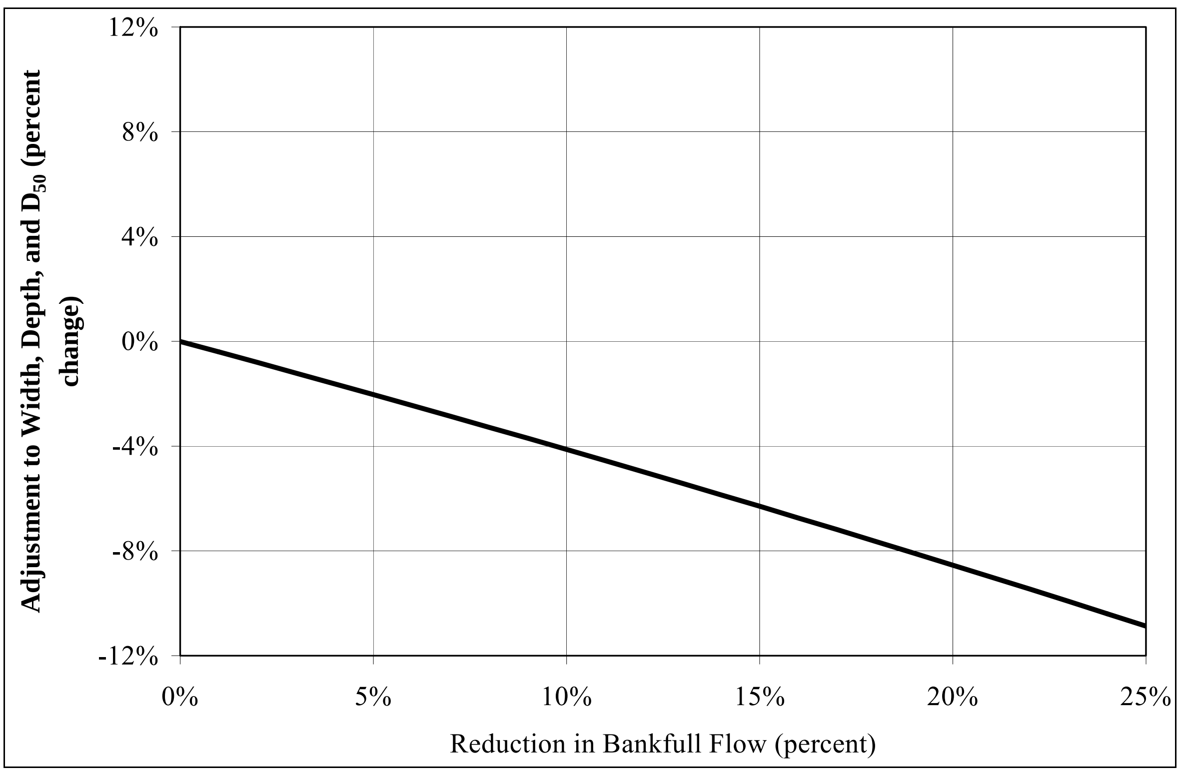

Figure 5. Predicted long-term potential changes in channel width, depth, and grain size distribution resulting from a reduction in bankfull flow

Five MCD alternatives were selected for the water diversion - passage and spawning habitat sensitivity study. These alternatives were formulated as reductions or increases in the restrictiveness of the Draft Policy regionally protective MCD in terms of percent of the 1.5-year peak flow:

MCD A1:	1% of 1.5-year peak flow
MCD A2:	5% of 1.5-year peak flow
MCD A3:	10% of 1.5-year peak flow
MCD A4:	12% of 1.5-year peak flow
MCD A5:	15% of 1.5-year peak flow

MCD A1 is approximately equal to 15% of the 20% exceedance flow recommended by DFG-NMFS (2002) in the Draft Guidelines. MCD A2 is the Draft Policy regionally protective MCD and is estimated to result in a roughly 2% channel size reduction. MCD A4 is estimated to result in a roughly 5% channel size reduction.

2.3 2006 Validation Sites

Figure 6 shows the location of the sites in the Policy area where, in 2006, R2 and Stetson collected data on channel characteristics, including cross-section, slope, and particle size distribution (2006 validation sites). The hydrologic analysis of the 2006 validation sites is described in Appendix F of the Task 3 Report and the field data collection is described in Section G.1 of the Task 3 Report. Eleven of the thirteen sites had sufficient information for the water cost analysis presented in Section 6.8 of the SED (State Water Board, March 2008). These eleven sites were also used for the water diversion - passage and spawning habitat sensitivity study described in this report. The Olema Creek and Lagunitas Creek validation sites were not considered in the study because there were insufficient records of annual peak flow data to estimate the 1.5-year peak flows at these locations.

For each validation site, the flow rate corresponding to each MBF and MCD alternative, in cubic feet per second, was calculated for each validation site using the equations in Sections 2.1 and 2.2. The results are presented in Tables 1-3.

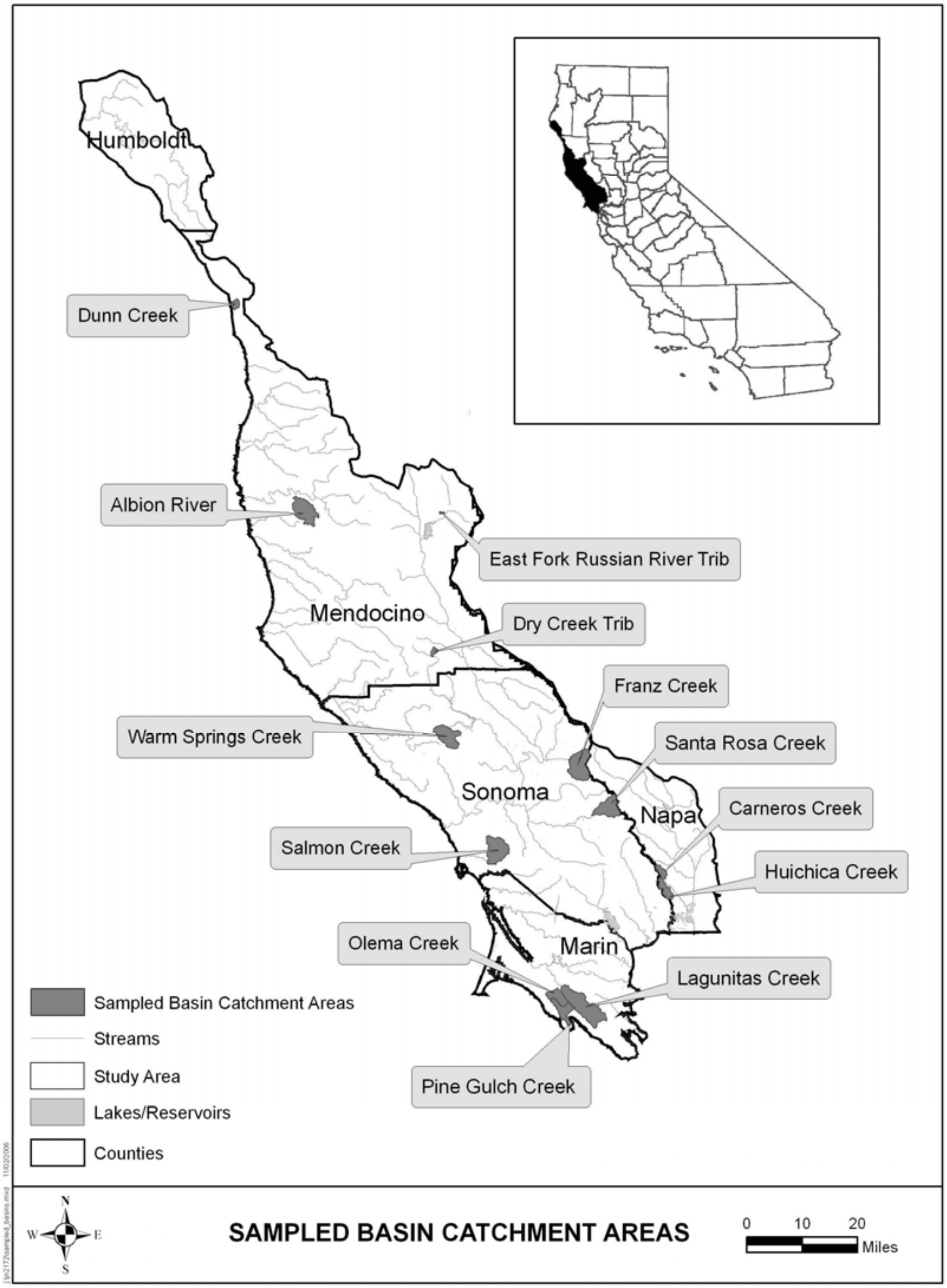

Figure 6. Locations of 2006 Validation Sites

Table 1. MBF Alternatives A1-A5 at Validation Sites

Validation Site	Drainage Area	Qm	MBF A1	MBF A2	MBF A3	MBF A4	MBF A5
	(sq. miles)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
E. Fk. Russian River Trib	0.25	0.13	1.6	1.9	2.2	2.5	1.4
Dry Creek Trib	1.19	2.2	13	15	17	20	11
Dunn Creek	1.88	2.5	12	13	15	18	10
Carneros Creek	2.75	3.8	15	17	19	23	13
Huichica Creek	4.92	7.4	21	25	28	33	20
Pine Gulch Creek	7.83	12	28	32	37	43	26
Warm Springs Creek	12.2	35	65	75	86	101	60
Santa Rosa Creek	12.5	19	35	40	46	54	32
Albion River	14.4	20	34	40	45	53	32
Salmon Creek	15.7	25	41	47	54	64	38
Franz Creek	15.7	24	39	45	52	61	37

Table 2. MBF Alternatives A6-A9 at Validation Sites

Validation Site	Drainage Area	Qm	MBF A6	MBF A7	MBF A8	MBF A9
	(sq. miles)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
E. Fk. Russian River Trib	0.25	0.13	1.6	1.9	2.2	6.5
Dry Creek Trib	1.19	2.2	13	15	18	36
Dunn Creek	1.88	2.5	12	14	16	30
Carneros Creek	2.75	3.8	15	18	21	34
Huichica Creek	4.92	7.4	23	27	31	44
Pine Gulch Creek	7.83	12	30	35	40	52
Warm Springs Creek	12.2	35	70	82	95	119
Santa Rosa Creek	12.5	19	38	44	51	64
Albion River	14.4	20	37	43	50	64
Salmon Creek	15.7	25	45	52	60	77
Franz Creek	15.7	24	43	50	58	74

Table 3. MCD Alternatives at Validation Sites

Validation Site	1.5-year peak flood flow	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)	(cfs)
E. Fk. Russian River Trib	25	0.3	1.3	2.5	3	3.8
Dry Creek Trib	110	1.1	5.5	11	13	17
Dunn Creek	93	0.9	4.7	9.3	11	14
Carneros Creek	254	2.5	13	25	30	38
Huichica Creek	219	2.2	11	22	26	33
Pine Gulch Creek	731	7.3	37	73	88	110
Warm Springs Creek	857	8.6	43	86	103	129
Santa Rosa Creek	1170	12	59	117	140	176
Albion River	740	7.4	37	74	89	111
Salmon Creek	1380	14	69	138	166	207
Franz Creek	1230	12	62	123	148	185

3 Water Diversion Analysis

The water diversion analysis determined the volume of water available for diversion at each validation site for the period of record under every combination of MBF alternative (MBF A1 - A9) and MCD alternative (MCD A1-A5). A diversion season of December 15 to March 31 was used for the analysis.

3.1 Methods

The water diversion analysis was based on a continuous daily record (timeseries) of flow and calculated (1) the daily maximum rate of diversion that could potentially be made in compliance with the alternative policy criteria that restrict water diversions (diversion season, MBF, and MCD) acting in concert, (2) the potential daily volume of water diverted at the calculated maximum rate of diversion, and (3) the daily volume of water that remains instream after the maximum volume is diverted. The potential daily volumes of water that could be diverted during the diversion season were summed over the period of record and divided by the number of diversion seasons to determine the average seasonal volume of water potentially available for the diversion. The percentage of mean annual flow volume that could be diverted was calculated by dividing the average seasonal diversion volume by the mean annual flow volume.

These were the same methods used in the analysis presented in Section 6.8 of the SED (State Water Board, March 2008) previously referred to as the water *cost* analysis.

3.2 Results

Appendix B provides tabular results of the water diversion analysis. Results are reported in terms of (a) the volume of water potentially available for diversion during the diversion season, and (b) the percentage of the mean annual flow volume that would potentially be available for diversion. A table is presented for each of the eleven validation sites. The tables provide a comparison of the potentially available diversion volume and percentage of water available under the combinations of MBF and MCD alternatives.

Tables 4 - 7 provide summary results of the water diversion analysis averaged for all eleven validation sites and for each range of watershed size: less than 2 square miles (East Fork Russian River Tributary, Dry Creek Tributary, and Dunn Creek), 2 - 10 square miles (Carneros Creek, Huichica Creek, and Pine Gulch Creek), and greater than10 square miles (Warm Springs Creek, Santa Rosa Creek, Albion River, Salmon Creek, and Franz Creek).

Figure 7 displays the potentially available diversion volume for each combination of the MBF-MCD alternatives averaged for the eleven validation sites used in the analysis; Figure 8 displays the same information grouped by drainage area (less than 2 square miles, 2 - 10 square miles, and greater than 10 square miles). Figure 9 displays the percentage of the mean annual flow volume potentially available for diversion, on average, for the eleven validation sites used in the analysis; Figure 10 displays the same information grouped by drainage area.

Table 4. Estimated Average Potential Diversion at Validation Sites

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	343	1,342	2,133	2,371	2,668	3.2%	11.8%	18.3%	20.1%	22.6%
MBF A2	313	1,242	1,988	2,214	2,497	2.7%	10.6%	16.5%	18.3%	20.6%
MBF A3	288	1,149	1,850	2,064	2,333	2.5%	9.4%	15.0%	16.7%	18.8%
MBF A4	257	1,034	1,679	1,878	2,128	2.1%	8.2%	13.3%	14.8%	16.7%
MBF A5	361	1,396	2,210	2,454	2,759	3.4%	12.7%	19.5%	21.4%	24.0%
MBF A6	325	1,285	2,052	2,284	2,573	3.1%	11.4%	17.7%	19.5%	21.9%
MBF A7	296	1,181	1,898	2,117	2,390	2.6%	10.1%	15.8%	17.6%	19.9%
MBF A8	269	1,079	1,745	1,950	2,208	2.4%	8.8%	14.1%	15.8%	17.8%
MBF A9	219	898	1,477	1,655	1,884	1.5%	6.4%	10.5%	11.7%	13.4%

Table 5. Estimated Average Potential Diversion at Validation Sites with Drainage Area Less Than 2 mi^2

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	16	68	111	122	140	2.7%	8.7%	12.4%	13.1%	14.6%
MBF A2	14	59	96	106	122	1.9%	6.8%	9.7%	10.7%	12.1%
MBF A3	13	50	81	90	103	1.8%	5.2%	7.8%	8.7%	9.5%
MBF A4	10	37	63	70	80	1.3%	3.7%	6.0%	6.7%	7.4%
MBF A5	19	79	131	143	164	2.9%	10.4%	14.6%	15.4%	17.0%
MBF A6	16	68	111	122	140	2.7%	8.7%	12.4%	13.1%	14.6%
MBF A7	14	59	94	104	120	1.9%	6.8%	9.6%	10.6%	12.0%
MBF A8	12	46	75	83	95	1.7%	4.9%	7.4%	8.2%	9.0%
MBF A9	3	13	23	26	31	0.2%	0.8%	1.4%	1.6%	1.9%

Note: There are three validation sites with drainage area less than 2 mi^2; East Fork Russian River Tributary, Dry Creek Tributary, and Dunn Creek.

Table 6. Estimated Average Potential Diversion at Validation Sites with Drainage Area 2-10 mi^2

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	177	671	1,047	1,165	1,316	2.8%	10.5%	16.4%	18.2%	20.6%
MBF A2	155	605	956	1,070	1,211	2.4%	9.4%	14.9%	16.6%	18.8%
MBF A3	138	548	878	986	1,119	2.1%	8.5%	13.6%	15.2%	17.3%
MBF A4	119	482	789	887	1,008	1.8%	7.3%	12.0%	13.5%	15.3%
MBF A5	187	708	1,097	1,217	1,373	2.9%	11.2%	17.4%	19.2%	21.7%
MBF A6	167	640	1,005	1,121	1,268	2.6%	10.1%	15.8%	17.6%	19.9%
MBF A7	144	569	907	1,018	1,154	2.2%	8.9%	14.1%	15.8%	17.9%
MBF A8	128	512	830	932	1,058	1.9%	7.9%	12.7%	14.3%	16.2%
MBF A9	95	400	665	748	859	1.4%	5.8%	9.6%	10.8%	12.5%

Note: There are three sites with drainage area between 2 and 10 mi2, Carneros Creek, Huichica Creek, and Pine Gulch Creek.

Table 7. Estimated Average Potential Diversion at Validation Sites with Drainage Area Greater Than 10 mi^2

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	640	2,509	3,998	4,444	4,996	3.7%	14.5%	23.0%	25.5%	28.6%
MBF A2	587	2,334	3,743	4,165	4,693	3.4%	13.5%	21.5%	23.9%	26.9%
MBF A3	544	2,169	3,495	3,896	4,400	3.2%	12.6%	20.1%	22.4%	25.3%
MBF A4	488	1,964	3,183	3,558	4,029	2.8%	11.4%	18.4%	20.5%	23.2%
MBF A5	670	2,598	4,126	4,583	5,147	3.9%	15.0%	23.7%	26.3%	29.5%
MBF A6	606	2,402	3,846	4,278	4,816	3.5%	13.9%	22.1%	24.6%	27.6%
MBF A7	557	2,221	3,575	3,983	4,494	3.3%	12.9%	20.6%	22.9%	25.8%
MBF A8	509	2,038	3,296	3,682	4,165	3.0%	11.8%	19.0%	21.2%	23.9%
MBF A9	424	1,728	2,836	3,176	3,611	2.5%	10.0%	16.4%	18.3%	20.8%

Note: There are five sites with drainage area greater than 10 mi^2, Warm Springs Creek, Santa Rosa Creek, Albion River, Salmon Creek, and Franz Creek.

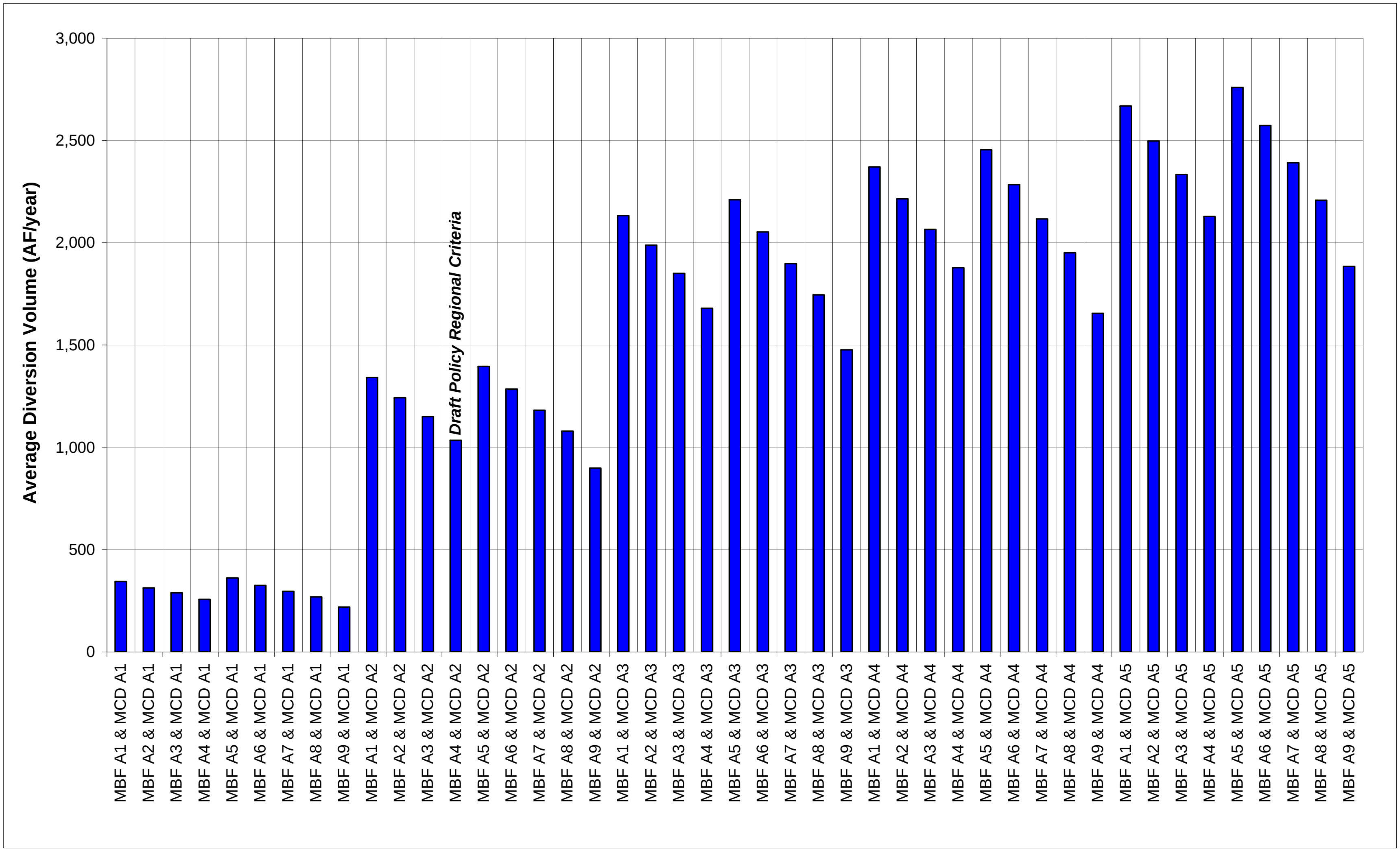

Figure 7. Estimated Average Annual Diversion Volume at All 2006 Validation Sites

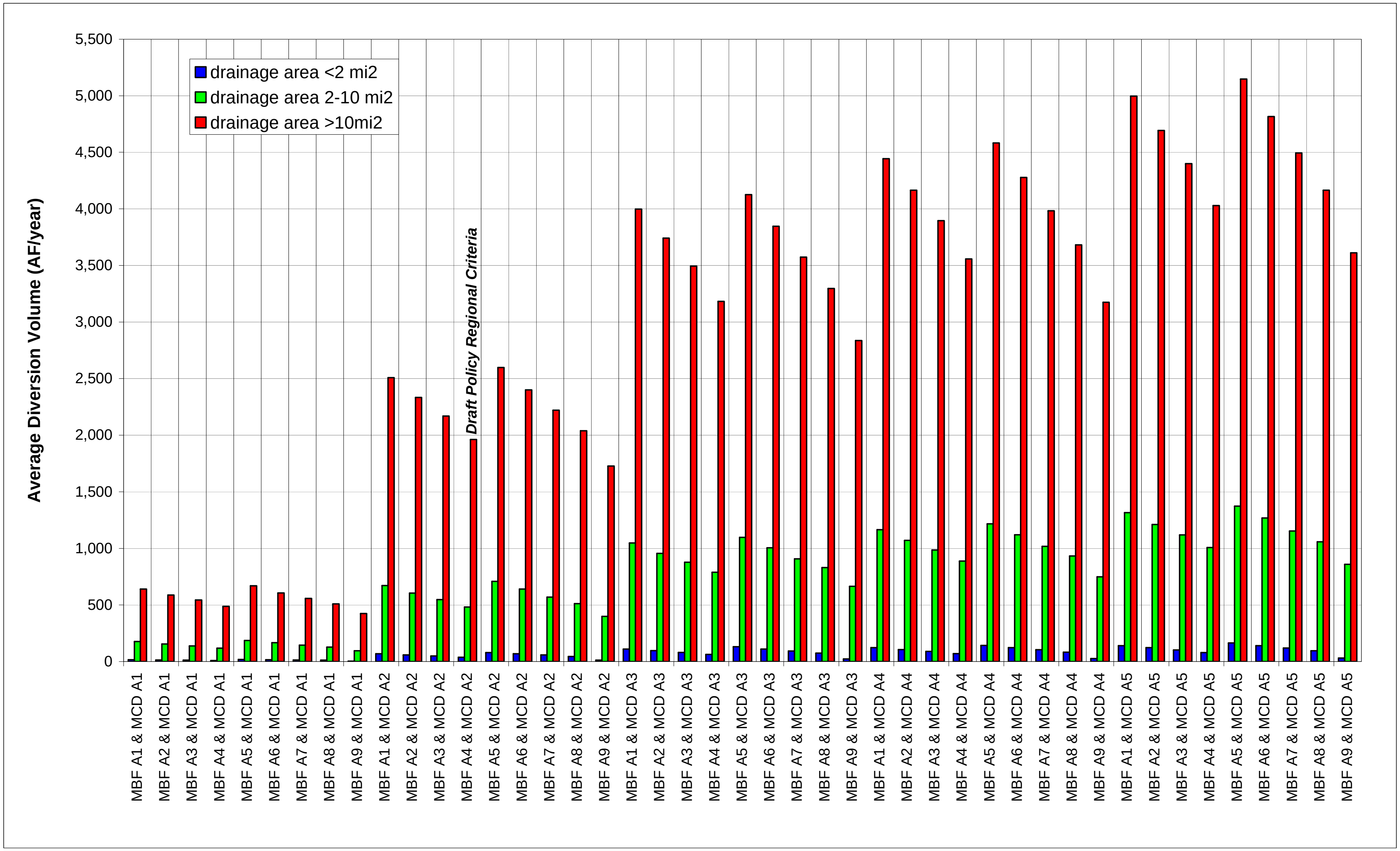

Figure 8. Estimated Average Annual Diversion Volume at 2006 Validation Sites Grouped by Size

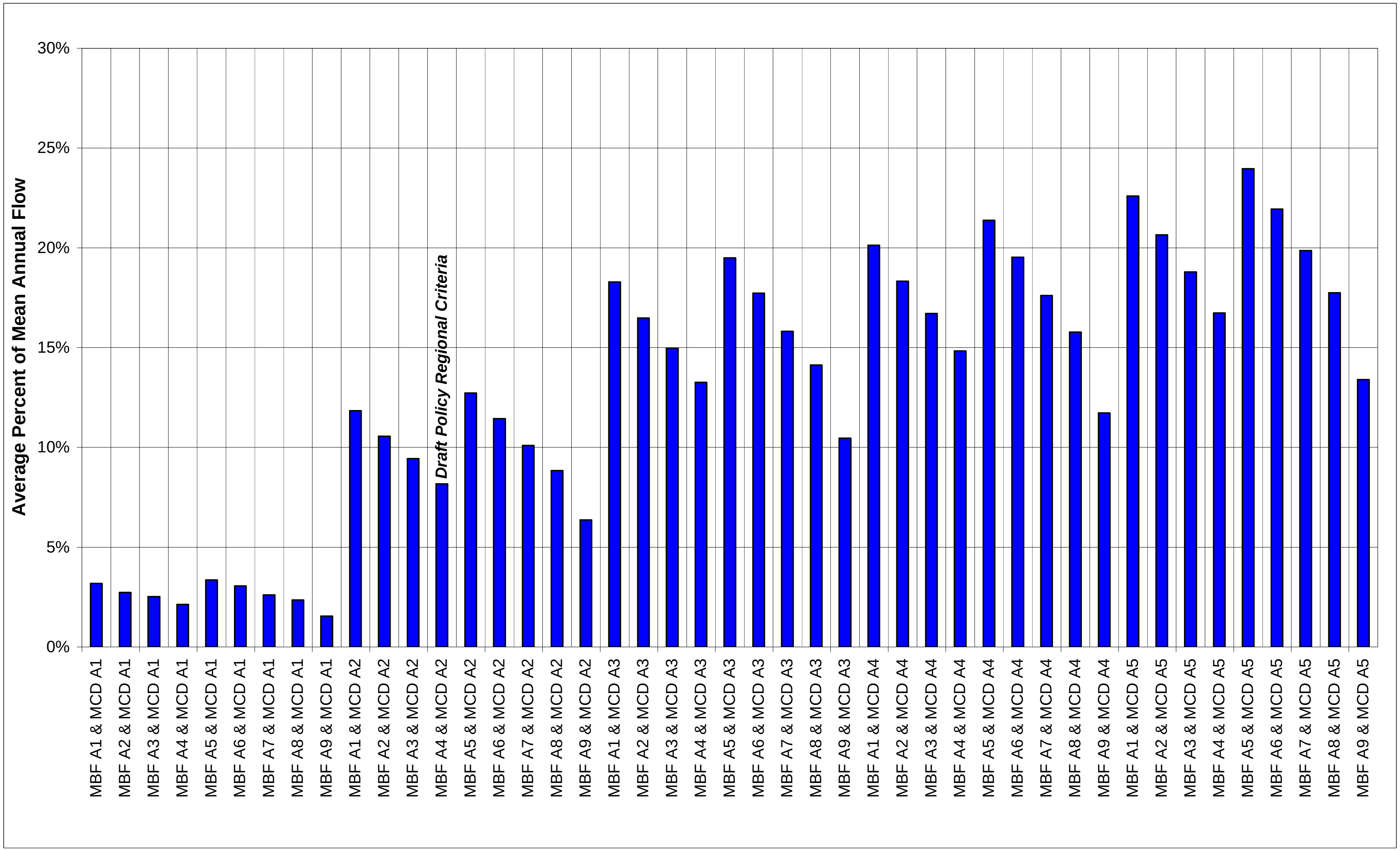

Figure 9. Estimated Percent of Mean Annual Flow Volume Potentially Available for Diversion at All 2006 Validation Sites

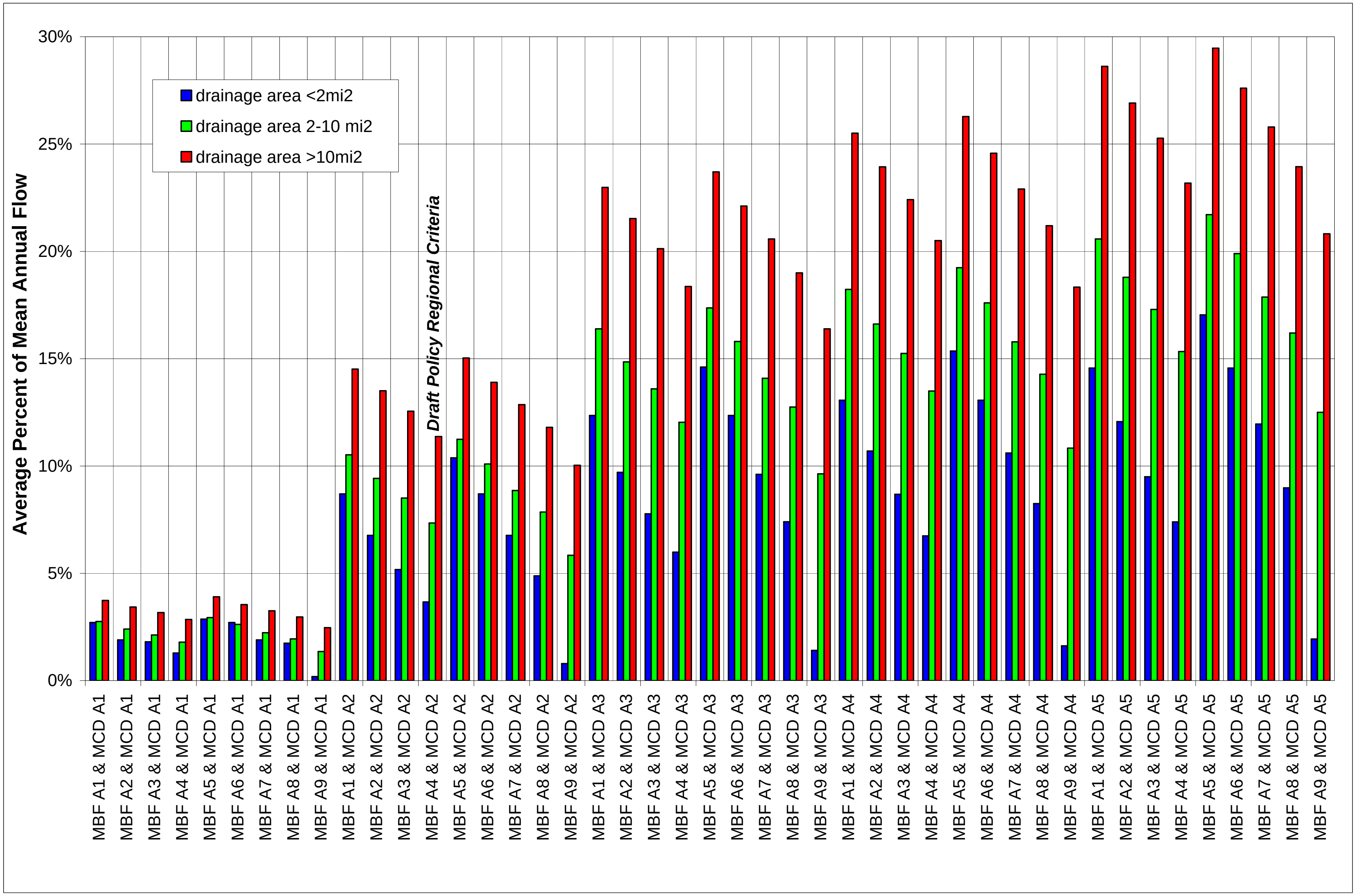

Figure 10. Estimated Percent of Mean Annual Flow Volume Potentially Available for Diversion at 2006 Validation Sites Grouped by Size

4 Passage and Spawning Habitat Availability Analysis

R2 completed a passage and spawning habitat availability analysis for the following subset of MBF sensitivity study alternatives selected by the State Water Board:

1. MBF A4, 0.8 ft mean regression line + 3 SE
2. MBF A5, 0.7 ft mean regression line
3. MBF A6, 0.7 ft regression line + 1 SE
4. MBF A7, 0.7 ft regression line + 2 SE
5. MBF A8, 0.7 ft regression line + 3 SE
6. MBF A9, DFG 1.0 ft Chinook passage and spawning + 3SE

The passage and spawning habitat availability analysis used a diversion season of December 15 to March 31 and a MCD of 5% of the 1.5 year flow (MCD A2) with each of the MBF alternatives. The MBF was the only criterion that changed for each of the six alternatives considered. This allowed a direct assessment of the sensitivity of habitat availability to the MBF criterion. The subset of MBF alternatives was selected to allow comparison of effects of selecting a 0.8 ft or 0.7 ft minimum depth criterion and the method of adjusting the intercept coefficient (addition of zero, one, two or three standard errors) on the passage and spawning opportunities.

Although the MCD does influence the habitat availability, the primary purpose of limiting water diversions using the MCD is to protect channel maintenance flows. MCD A2 was selected for the passage and spawning habitat availability analysis because it was concluded to be regionally protective based on an estimated potential reduction of bankfull width, depth and surface grain distribution of approximately two percent (Section D.3.1.2, Task 3 Report). A range of MCD alternatives were not analyzed in the passage and spawning habitat availability analysis because the passage and spawning habitat availability analysis does not assess channel maintenance flow availability and therefore cannot be used to comprehensively determine the protectiveness of an MCD alternative.

4.1 Methods

The methods used for the passage and spawning habitat availability analysis were the same as those described in Sections 4.3.1 and 4.3.2 of the Task 3 Report.

The impaired flow is the water that remains instream after diversions have been made. The impaired flow for each selected MBF alternative was calculated during the water diversion analysis (Section 3.1) as the unimpaired flow less the daily maximum rate of diversion that could be made in compliance with the combination of the selected MBF and a MCD of 5% of the 1.5 year flow (MCD A2) acting in concert during a diversion season of December 15 to March 31.

The number of days of passage and spawning opportunities for steelhead, coho and Chinook under the unimpaired flow condition and for each of the impaired flow alternatives (impaired flow for the combination of selected MBF and MCD A2 acting in concert) were determined for each validation site. Useable passage habitat is expressed as the number of days per water year in which flow conditions meet the depth specified in Table 8 (same as Table G-4 in the Task 3 Report). Useable spawning habitat is expressed as the number of days per water year in which flow conditions meet the depth and velocity criteria listed in Table 9 (same as Table G-7 in the Task 3 Report) and remain wetted for a minimum number of days thereafter (see Section 3.2.4 iii and Table G-8 in the Task 3 Report)

Each impaired flow alternative was assessed using the same criteria (shown in Table 8 and Table 9), regardless of the depth criterion basis for the MBF alternative. For example, a minimum spawning depth of 0.8 ft (Table 9, Steelhead minimum depth) was used to assess the number of Steelhead spawning opportunities for all the MBF alternatives (A4 - A9) even though MBF A5 – A8 were developed based on the 0.7 ft mean regression line. This provided consistent comparable results for each alternative.

Table 8. Minimum Upstream Passage Depth Criteria Used for Passage Habitat Availability Analysis

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

Table 9. Minimum Depth and Favorable Velocity Used for Spawning Habitat Availability Analysis

Species	Minimum Depth (ft)	Favorable Velocities (ft/s)
Steelhead	0.8	1.0-3.0
Coho	0.8	1.0-2.6
Chinook	1.0	1.0-3.0

4.2 Results

Appendix C provides a visual summary of the results of the passage and spawning habitat availability analysis. Figures C-1 to C-11 show the minimum, mean, and maximum number of days of passage and spawning opportunities for steelhead, coho, and Chinook for the unimpaired flow and each impaired flow alternative (impaired flow for the selected MBF combined with MCD A2 acting in concert) for each validation site. Figures C-12 to C-14 show the average number of days of passage and spawning opportunities for steelhead, coho, and Chinook for the unimpaired flow and each impaired flow alternative for validation sites in each range of drainage area.

Figures 11 - 22 provide a visual summary of the predicted effects of the impaired flow alternative on upstream passage and spawning opportunities in the validation sites as a function of drainage area. Results are plotted as the average number of days per year and as the corresponding percent change from unimpaired flow conditions.

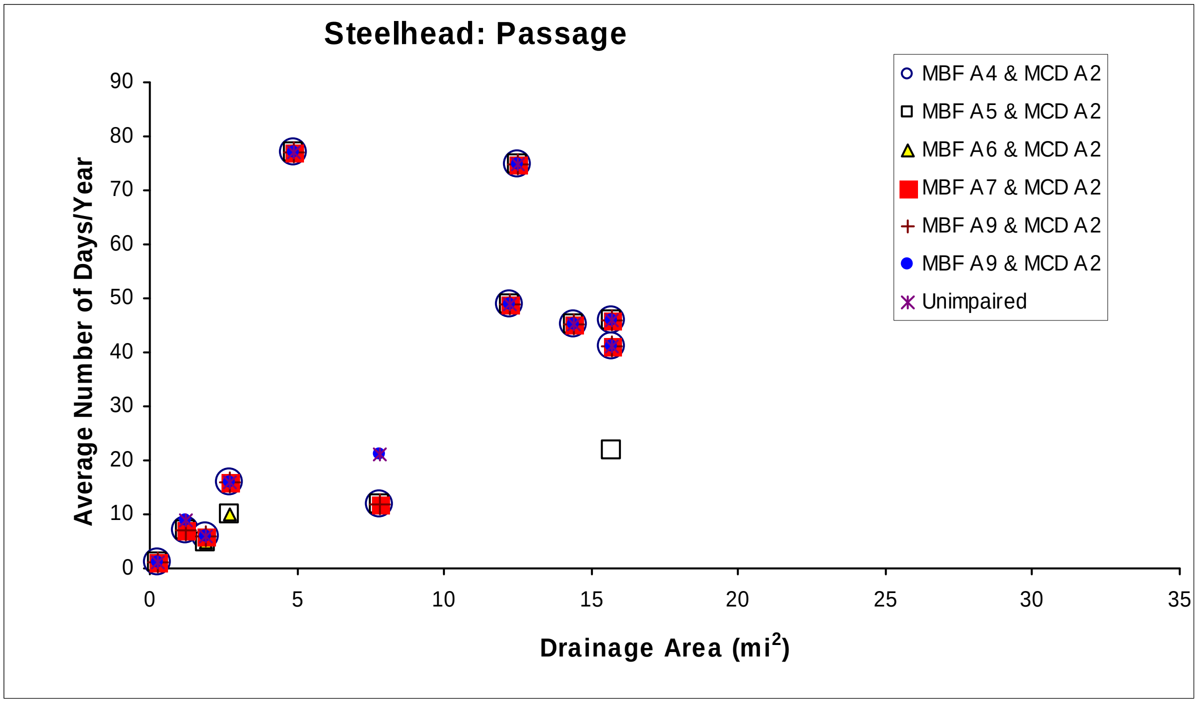

Figure 11. Predicted effects of the impaired flow alternative on passage opportunities for steelhead salmon at validation sites, expressed as average number of days per year

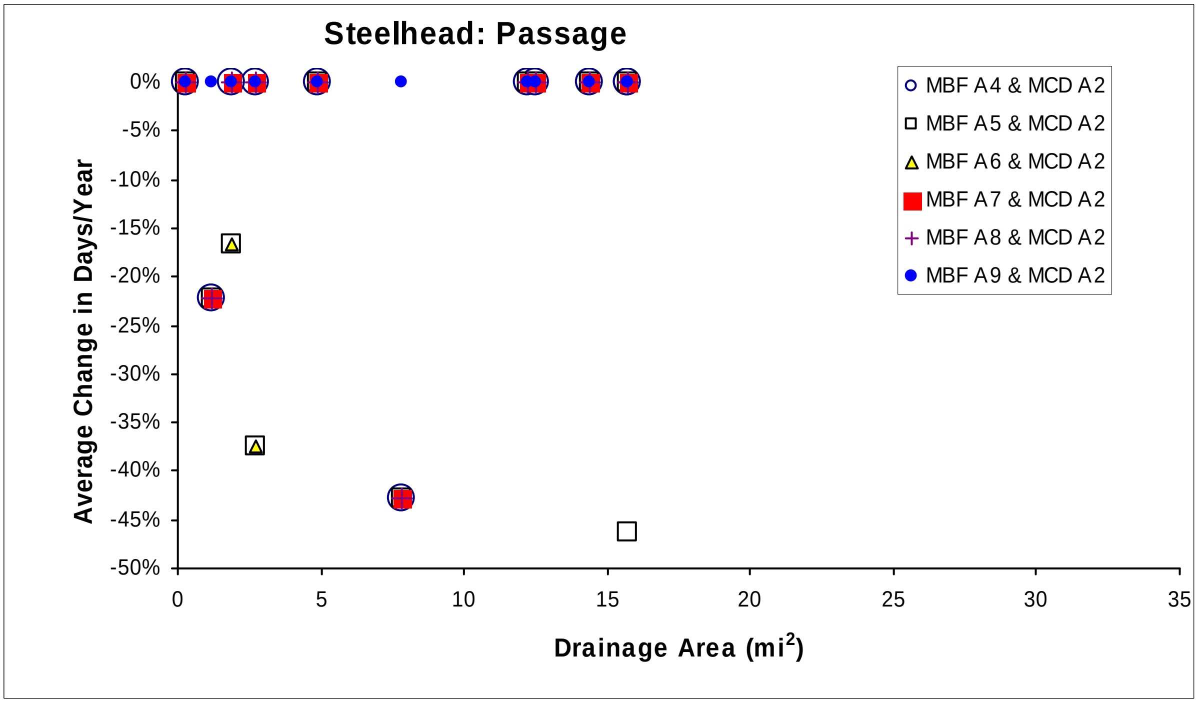

Figure 12. Predicted effects of the impaired flow alternative on passage opportunities for steelhead salmon at validation sites, expressed as percent change from unimpaired flow conditions

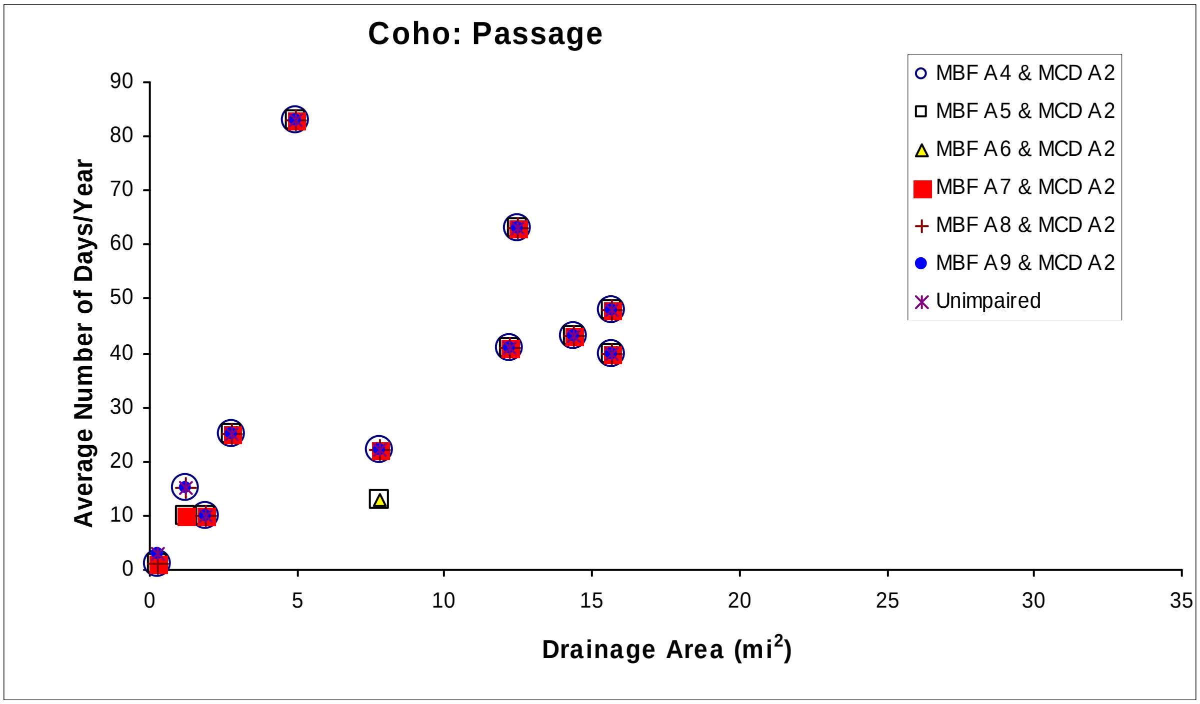

Figure 13. Predicted effects of the impaired flow alternative on passage opportunities for coho salmon at validation sites, expressed as average number of days per year

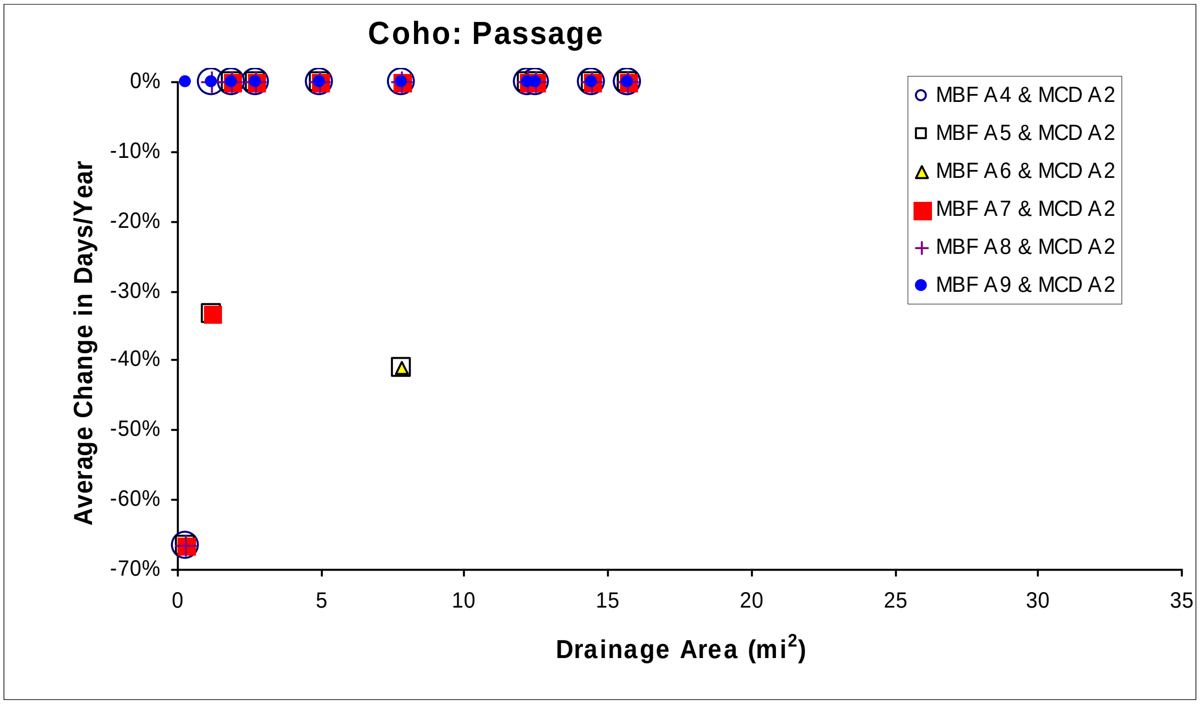

Figure 14. Predicted effects of the impaired flow alternative on passage opportunities for coho salmon at validation sites, expressed as percent change from unimpaired flow conditions

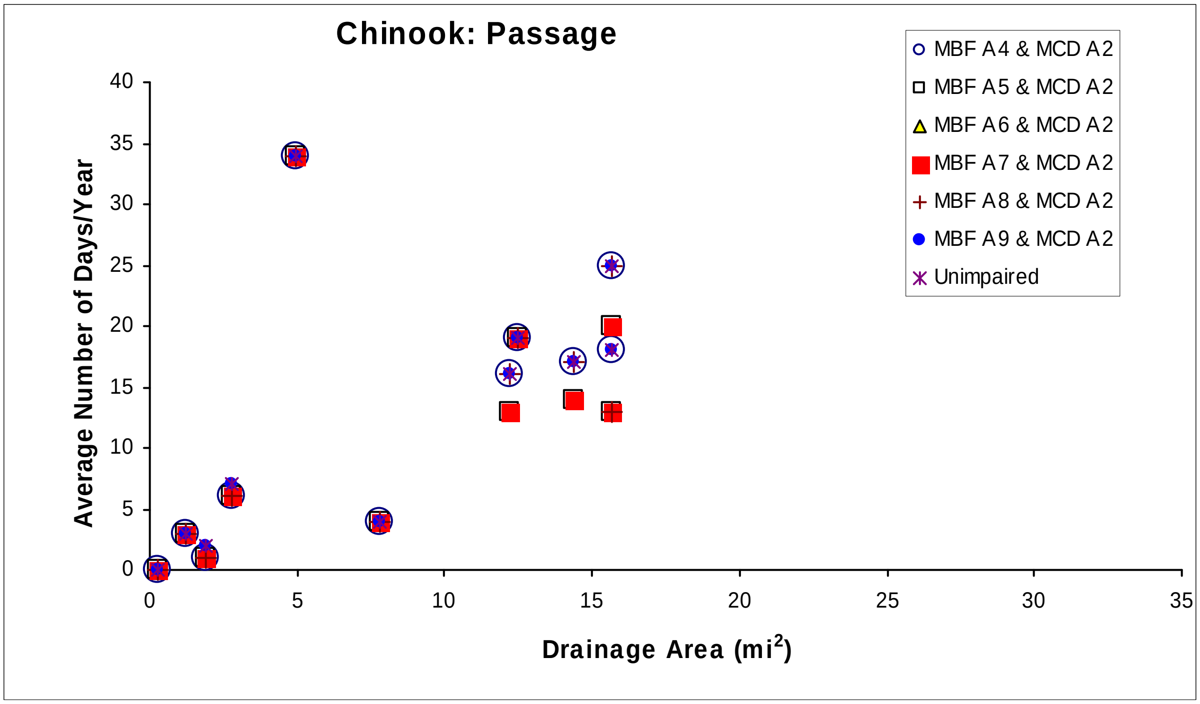

Figure 15. Predicted effects of the impaired flow alternative on passage opportunities for Chinook salmon at validation sites, expressed as average number of days per year

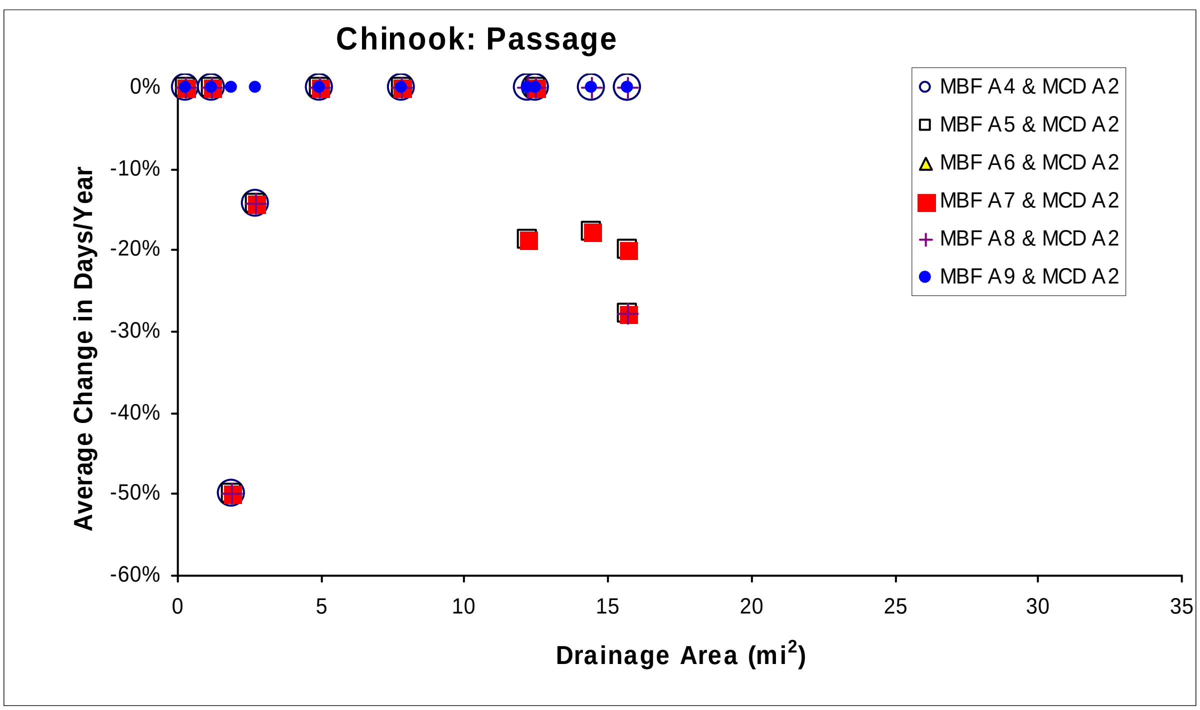

Figure 16. Predicted effects of the impaired flow alternative on passage opportunities for Chinook salmon at validation sites, expressed as percent change from unimpaired flow conditions

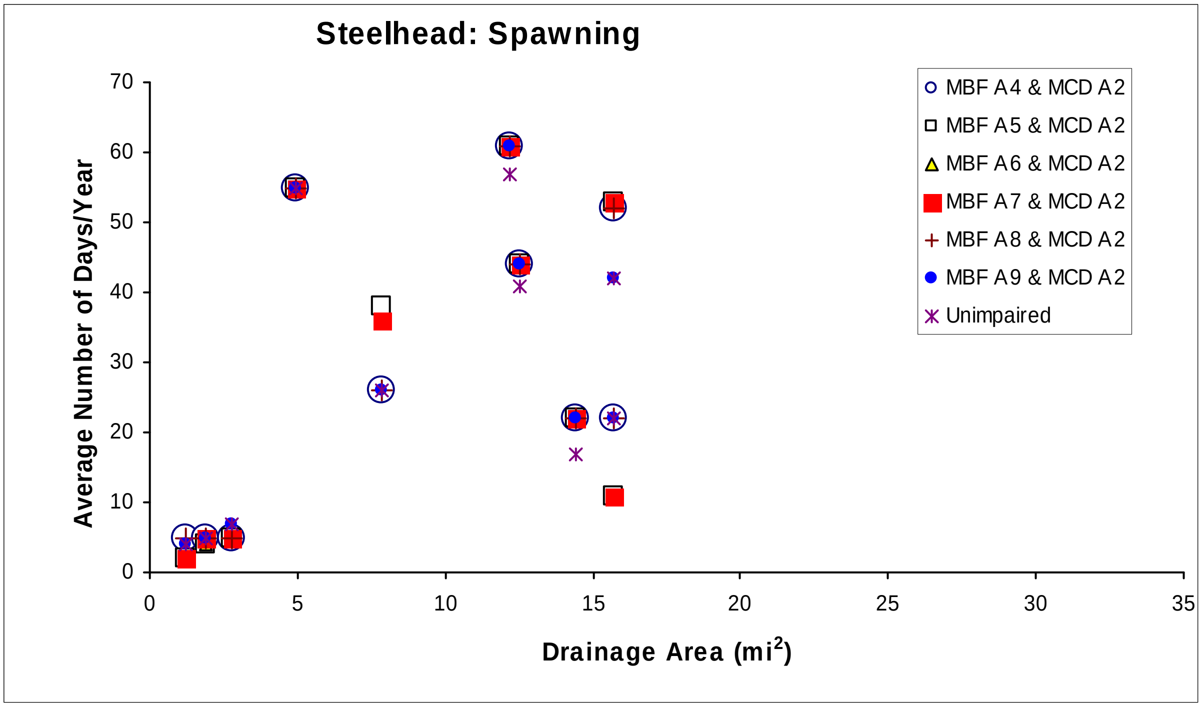

Figure 17. Predicted effects of the impaired flow alternative on spawning opportunities for steelhead salmon at validation sites, expressed as average number of days per year

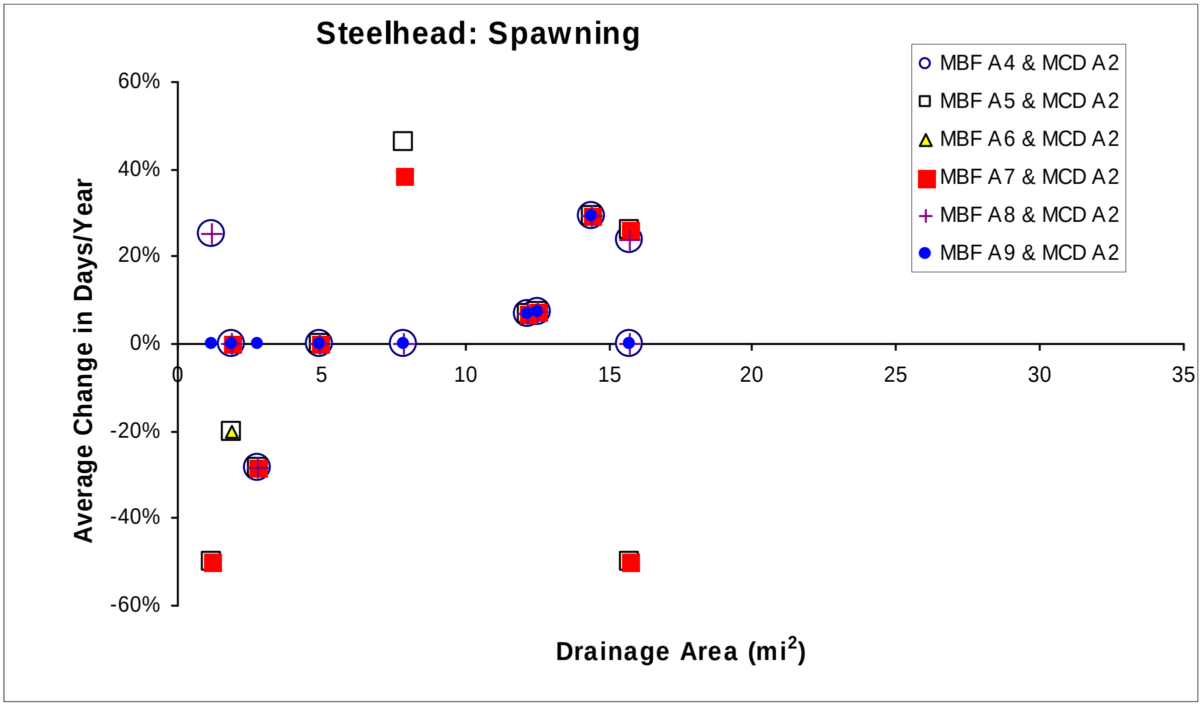

Figure 18. Predicted effects of the impaired flow alternative on spawning opportunities for steelhead salmon at validation sites, expressed as percent change from unimpaired flow conditions

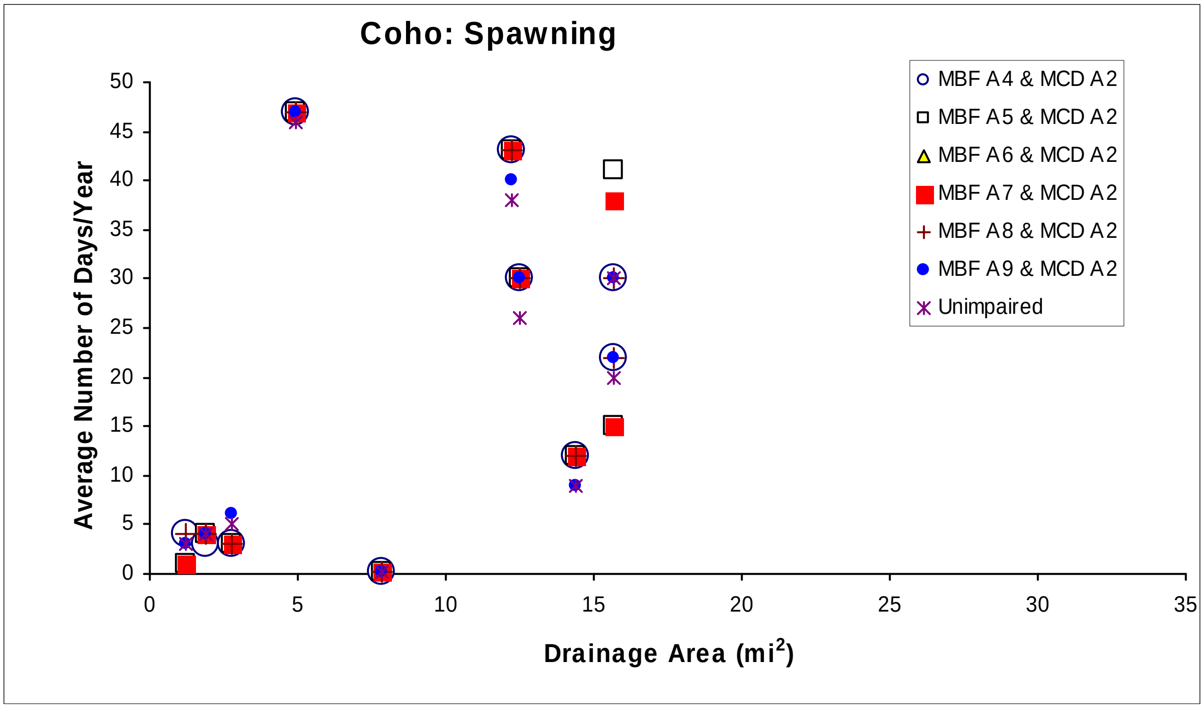

Figure 19. Predicted effects of the impaired flow alternative on spawning opportunities for coho salmon at validation sites, expressed as average number of days per year

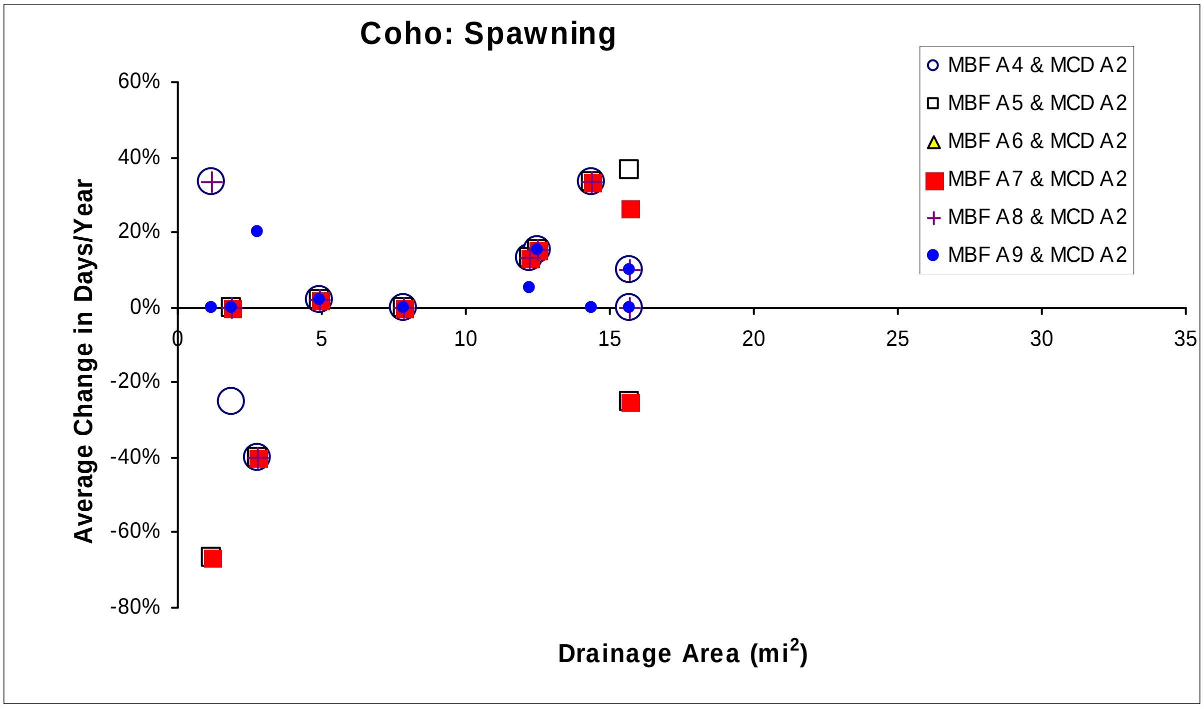

Figure 20. Predicted effects of the impaired flow alternative on spawning opportunities for coho salmon at validation sites, expressed as percent change from unimpaired flow conditions

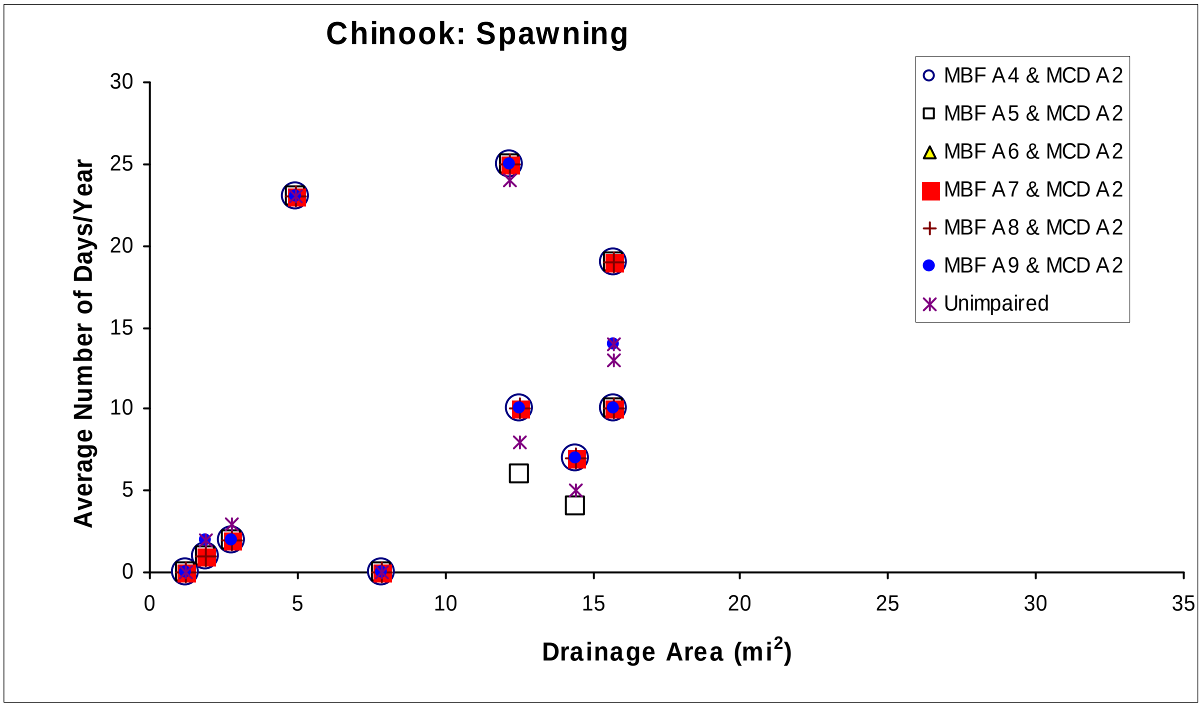

Figure 21. Predicted effects of the impaired flow alternative on spawning opportunities for Chinook salmon at validation sites, expressed as average number of days per year

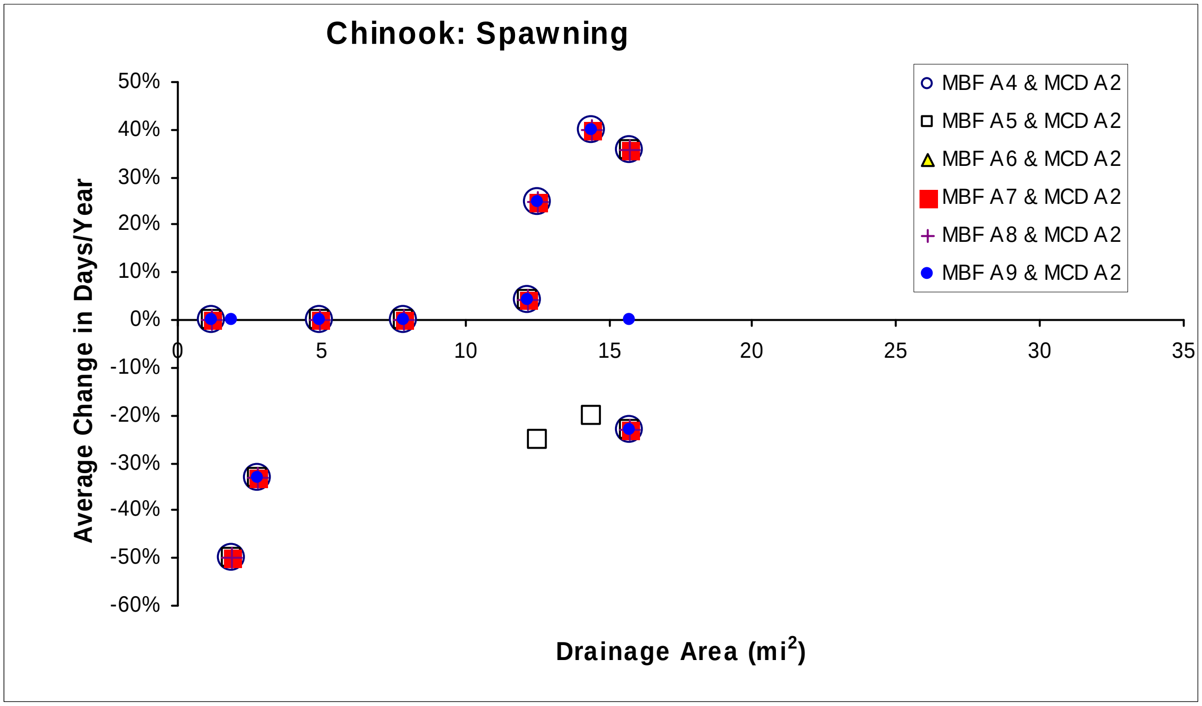

Figure 22. Predicted effects of the impaired flow alternative on spawning opportunities for Chinook salmon at validation sites, expressed as percent change from unimpaired flow conditions

4.3 Interpretation of Results

The passage and spawning habitat availability analysis results for the six impaired flow alternatives (impaired flow for the selected MBF and MCD A2 combination) can be used to assess the relative protectiveness of the MBF alternatives. The same MCD alternative (MCD A2, 5% of the 1.5 year flow) and diversion season (December 15 to March 31) were used for each impaired flow alternative.

The passage and spawning habitat availability analysis in both the Task 3 Report and this sensitivity study evaluated habitat availability in terms of the number of days of passage and spawning opportunities rather than the wetted useable width[4]. The use of number of days of passage and spawning opportunities as the evaluation criterion simplifies the results. Each day, habitat is determined to be either available or not available, irrespective of the amount of habitat (see habitat-flow relationships in Appendix A). Passage opportunities occur each day that passage habitat is available, i.e. the minimum upstream passage depth criteria listed in Table 8 are met. Spawning opportunities occur each day that spawning habitat is available and the habitat remains continuously wetted over the combined redd construction and incubation period, i.e. the minimum depth and favorable velocity criteria listed in Table 9 and the incubation time listed in Table G-9 of the Task 3 Report are met.

Wetted useable width was not an appropriate evaluation criterion because the width of useable habitat at a given flow provides different biological benefits depending on the site and may not be directly comparable from site to site in terms of effect to passage and spawning habitat. Furthermore, the minimum redd width criterion of 2 ft does not necessarily mean that a 6 ft wide patch would support three redds because territoriality and density-dependent effects would likely result in still just one redd occupying a 6 ft width when available. Evaluation of habitat availability in terms of the number of days of passage and spawning opportunities is therefore more appropriate for evaluating the results of the sensitivity analysis than wetted useable width.

Evaluation of passage habitat availability is relatively straightforward because the number of days of passage opportunities would generally be expected to increase as the MBF becomes more restrictive (i.e., increases). This is because a minimum depth can be established above which passage occurs, and below which it does not. Table 8 lists the minimum upstream passage depth criteria used in this sensitivity study. Impaired flows may remain below the minimum upstream passage depth for longer than under unimpaired conditions. For evaluating the results of the passage habitat availability analysis at the validation sites, a lower MBF rate is inferred to have an adverse effect on passage habitat availability compared with a higher MBF rate if the number of days of passage opportunities decreases.

The effect of a lower MBF rate on spawning habitat availability is more complicated because the spawning criteria (stated in terms of both depth and velocity) describe a range of acceptable spawning flows rather than a simple threshold (as for passage).

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[4] Wetted useable width analyses are typically done on a site-specific study basis when evaluating water demand trade-offs.

The effect of a change to the MBF rate at any given site depends on the position of the MBF relative to this spawning flow range. To illustrate the possible effects, seven spawning flow range cases were conceived using two hypothetical MBF levels, MBF1 and MBF2. Each spawning flow range case has the same unimpaired flow hydrograph, MCD, and impaired flow hydrographs (unimpaired flow less the diversions allowed under MBF1 and MBF2). The only difference in each case is the spawning flow range relative to MBF1, MBF2 and the peak flow.

Table 10 summarizes the spawning flow range cases and lists the relative duration of spawning habitat availability for each flow condition.

Table 10. Summary of Spawning Flow Range Cases

Case	Spawning Flow Range Relative to MBF1 and MBF2	Spawning Flow Range Relative to Peak Flow	Relative Spawning Habitat Availability
1	spawning flows bracket MBFs	spawning flows below peak flow	MBF1 = MBF2 > Unimpaired
1A	spawning flows bracket MBFs	spawning flows above peak flow	MBF1 = MBF2 = Unimpaired
2	spawning flows bracket MBF 1 spawning flows below MBF2	spawning flows below peak flow	MBF1 > MBF2 = Unimpaired
3	spawning flows above MBF 1 spawning flows bracket MBF2	spawning flows below peak flow	MBF2 > Unimpaired > MBF1
3A	spawning flows above MBF 1 spawning flows bracket MBF2	spawning flows above peak flow	MBF2 = Unimpaired > MBF1
4	spawning flows above MBFs	spawning flows below peak flow	Unimpaired <> MBF1 = MBF2 (function of hydrograph shape)
4A	spawning flows above MBFs	spawning flows above peak flow	Unimpaired > MBF1 = MBF2

Note: Case 2A is not shown as it would be the same as Case 1A.

Figures 23 - 29 show the unimpaired flow hydrograph and the impaired flows hydrographs associated with the two hypothetical MBF levels, MBF1 and MBF2 for the spawning flow range cases. The dark horizontal bars under the figures indicate the duration of spawning habitat availability for each flow condition.

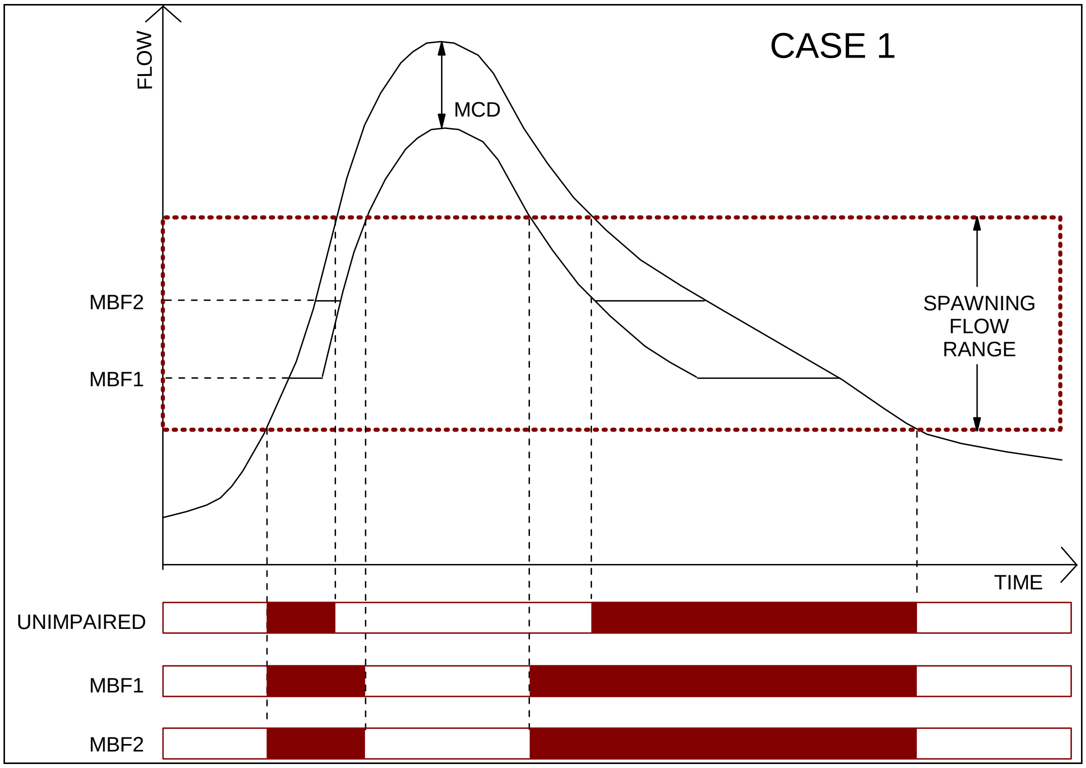

Figure 23. Case 1: Spawning flows bracket the MBFs and fall between base and peak flow

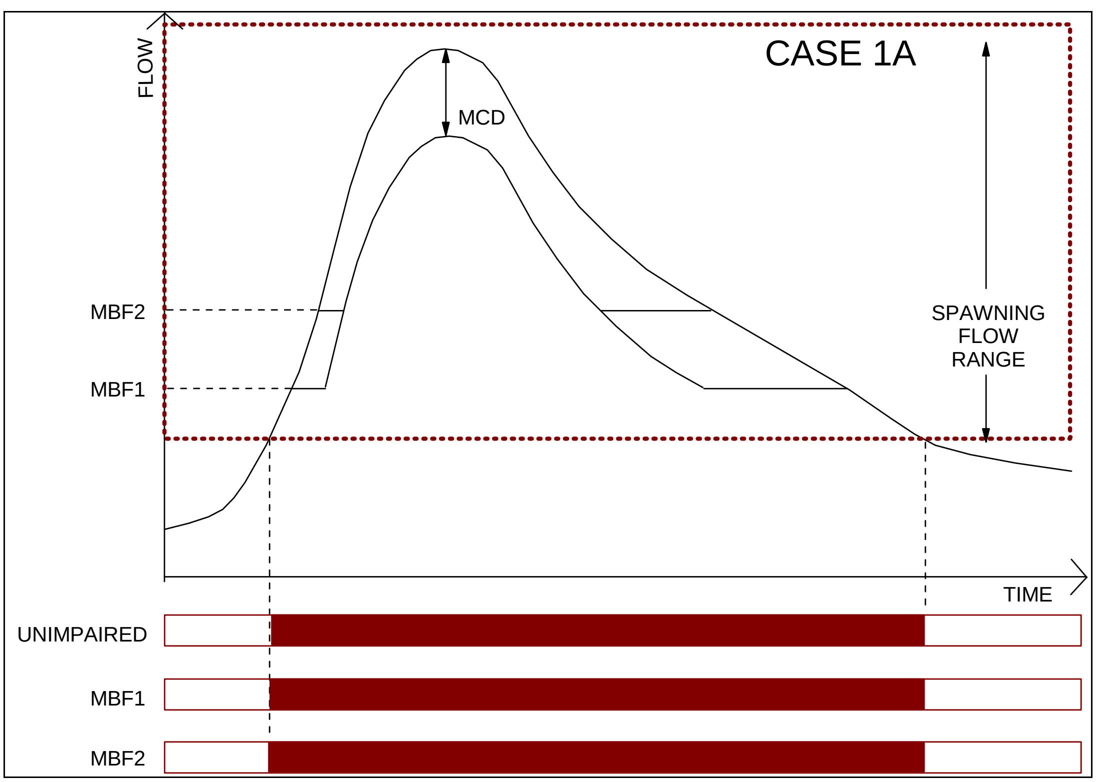

Figure 24. Case 1A: Spawning flows bracket the MBFs and peak flow

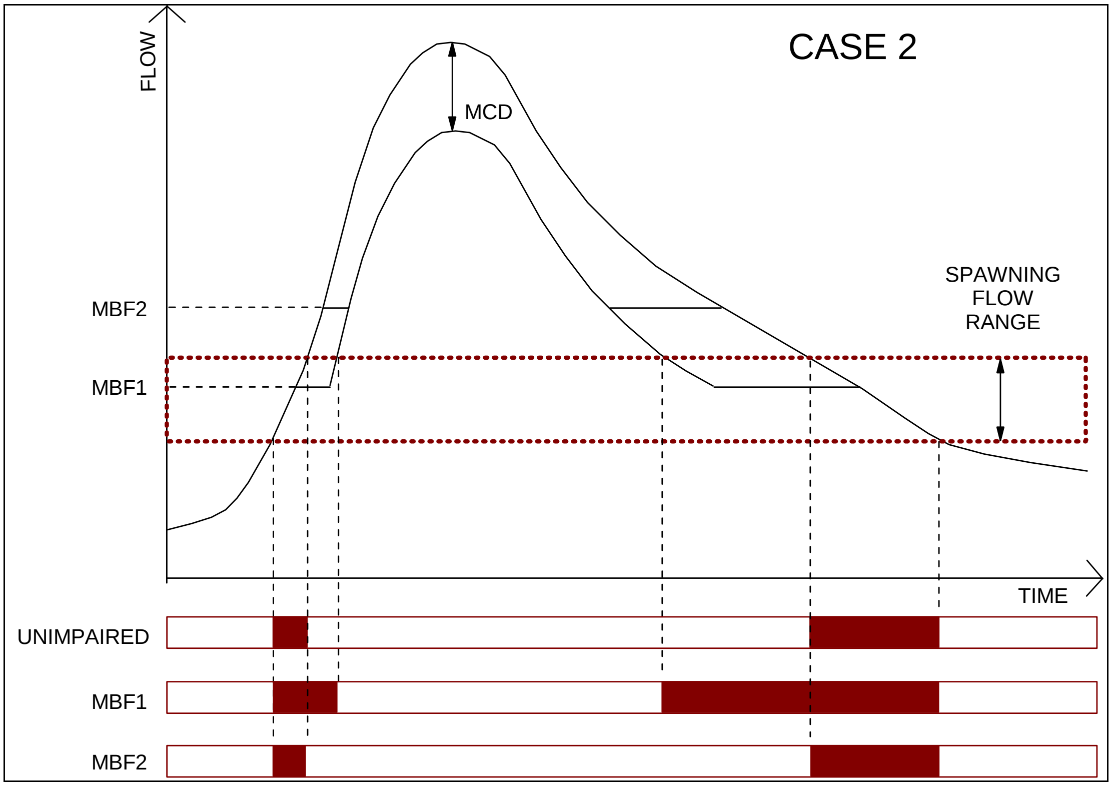

Figure 25. Case 2: Spawning flows bracket the lower MBF and fall between base and peak flow

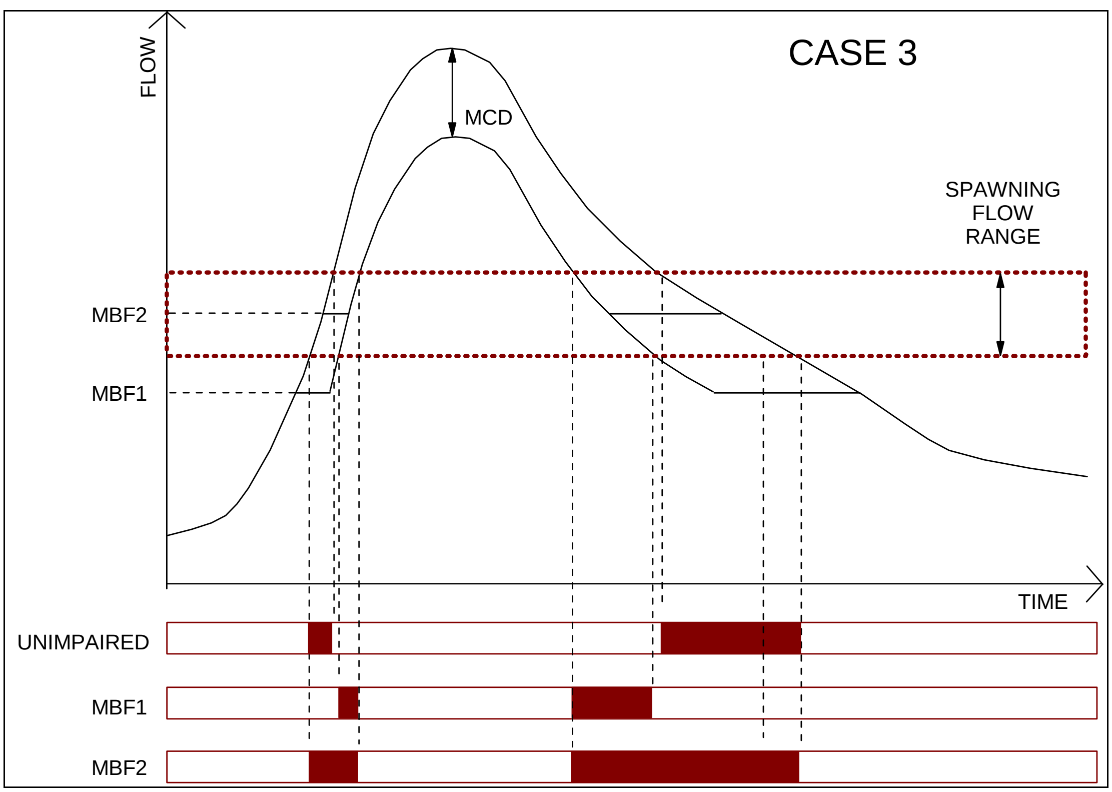

Figure 26. Case 3: Spawning flows bracket the upper MBF and fall between base and peak

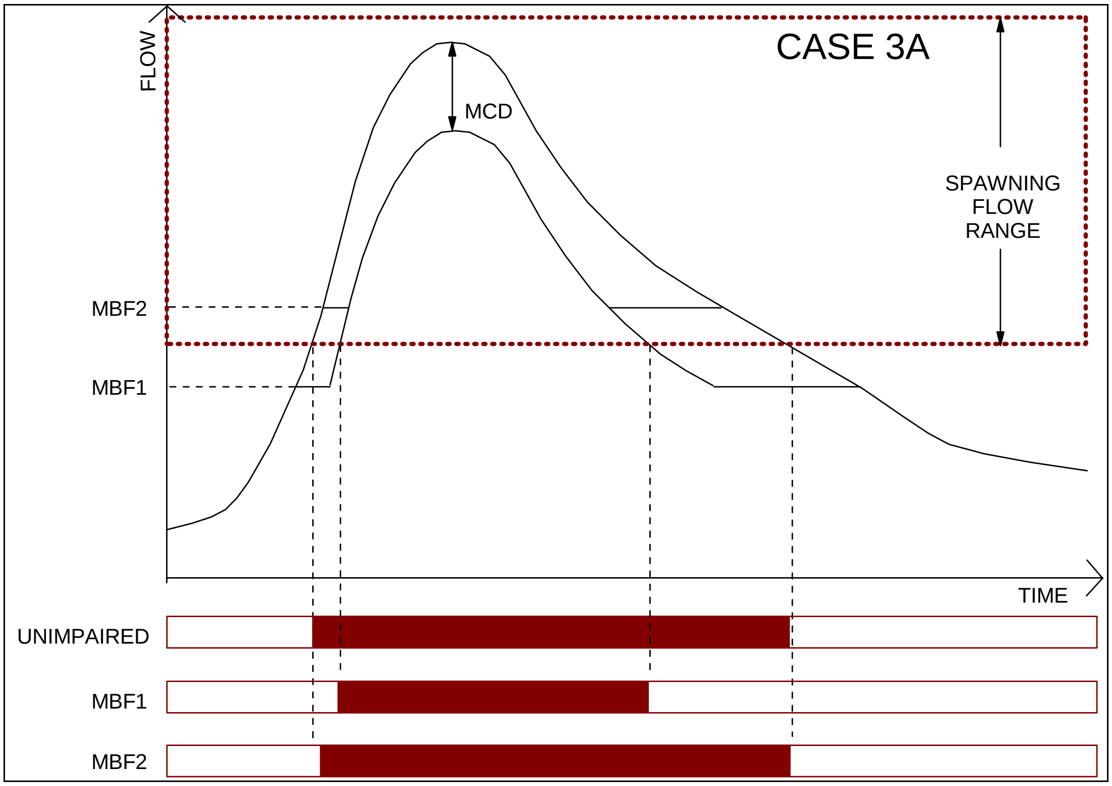

Figure 27. Case 3A: Spawning flows bracket the upper MBF and peak flow

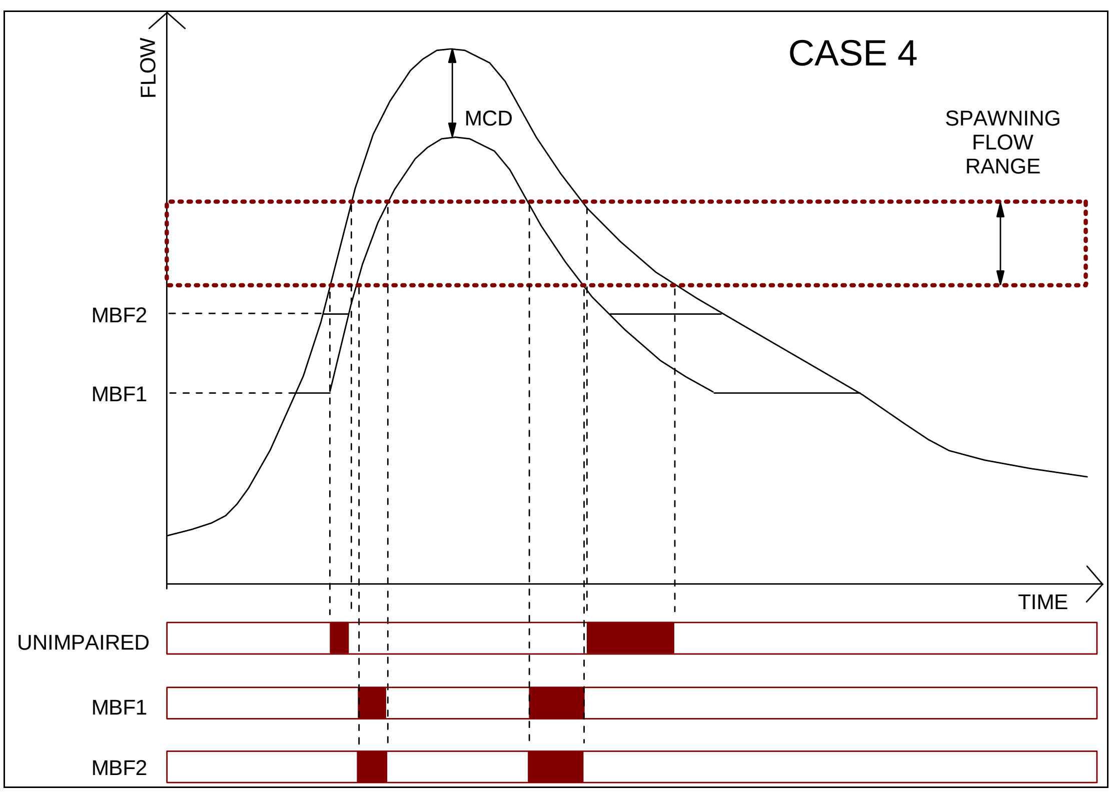

Figure 28. Case 4: Spawning flows fall between the upper MBF and peak flow

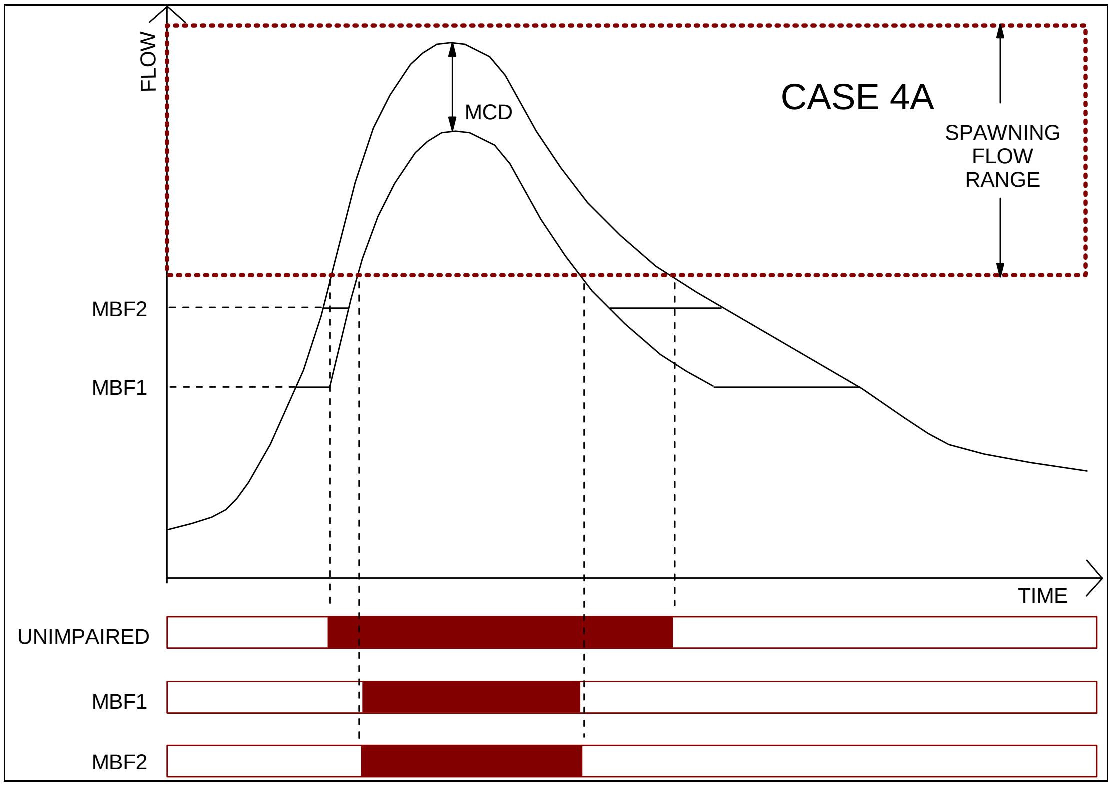

Figure 29. Case 4A: Spawning flows fall above the upper MBF and bracket the peak flow

The differences in spawning habitat availability for the seven spawning flow range cases demonstrate how spawning criteria, corresponding spawning flow ranges, and site-specific habitat-flow characteristics can influence whether an increase in the MBF (i.e., from MBF1 to MBF2) will give rise to an increase, decrease, or have no effect on the duration of spawning habitat availability relative to the unimpaired flow condition.

In a given flow time series, any number of spawning flow range cases may occur for a given site because of variability in flow peaks. The combination of cases can be expected to vary from site to site because of site-specific differences. It is clear from the above that it is difficult to make site-specific conclusions based on regional analysis. This is why regionally protective instream flow criteria must, out of necessity, be conservative when considering the inherent site-specific non-linearity of habitat-flow curves, hydrograph peak magnitude and shape, and flow duration and frequency. Given the conservative nature of the Draft Policy's regional criteria, the Draft Policy also proposes that site specific analysis of habitat conditions in lieu of the regional criteria can be utilized in the analysis of the effects of diversion on instream flows needed for habitat.

For evaluating the results of the passage and spawning habitat availability analysis, a less restrictive MBF was considered to be as protective as a more restrictive MBF if it results in the same number of spawning opportunities as the more restrictive MBF, and the number of passage opportunities is not reduced.

5 Summary and Conclusions

5.1 Minimum suitable spawning depth criterion

The water diversion - passage and spawning habitat sensitivity study used a minimum spawning depth criterion for two distinct purposes: (1) to select data points for the regression lines used to develop MBF alternatives for the sensitivity analysis; and (2) to assess the amount of spawning habitat that is available at a specific location under any given flow condition.

For the first purpose, the minimum depth criterion varied for the MBF alternatives. MBF A1 - A4 were based on a steelhead minimum suitable spawning depth criterion of 0.8 foot. MBF A5 - A8 were based on a steelhead minimum suitable spawning depth criterion of 0.7 foot. MBF A9 was based on a Chinook minimum suitable passage and spawning depth criterion of 1.0 foot. The water diversion - passage and spawning habitat sensitivity study provides an assessment of the volume of water which could potentially be diverted and the change in availability of passage and spawning habitat for each impaired flow alternative (impaired flow for the selected MBF and MCD alternatives).

For the second purpose, the minimum depth criteria did not vary during the passage and spawning habitat availability analysis. Minimum spawning depths of 0.8, 0.8, and 1.0 foot and minimum passage depths of 0.7, 0.6, and 0.9 foot were used for evaluation of steelhead, coho, and Chinook habitat availability, respectively (see Tables 8 & 9). Comparison of the habitat-flow relationships in Appendix A shows the impacts of using different minimum depth criteria for site-specific assessment. If the minimum suitable spawning depth criterion was reduced from 0.8 ft to 0.7 ft, habitat would be considered suitable at lower flows.

5.2 Maximum cumulative diversion

The results of the water diversion analysis (Tables 4 - 7 and Appendix B) show that the MCD has an important effect on the potential diversion volume. Table 11 provides the average potential diversion volume for each MCD alternative expressed as percent of mean annual flow averaged over all validation sites and for validations sites in each range of drainage area (<2 square miles, 2 - 10 square miles, and >10 square miles). Because all the MBF alternatives require a smaller percentage of the mean annual flow as the drainage areas increase, the average potential diversion volume increases with increasing drainage area range.

Table 11. Comparison of Potential Diversion at Validation Sites by MCD Alternative and Drainage Area Range

Alternative	Description	Average Potential Diversion (% mean annual flow)			
		DA < 2 mi^2	DA 2 - 10 mi^2	DA > 10 mi^2	All Sites
MCD A1	1% of 1.5-year peak flow	1.9%	2.2%	3.3%	2.6%
MCD A2	5% of 1.5-year peak flow	6.2%	8.9%	12.8%	9.9%
MCD A3	10% of 1.5-year peak flow	9.0%	14.1%	20.5%	15.6%
MCD A4	12% of 1.5-year peak flow	9.8%	15.7%	22.8%	17.3%
MCD A5	15% of 1.5-year peak flow	10.9%	17.8%	25.7%	19.5%

Notes:
1. Averaged over validation sites in the indicated drainage area (DA) range and all MBF alternatives.
2. DA < 2 mi^2: East Fork Russian River Tributary, Dry Creek Tributary, and Dunn Creek.
3. DA 2 - 10 mi^2: Carneros Creek, Huichica Creek, and Pine Gulch Creek.
4. DA > 10 mi^2: Warm Springs Creek, Santa Rosa Creek, Albion River, Salmon Creek, and Franz Creek.

Table 12 compares the average potential diversion volume expressed as percent of mean annual flow averaged over all validation sites and all MBF alternatives and the predicted channel size reduction (Figure 5) for each MCD alternative.

Table 12. Comparison of Potential Effects of MCD Alternatives at Validation Sites

Alternative	Description	Average Potential Diversion[1] (% mean annual flow)	Channel Size Reduction (% change width, depth, D_{50})
MCD A1	1% of 1.5-year peak flow	2.6%	-0.4%
MCD A2	5% of 1.5-year peak flow	9.9%	-2.0%
MCD A3	10% of 1.5-year peak flow	15.6%	-4.0%
MCD A4	12% of 1.5-year peak flow	17.3%	-4.8%
MCD A5	15% of 1.5-year peak flow	19.5%	-6.0%

[1] Averaged over all eleven validation sites and MBF alternatives.

5.3 Minimum bypass flow

A range of MBF alternatives was assessed in the water diversion - passage and spawning habitat sensitivity study. These alternatives were developed using regional regression lines with the intercept coefficient of the regression line increased by different multiples of the standard error.

The results of the water diversion analysis (Tables 4 - 7 and Appendix B) show that the MBF has an effect on the potential diversion volume. Table 13 provides the average potential diversion volume for each MBF alternative expressed as percent of mean annual flow averaged over all validation sites and for validations sites in each range of drainage area (<2 square miles, 2 - 10 square miles, and >10 square miles). Water can only be diverted from the portion of instream flow that is higher than the MBF. Because all the MBF alternatives require a larger percentage of the mean annual flow as the drainage areas decrease, the MBF criterion most strongly controls the rate of diversion in watersheds with small drainage areas. In these small watersheds, flows exceed the MBF less frequently therefore the MBF controls how often water can be diverted. The MBF has less influence in large drainage areas where flows exceed the MBF more frequently, and diversion volume is controlled by the MCD.

Table 13. Comparison of Potential Diversion at Validation Sites by MBF Alternative and Drainage Area Range

Alternative	Description	Average Potential Diversion (% mean annual flow)			
		DA < 2 mi^2	DA 2 - 10 mi^2	DA > 10 mi^2	All Sites
MBF A1	0.8 ft mean regression line	10.3%	13.7%	19.1%	15.2%
MBF A2	0.8 ft mean regression line + 1 SE	8.2%	12.4%	17.9%	13.7%
MBF A3	0.8 ft mean regression line + 2 SE	6.6%	11.4%	16.7%	12.5%
MBF A4	0.8 ft mean regression line + 3 SE	5.0%	10.0%	15.3%	11.0%
MBF A5	0.7 ft mean regression line	12.1%	14.5%	19.7%	16.2%
MBF A6	0.7 ft regression line + 1 SE	10.3%	13.2%	18.3%	14.7%
MBF A7	0.7 ft regression line + 2 SE	8.2%	11.8%	17.1%	13.2%
MBF A8	0.7 ft regression line + 3 SE	6.3%	10.6%	15.8%	11.8%
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	1.2%	8.0%	13.6%	8.7%

Notes:
1. Averaged over validation sites in the indicated drainage area (DA) range and all MCD alternatives.
2. DA < 2 mi^2: East Fork Russian River Tributary, Dry Creek Tributary, and Dunn Creek.
3. DA 2 - 10 mi^2: Carneros Creek, Huichica Creek, and Pine Gulch Creek.
4. DA > 10 mi^2: Warm Springs Creek, Santa Rosa Creek, Albion River, Salmon Creek, and Franz Creek.

Table 14 provides the average change in passage opportunities from the unimpaired condition for each MBF alternative averaged over all validation sites[5] and for validations sites in each range of drainage area (<2 square miles, 2 - 10 square miles, and >10 square miles). The steelhead and coho passage opportunities were more sensitive to the MBF alternative at the validation sites with drainage areas under 10 square miles but the opposite is true for Chinook passage opportunities which were more sensitive at the validation sites with drainage areas over 10 square miles. MBF A9 (DFG 1.0 ft Chinook passage and spawning regression line + 3SE) provides the same passage opportunities as the unimpaired condition.

Table 15 provides the qualitative change in spawning opportunities for each MBF alternative relative to the number of opportunities for MBF A4 (Draft Policy regional criteria) assessed at all validation sites and for validations sites in each range of drainage area (0-2 square miles, 2-10 square miles, and >10 square miles). It would not have been meaningful to calculate the average change in spawning opportunities because the values are highly variable and, in some cases, there are both positive and negative percent changes that would be lost in the averaging process.

As discussed in Section 4.3, comparisons of the effects of different MBF alternatives on the availability of spawning habitat is complicated because the spawning criteria (stated in terms of both depth and velocity) describe a range of acceptable spawning flows rather than a simple threshold. The results of the spawning habitat analysis varied considerably from site to site. Spawning transects were selected at locations with suitable spawning habitat[6].

[5] Either one or two passage transects were surveyed at each of the validation sites. At the validation sites where two transects were surveyed, results are given for the limiting transect, i.e. the transect that had the fewest passage and spawning opportunities.

[6] Spawning habitat was present at all of the validation sites and two spawning transects were surveyed at most validation sites. Only one spawning transect was surveyed at Dry Creek Tributary and Huichica Creek and no spawning transects were surveyed at East Fork Russian River Tributary due to limited access to the stream.

Table 16 summarizes the potential effects of the MBF alternatives. The average potential diversion volume for each MBF is given as the percent of mean annual flow averaged over all validation sites and all MCD alternatives. The results of the passage and spawning habitat availability analysis are summarized for each MBF alternative (in combination with MCD A2). Average change in passage opportunities is given in terms of percent change from opportunities under unimpaired flow condition (Figure 18) and the qualitative change in steelhead spawning opportunities is given relative to MBF A4.

Table 14. Comparison of Passage Opportunities at Validation Sites by MBF Alternative and Drainage Area Range

Alternative	Description	Drainage Area Range			
		DA < 2 mi^2	DA 2 - 10 mi^2	DA > 10 mi^2	All Sites
		Steelhead Passage Opportunities (% unimpaired)			
MBF A4	0.8 ft mean regression line + 3 SE	-7%	-14%	0%	-6%
MBF A5	0.7 ft mean regression line	-13%	-27%	-9%	-15%
MBF A6	0.7 ft regression line + 1 SE	-13%	-27%	0%	-11%
MBF A7	0.7 ft regression line + 2 SE	-7%	-14%	0%	-6%
MBF A8	0.7 ft regression line + 3 SE	-7%	-14%	0%	-6%
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	0%	0%	0%	0%
		Coho Passage Opportunities (% unimpaired)			
MBF A4	0.8 ft mean regression line + 3 SE	-22%	0%	0%	-6%
MBF A5	0.7 ft mean regression line	-33%	-14%	0%	-13%
MBF A6	0.7 ft regression line + 1 SE	-33%	-14%	0%	-13%
MBF A7	0.7 ft regression line + 2 SE	-33%	0%	0%	-9%
MBF A8	0.7 ft regression line + 3 SE	-22%	0%	0%	-6%
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	0%	0%	0%	0%
		Chinook Passage Opportunities (% unimpaired)			
MBF A4	0.8 ft mean regression line + 3 SE	-17%	-5%	0%	-6%
MBF A5	0.7 ft mean regression line	-17%	-5%	-17%	-13%
MBF A6	0.7 ft regression line + 1 SE	-17%	-5%	-17%	-13%
MBF A7	0.7 ft regression line + 2 SE	-17%	-5%	-17%	-13%
MBF A8	0.7 ft regression line + 3 SE	-17%	-5%	-6%	-8%
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	0%	0%	0%	0%

Notes:

1. Assessed in combination with MCD A2 and averaged over all validation sites in the indicated drainage area range.
2. DA < 2 mi^2: East Fork Russian River Tributary, Dry Creek Tributary, and Dunn Creek.
3. DA 2 - 10 mi^2: Carneros Creek, Huichica Creek, and Pine Gulch Creek.
4. DA > 10 mi^2: Warm Springs Creek, Santa Rosa Creek, Albion River, Salmon Creek, and Franz Creek.

Table 15. Comparison of Spawning Opportunities at Validation Sites by MBF Alternative and Drainage Area Range

Alternative	Description	Drainage Area Range			
		DA < 2 mi²	DA 2 - 10 mi²	DA > 10 mi²	All Sites
		Steelhead Spawning Opportunities (relative to MBF A4)			
MBF A5	0.7 ft mean regression line	reduced	increased	reduced	reduced
MBF A6	0.7 ft regression line + 1 SE	reduced	increased	reduced	reduced
MBF A7	0.7 ft regression line + 2 SE	reduced	increased	reduced	reduced
MBF A8	0.7 ft regression line + 3 SE	similar	similar	similar	similar
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	reduced	increased	reduced	increased
		Coho Spawning Opportunities (% unimpaired)			
MBF A5	0.7 ft mean regression line	reduced	similar	similar	reduced
MBF A6	0.7 ft regression line + 1 SE	reduced	similar	similar	reduced
MBF A7	0.7 ft regression line + 2 SE	reduced	similar	similar	reduced
MBF A8	0.7 ft regression line + 3 SE	increased	similar	similar	similar
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	reduced	increased	reduced	similar
		Chinook Spawning Opportunities (% unimpaired)			
MBF A5	0.7 ft mean regression line	similar	similar	reduced	reduced
MBF A6	0.7 ft regression line + 1 SE	similar	similar	similar	similar
MBF A7	0.7 ft regression line + 2 SE	similar	similar	similar	similar
MBF A8	0.7 ft regression line + 3 SE	similar	similar	similar	similar
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	increased	similar	reduced	similar

Notes:
1. Assessed in combination with MCD A2 and compared at validation sites in the indicated drainage area range.
2. DA < 2 mi^2: East Fork Russian River Tributary, Dry Creek Tributary, and Dunn Creek.
3. DA 2 - 10 mi^2: Carneros Creek, Huichica Creek, and Pine Gulch Creek.
4. DA > 10 mi^2: Warm Springs Creek, Santa Rosa Creek, Albion River, Salmon Creek, and Franz Creek.

Table 16. Comparison of Potential Effects of MBF Alternatives at Validation Sites

Alternative	Description	Average Potential Diversion[1] (% mean annual flow)	Steelhead Passage Opportunities[2] (% unimpaired)	Steelhead Spawning Opportunities[3] (relative to MBF A4)
MBF A1	0.8 ft mean regression line	15.2%	not analyzed	not analyzed
MBF A2	0.8 ft mean regression line + 1 SE	13.7%	not analyzed	not analyzed
MBF A3	0.8 ft mean regression line + 2 SE	12.5%	not analyzed	not analyzed
MBF A4	0.8 ft mean regression line + 3 SE	11.0%	-6%	baseline
MBF A5	0.7 ft mean regression line	16.2%	-15%	reduced
MBF A6	0.7 ft regression line + 1 SE	14.7%	-11%	reduced
MBF A7	0.7 ft regression line + 2 SE	13.2%	-6%	reduced
MBF A8	0.7 ft regression line + 3 SE	11.8%	-6%	similar
MBF A9	DFG 1.0 ft Chinook passage and spawning regression line + 3SE	8.7%	0%	increased

[1] Averaged over all eleven validation sites and MCD alternatives.
[2] Assessed in combination with MCD A2 and averaged over all validation sites.
[3] Assessed in combination with MCD A2 and compared at all validation sites.

The results depicted of the passage and spawning habitat availability analysis suggest that:

- MBF A4 and MBF A8 result in similar passage and spawning opportunities;
- MBF A5 & MBF A6 reduce steelhead passage opportunities in some of the validation streams compared with MBF A4;
- MBF A5, A6, and A7 reduce steelhead spawning opportunities in some of the validation streams compared with MBF A4; and
- in most cases, MBF A9 results in steelhead passage and spawning opportunities similar to unimpaired flow conditions.

Comparison of the results of the passage and spawning habitat availability analysis for MBF A4 (0.8 ft mean regression line + 3 SE) and MBF A8 (0.7 ft mean regression line + 3 SE) shows that there is almost no change in the number of days of passage and spawning opportunities between these two alternatives. MBF A8 (0.7 ft mean regression line + 3 SE) likely provides a comparable level of protection as MBF A4 (0.8 ft mean regression line + 3 SE) for the same diversion season and MCD.

Comparison of the results of the passage and spawning habitat availability analysis for MBF A5 (0.7 ft mean regression line), MBF A6 (0.7 ft mean regression line + 3 SE), MBF A7 (0.7 ft mean regression line + 3 SE) and MBF A8 (0.7 ft mean regression line + 3 SE) shows that the number of passage and spawning opportunities would be reduced in some streams if the MBF is based on the regression line with a lower intercept coefficient (i.e., without the addition of 3 standard errors).

In conclusion, the passage and spawning habitat availability analysis results suggest that MBF A8 (0.7 ft regression line plus 3 standard errors) would provide a similar level of steelhead passage and spawning opportunities and slightly higher potential diversion volume (0.8%) as compared to MBF A4 (Draft Policy regionally protective MBF).

Use of MBF A5 (0.7 ft mean regression line), MBF A6 (0.7 ft mean regression line + 3 SE), and MBF A7 (0.7 ft mean regression line + 3 SE) as the regional MBF criterion would potentially allow for more diversion, particularly in smaller watersheds, but would also reduce the number of passage and spawning opportunities at some locations.

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APPENDIX A. Steelhead Spawning Habitat-Flow Relationships

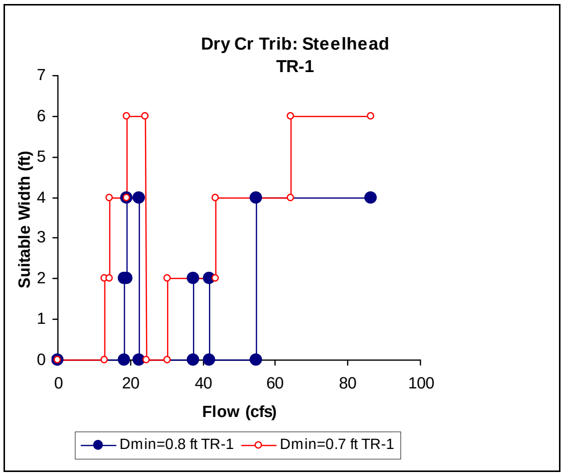

Figure A-1. Habitat-flow curves for the spawning transect sampled in Dry Creek Tributary (drainage area = 1.19 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

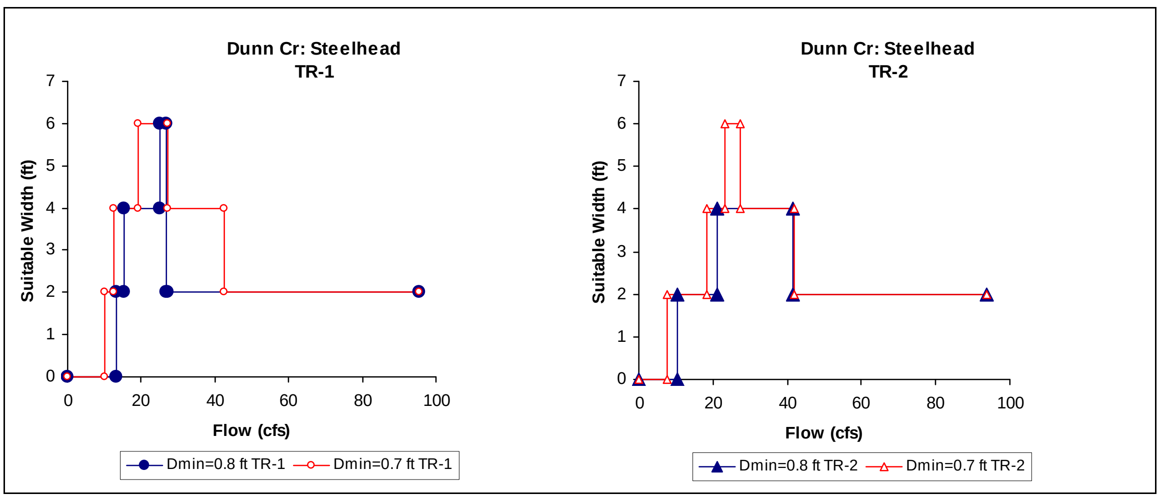

Figure A-2. Habitat-flow curves for the spawning transects sampled in Dunn Creek (drainage area = 1.88 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

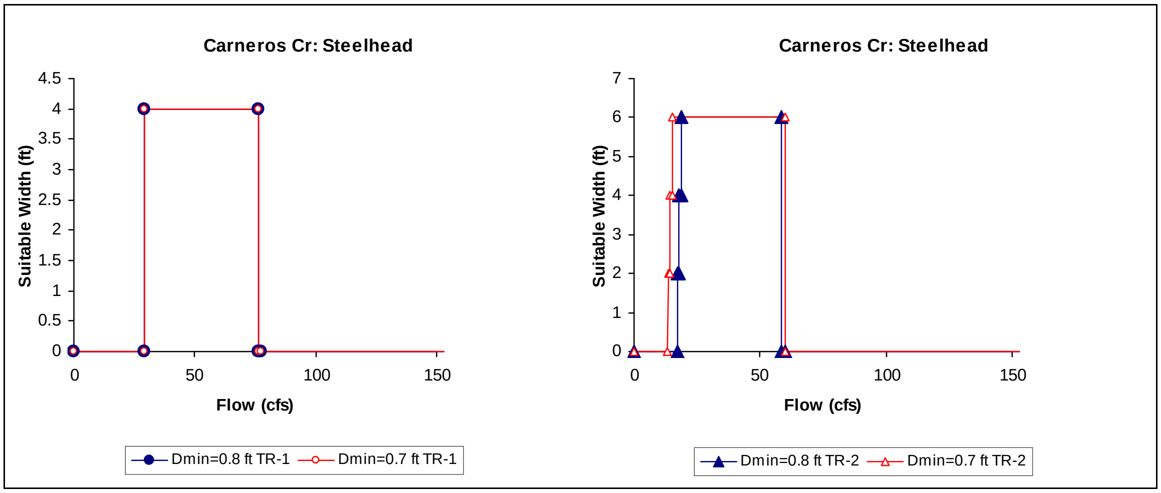

Figure A-3. Habitat-flow curves for the spawning transects sampled in Carneros Creek (drainage area = 2.75 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

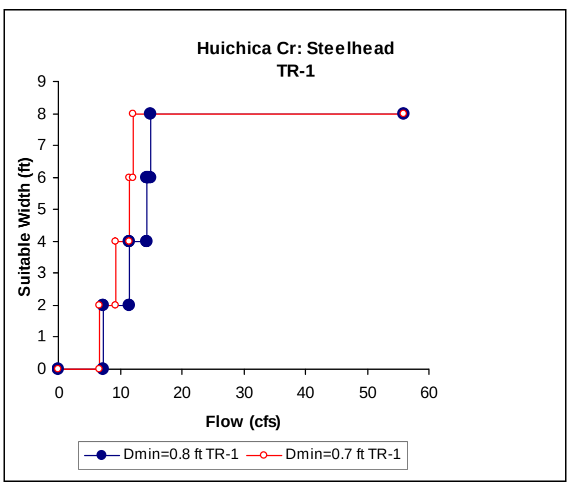

Figure A-4. Habitat-flow curves for the spawning transect sampled in Huichica Creek (drainage area = 4.92 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

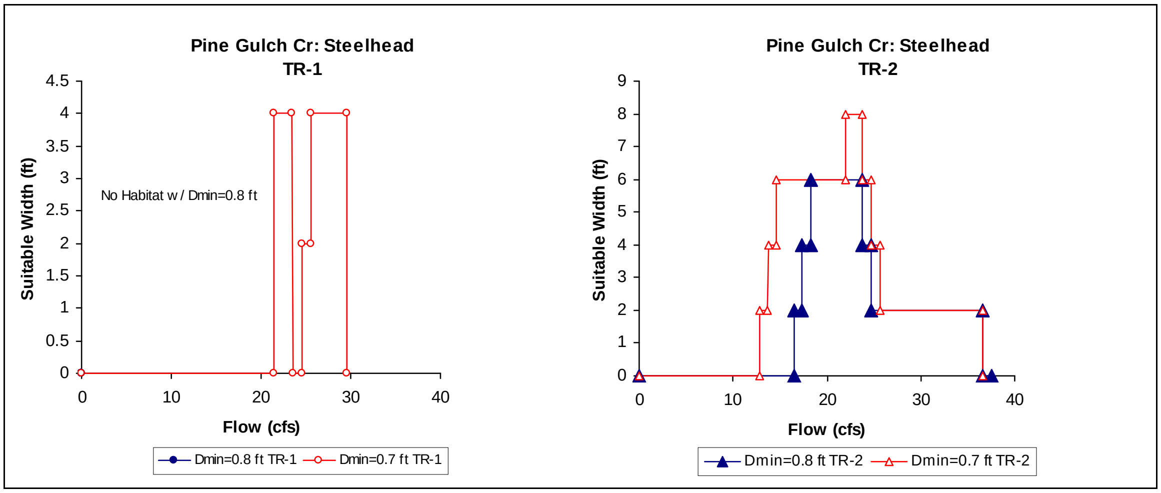

Figure A-5. Habitat-flow curves for the spawning transects sampled in Pine Gulch Creek (drainage area = 7.83 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

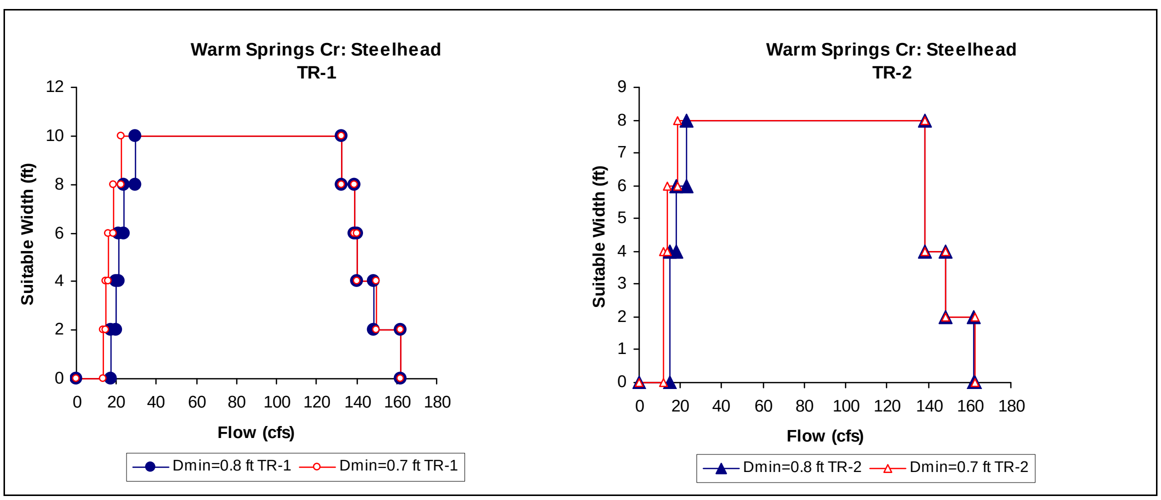

Figure A-6. Habitat-flow curves for the spawning transects sampled in Warm Springs Creek (drainage area = 12.2 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

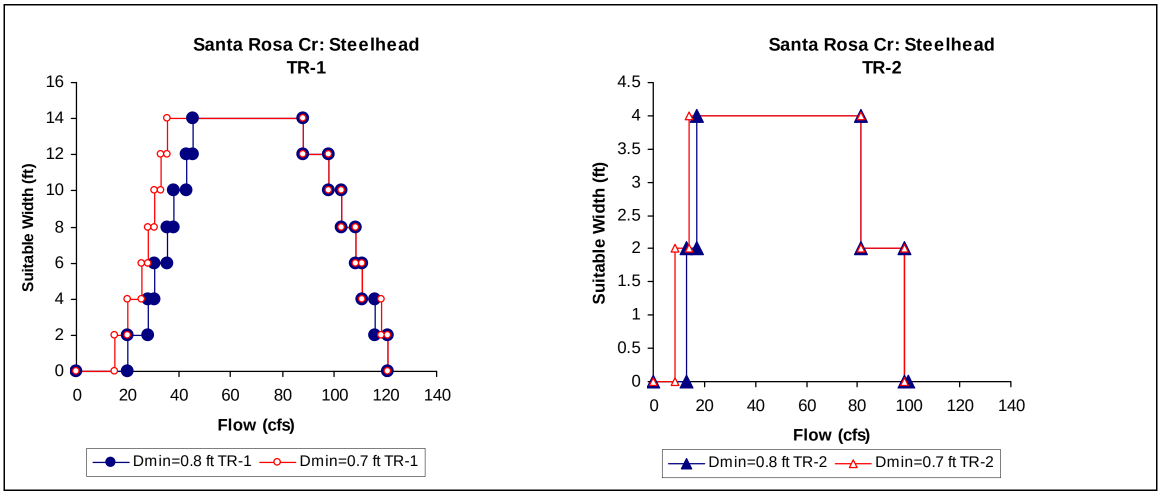

Figure A-7. Habitat-flow curves for the spawning transects sampled in Santa Rosa Creek (drainage area = 12.5 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

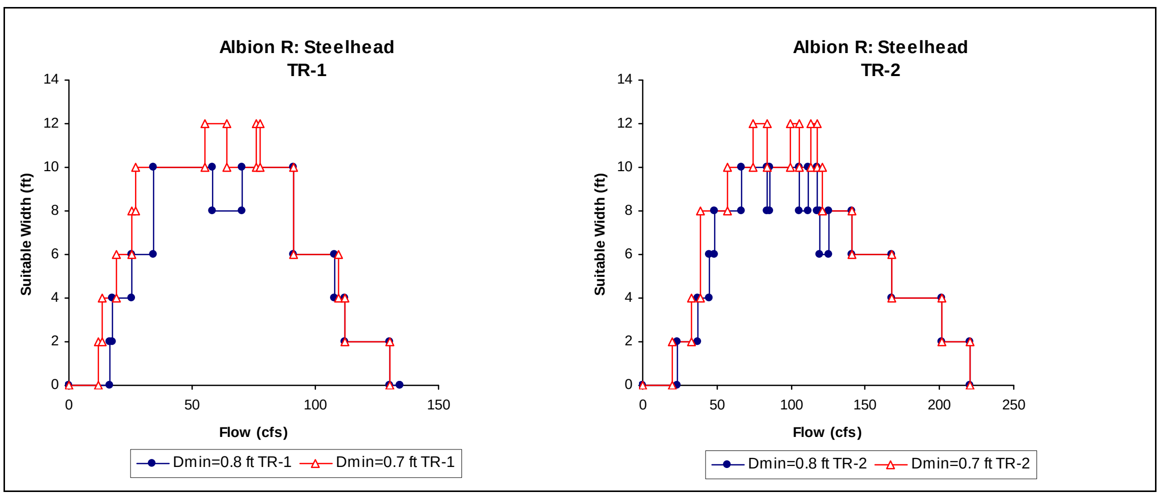

Figure A-8. Habitat-flow curves for the spawning transects sampled in Albion River (drainage area = 14.4 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

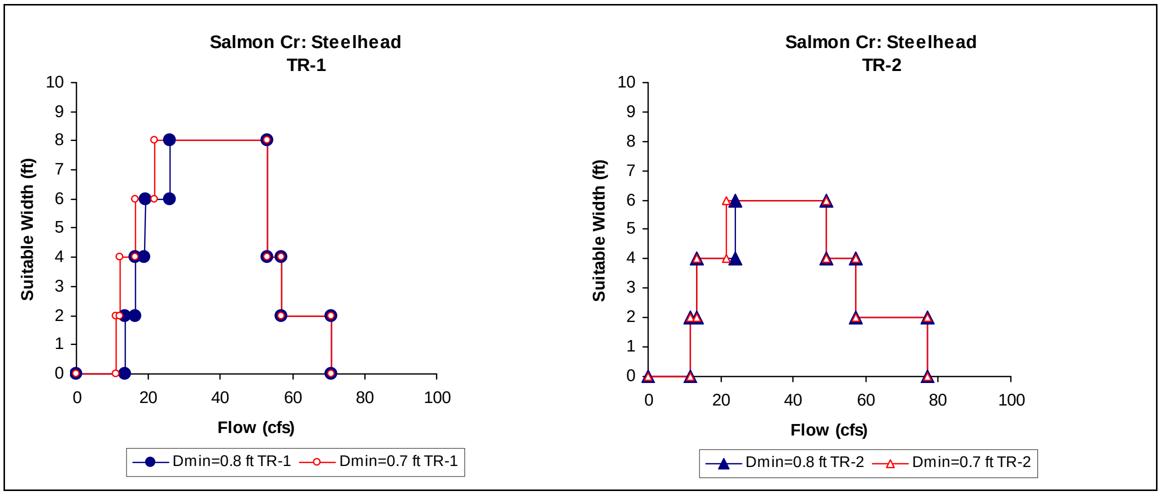

Figure A-9. Habitat-flow curves for the spawning transects sampled in Salmon Creek (drainage area = 15.7 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

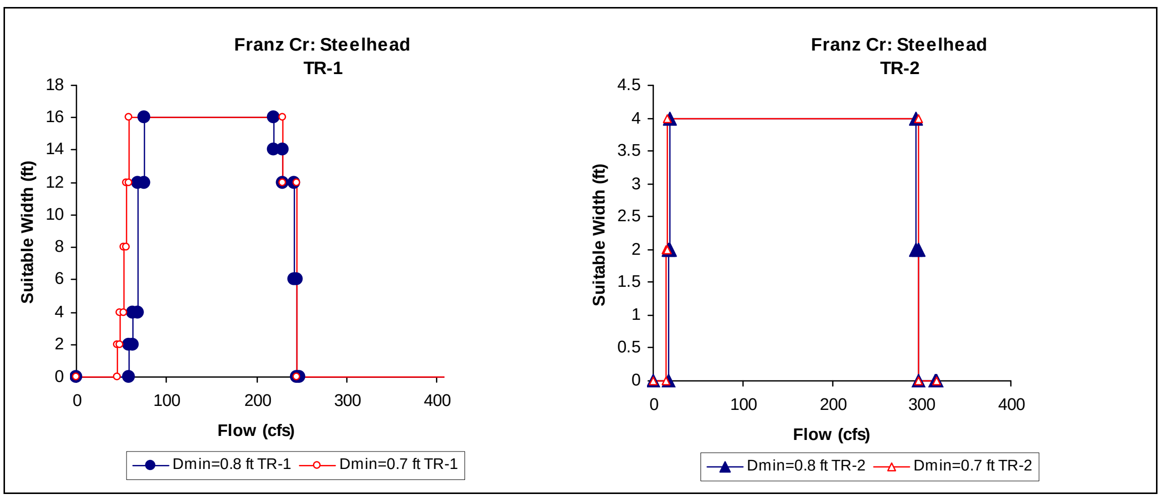

Figure A-10. Habitat-flow curves for the spawning transects sampled in Franz Creek (drainage area = 15.7 mi^2) using a 0.7 ft and 0.8 ft minimum depth criterion

APPENDIX B. Water Diversion Analysis Results

Table B.1 East Fork Russian River Tributary
(drainage area = 0.25 square miles, mean annual unimpaired flow = 92 acre-feet/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	5	13	16	16	17	5.4%	14.1%	17.4%	17.4%	18.5%
MBF A2	3	9	11	12	13	3.3%	9.8%	12.0%	13.0%	14.1%
MBF A3	3	6	8	9	9	3.3%	6.5%	8.7%	9.8%	9.8%
MBF A4	2	4	6	7	7	2.2%	4.3%	6.5%	7.6%	7.6%
MBF A5	5	16	19	19	20	5.4%	17.4%	20.7%	20.7%	21.7%
MBF A6	5	13	16	16	17	5.4%	14.1%	17.4%	17.4%	18.5%
MBF A7	3	9	11	12	13	3.3%	9.8%	12.0%	13.0%	14.1%
MBF A8	3	6	8	9	9	3.3%	6.5%	8.7%	9.8%	9.8%
MBF A9	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%	0.0%

Table B.2 Dry Creek Tributary
(drainage area = 1.19 square miles; mean annual unimpaired flow = 1,561 acre-feet/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	35	156	254	282	330	2.2%	10.0%	16.3%	18.1%	21.1%
MBF A2	32	135	219	245	287	2.0%	8.6%	14.0%	15.7%	18.4%
MBF A3	28	113	188	211	245	1.8%	7.2%	12.0%	13.5%	15.7%
MBF A4	21	86	152	169	196	1.3%	5.5%	9.7%	10.8%	12.6%
MBF A5	40	176	295	324	378	2.6%	11.3%	18.9%	20.8%	24.2%
MBF A6	35	156	254	282	330	2.2%	10.0%	16.3%	18.1%	21.1%
MBF A7	32	135	219	245	287	2.0%	8.6%	14.0%	15.7%	18.4%
MBF A8	25	102	175	195	226	1.6%	6.5%	11.2%	12.5%	14.5%
MBF A9	8	32	56	63	76	0.5%	2.0%	3.6%	4.0%	4.9%

Table B.3. Dunn Creek
(drainage area = 1.88 square miles, mean annual unimpaired flow = 1,821 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					**Percentage of Mean Annual Flow Volume Potentially Available for Diversion**				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	8	36	62	68	74	0.4%	2.0%	3.4%	3.7%	4.1%
MBF A2	7	34	57	61	67	0.4%	1.9%	3.1%	3.3%	3.7%
MBF A3	7	32	47	50	55	0.4%	1.8%	2.6%	2.7%	3.0%
MBF A4	6	21	31	33	37	0.3%	1.2%	1.7%	1.8%	2.0%
MBF A5	11	45	78	85	94	0.6%	2.5%	4.3%	4.7%	5.2%
MBF A6	8	36	62	68	74	0.4%	2.0%	3.4%	3.7%	4.1%
MBF A7	7	34	52	56	61	0.4%	1.9%	2.9%	3.1%	3.3%
MBF A8	7	29	42	45	49	0.4%	1.6%	2.3%	2.5%	2.7%
MBF A9	1	6	12	15	17	0.1%	0.3%	0.7%	0.8%	0.9%

Table B.4. Carneros Creek
(drainage area = 2.75 square miles, mean annual unimpaired flow = 2,732 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					**Percentage of Mean Annual Flow Volume Potentially Available for Diversion**				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	66	255	385	428	479	2.4%	9.3%	14.1%	15.7%	17.5%
MBF A2	59	229	350	391	437	2.2%	8.4%	12.8%	14.3%	16.0%
MBF A3	51	205	319	356	398	1.9%	7.5%	11.7%	13.0%	14.6%
MBF A4	40	167	272	300	337	1.5%	6.1%	10.0%	11.0%	12.3%
MBF A5	73	286	426	471	528	2.7%	10.5%	15.6%	17.2%	19.3%
MBF A6	66	255	385	428	479	2.4%	9.3%	14.1%	15.7%	17.5%
MBF A7	55	216	334	373	416	2.0%	7.9%	12.2%	13.7%	15.2%
MBF A8	45	184	294	326	365	1.6%	6.7%	10.8%	11.9%	13.4%
MBF A9	25	117	181	201	233	0.9%	4.3%	6.6%	7.4%	8.5%

Table B.5. Huichica Creek
(drainage area = 4.92 square miles, mean annual unimpaired flow = 5,341 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	87	348	573	634	729	1.6%	6.5%	10.7%	11.9%	13.6%
MBF A2	68	290	483	538	625	1.3%	5.4%	9.0%	10.1%	11.7%
MBF A3	60	260	434	487	569	1.1%	4.9%	8.1%	9.1%	10.7%
MBF A4	51	216	368	415	488	1.0%	4.0%	6.9%	7.8%	9.1%
MBF A5	91	365	599	661	759	1.7%	6.8%	11.2%	12.4%	14.2%
MBF A6	78	315	524	581	672	1.5%	5.9%	9.8%	10.9%	12.6%
MBF A7	62	269	449	503	586	1.2%	5.0%	8.4%	9.4%	11.0%
MBF A8	54	234	394	442	518	1.0%	4.4%	7.4%	8.3%	9.7%
MBF A9	34	152	272	309	374	0.6%	2.8%	5.1%	5.8%	7.0%

Table B.6. Pine Gulch Creek
(drainage area = 7.83 square miles, mean annual unimpaired flow = 8,966 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	377	1,409	2,183	2,434	2,740	4.2%	15.7%	24.3%	27.1%	30.6%
MBF A2	339	1,296	2,035	2,282	2,572	3.8%	14.5%	22.7%	25.5%	28.7%
MBF A3	304	1,178	1,881	2,115	2,389	3.4%	13.1%	21.0%	23.6%	26.6%
MBF A4	265	1,063	1,727	1,947	2,198	3.0%	11.9%	19.3%	21.7%	24.5%
MBF A5	397	1,473	2,266	2,518	2,833	4.4%	16.4%	25.3%	28.1%	31.6%
MBF A6	356	1,349	2,106	2,354	2,652	4.0%	15.0%	23.5%	26.3%	29.6%
MBF A7	316	1,221	1,938	2,178	2,459	3.5%	13.6%	21.6%	24.3%	27.4%
MBF A8	284	1,117	1,801	2,029	2,290	3.2%	12.5%	20.1%	22.6%	25.5%
MBF A9	225	931	1,541	1,735	1,970	2.5%	10.4%	17.2%	19.4%	22.0%

Table B.7. Warm Springs Creek
(drainage area = 12.2 square miles, mean annual unimpaired flow = 25,168 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	608	2,633	4,537	5,118	5,883	2.4%	10.5%	18.0%	20.3%	23.4%
MBF A2	546	2,432	4,187	4,727	5,444	2.2%	9.7%	16.6%	18.8%	21.6%
MBF A3	509	2,251	3,852	4,353	5,022	2.0%	8.9%	15.3%	17.3%	20.0%
MBF A4	455	2,012	3,429	3,884	4,486	1.8%	8.0%	13.6%	15.4%	17.8%
MBF A5	648	2,754	4,735	5,338	6,130	2.6%	10.9%	18.8%	21.2%	24.4%
MBF A6	572	2,524	4,353	4,914	5,654	2.3%	10.0%	17.3%	19.5%	22.5%
MBF A7	521	2,316	3,971	4,486	5,172	2.1%	9.2%	15.8%	17.8%	20.5%
MBF A8	476	2,106	3,591	4,065	4,691	1.9%	8.4%	14.3%	16.2%	18.6%
MBF A9	400	1,740	2,990	3,391	3,935	1.6%	6.9%	11.9%	13.5%	15.6%

Table B.8. Santa Rosa Creek
(drainage area = 12.5 square miles, mean annual unimpaired flow = 13,867 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	654	2,321	3,528	3,895	4,339	4.7%	16.7%	25.4%	28.1%	31.3%
MBF A2	600	2,160	3,323	3,676	4,106	4.3%	15.6%	24.0%	26.5%	29.6%
MBF A3	542	1,994	3,105	3,438	3,857	3.9%	14.4%	22.4%	24.8%	27.8%
MBF A4	478	1,807	2,856	3,162	3,570	3.4%	13.0%	20.6%	22.8%	25.7%
MBF A5	693	2,430	3,666	4,039	4,494	5.0%	17.5%	26.4%	29.1%	32.4%
MBF A6	620	2,222	3,401	3,761	4,195	4.5%	16.0%	24.5%	27.1%	30.3%
MBF A7	560	2,046	3,174	3,514	3,936	4.0%	14.8%	22.9%	25.3%	28.4%
MBF A8	501	1,872	2,943	3,260	3,672	3.6%	13.5%	21.2%	23.5%	26.5%
MBF A9	411	1,610	2,596	2,874	3,264	3.0%	11.6%	18.7%	20.7%	23.5%

Table B.9. Albion River
(drainage area = 14.4 square miles, mean annual unimpaired flow = 14,489 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	481	2,006	3,275	3,642	4,088	3.3%	13.8%	22.6%	25.1%	28.2%
MBF A2	445	1,855	3,038	3,376	3,804	3.1%	12.8%	21.0%	23.3%	26.3%
MBF A3	420	1,743	2,853	3,174	3,591	2.9%	12.0%	19.7%	21.9%	24.8%
MBF A4	373	1,575	2,578	2,880	3,274	2.6%	10.9%	17.8%	19.9%	22.6%
MBF A5	497	2,059	3,360	3,738	4,190	3.4%	14.2%	23.2%	25.8%	28.9%
MBF A6	460	1,926	3,154	3,504	3,941	3.2%	13.3%	21.8%	24.2%	27.2%
MBF A7	431	1,787	2,927	3,253	3,675	3.0%	12.3%	20.2%	22.5%	25.4%
MBF A8	389	1,635	2,677	2,986	3,389	2.7%	11.3%	18.5%	20.6%	23.4%
MBF A9	330	1,384	2,261	2,543	2,903	2.3%	9.6%	15.6%	17.6%	20.0%

Table B.10. Salmon Creek
(drainage area = 15.7 square miles, mean annual unimpaired flow = 17,912 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					Percentage of Mean Annual Flow Volume Potentially Available for Diversion				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	842	3,144	4,955	5,522	6,206	4.7%	17.6%	27.7%	30.8%	34.6%
MBF A2	774	2,942	4,702	5,248	5,909	4.3%	16.4%	26.3%	29.3%	33.0%
MBF A3	720	2,745	4,444	4,971	5,607	4.0%	15.3%	24.8%	27.8%	31.3%
MBF A4	657	2,507	4,116	4,616	5,221	3.7%	14.0%	23.0%	25.8%	29.1%
MBF A5	881	3,254	5,092	5,671	6,366	4.9%	18.2%	28.4%	31.7%	35.5%
MBF A6	794	3,006	4,783	5,336	6,005	4.4%	16.8%	26.7%	29.8%	33.5%
MBF A7	734	2,798	4,515	5,047	5,690	4.1%	15.6%	25.2%	28.2%	31.8%
MBF A8	683	2,599	4,243	4,755	5,371	3.8%	14.5%	23.7%	26.5%	30.0%
MBF A9	567	2,244	3,744	4,206	4,779	3.2%	12.5%	20.9%	23.5%	26.7%

Table B.11. Franz Creek
(drainage area = 15.7 square miles, mean annual unimpaired flow = 17,450 ac-ft/year)

	Average Potentially Available Diversion Volume (ac-ft/diversion season)					**Percentage of Mean Annual Flow Volume Potentially Available for Diversion**				
	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5	MCD A1	MCD A2	MCD A3	MCD A4	MCD A5
MBF A1	615	2,439	3,695	4,041	4,464	3.5%	14.0%	21.2%	23.2%	25.6%
MBF A2	570	2,279	3,463	3,800	4,201	3.3%	13.1%	19.8%	21.8%	24.1%
MBF A3	529	2,113	3,219	3,545	3,922	3.0%	12.1%	18.4%	20.3%	22.5%
MBF A4	479	1,917	2,937	3,246	3,595	2.7%	11.0%	16.8%	18.6%	20.6%
MBF A5	631	2,495	3,777	4,127	4,557	3.6%	14.3%	21.6%	23.7%	26.1%
MBF A6	584	2,331	3,538	3,877	4,286	3.3%	13.4%	20.3%	22.2%	24.6%
MBF A7	540	2,159	3,286	3,616	3,999	3.1%	12.4%	18.8%	20.7%	22.9%
MBF A8	496	1,980	3,028	3,343	3,703	2.8%	11.3%	17.4%	19.2%	21.2%
MBF A9	412	1,664	2,590	2,865	3,176	2.4%	9.5%	14.8%	16.4%	18.2%

APPENDIX C. Passage and Spawning Habitat Availability Analysis Results

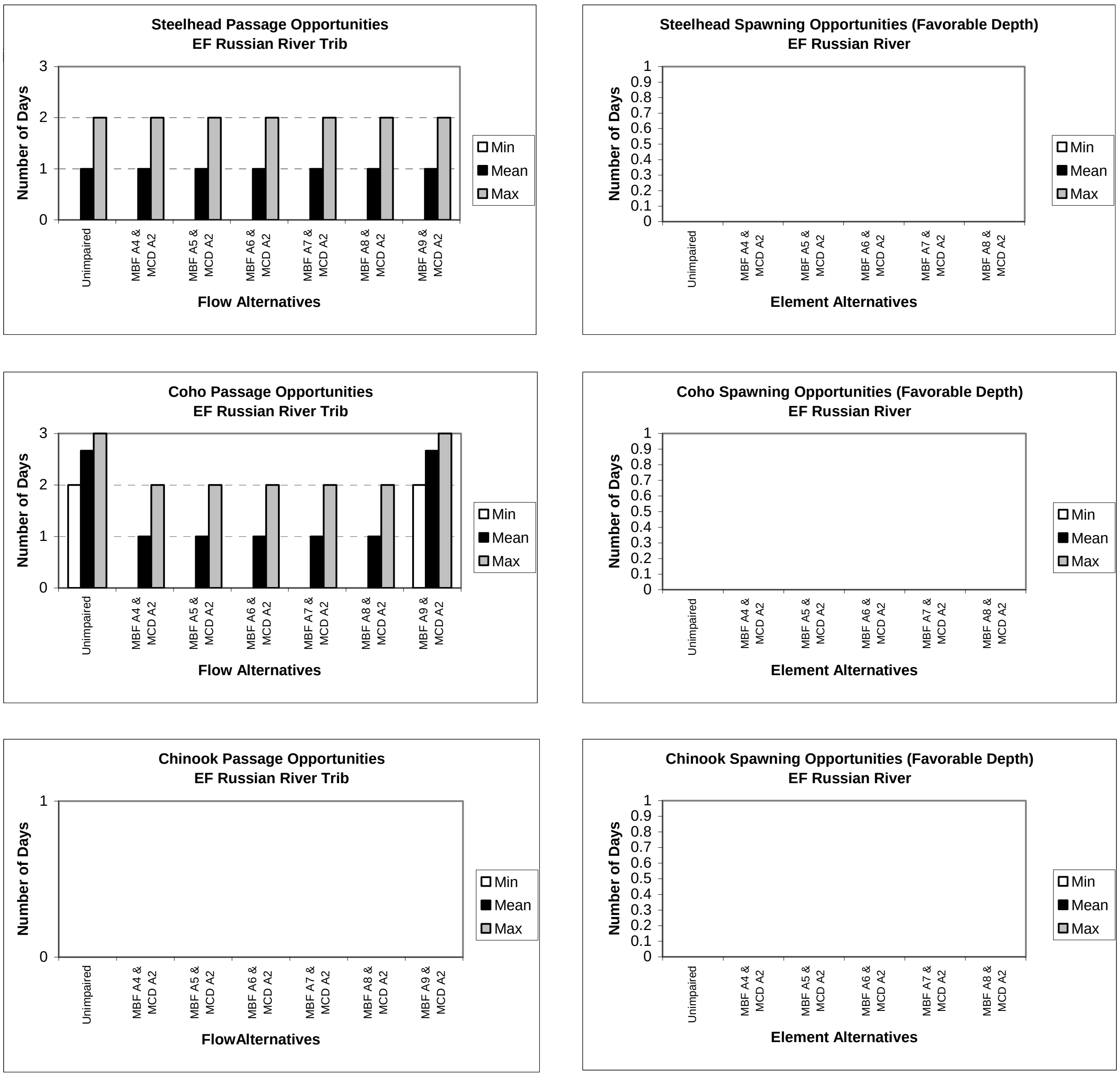

Figure C-1. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in East Fork Russian River Tributary (drainage area = 0.25 mi^2) expressed as minimum, mean and maximum number of days per water year

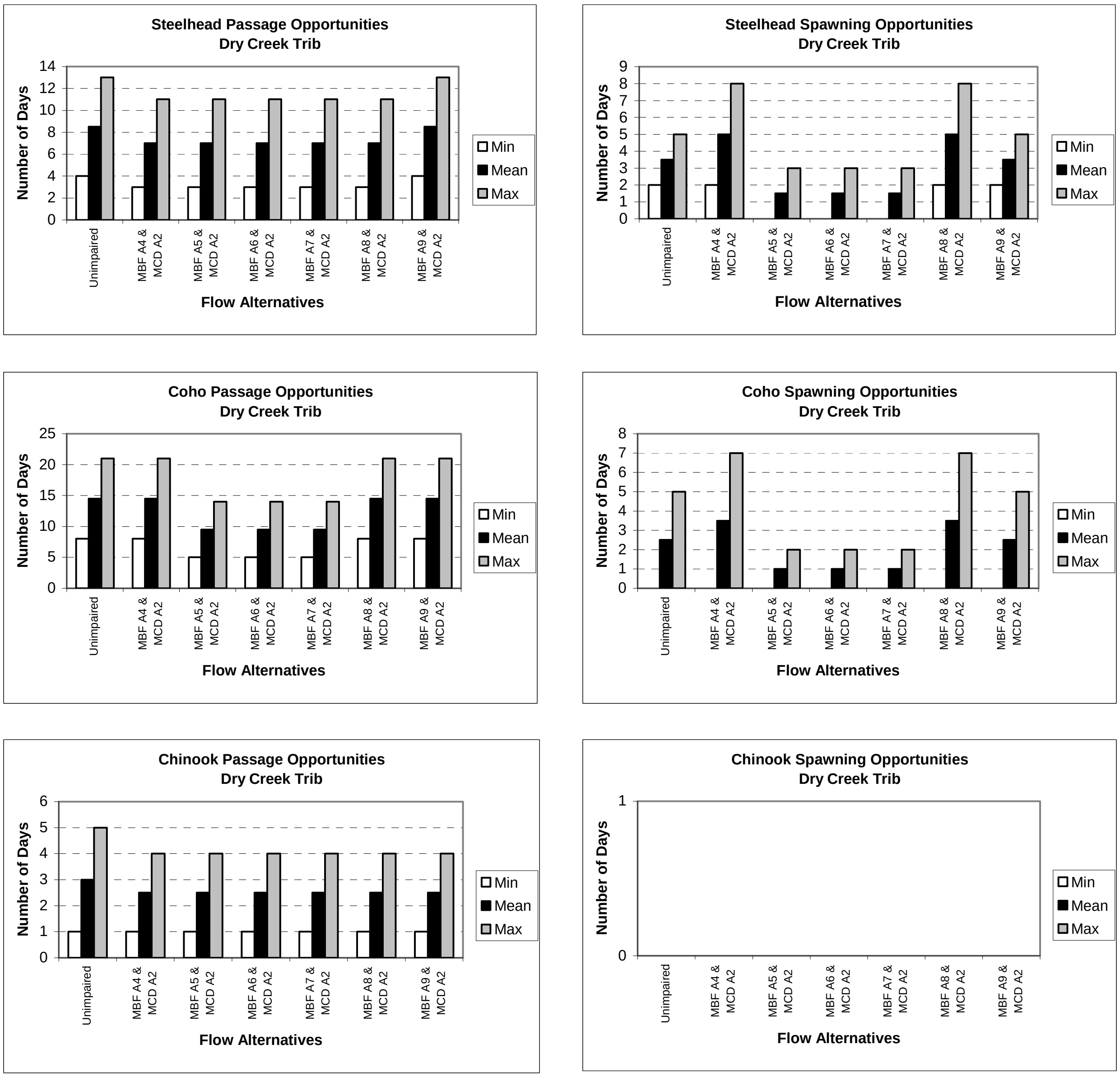

Figure C-2. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in Dry Creek (drainage area = 1.19 mi^2) expressed as minimum, mean and maximum number of days per water year

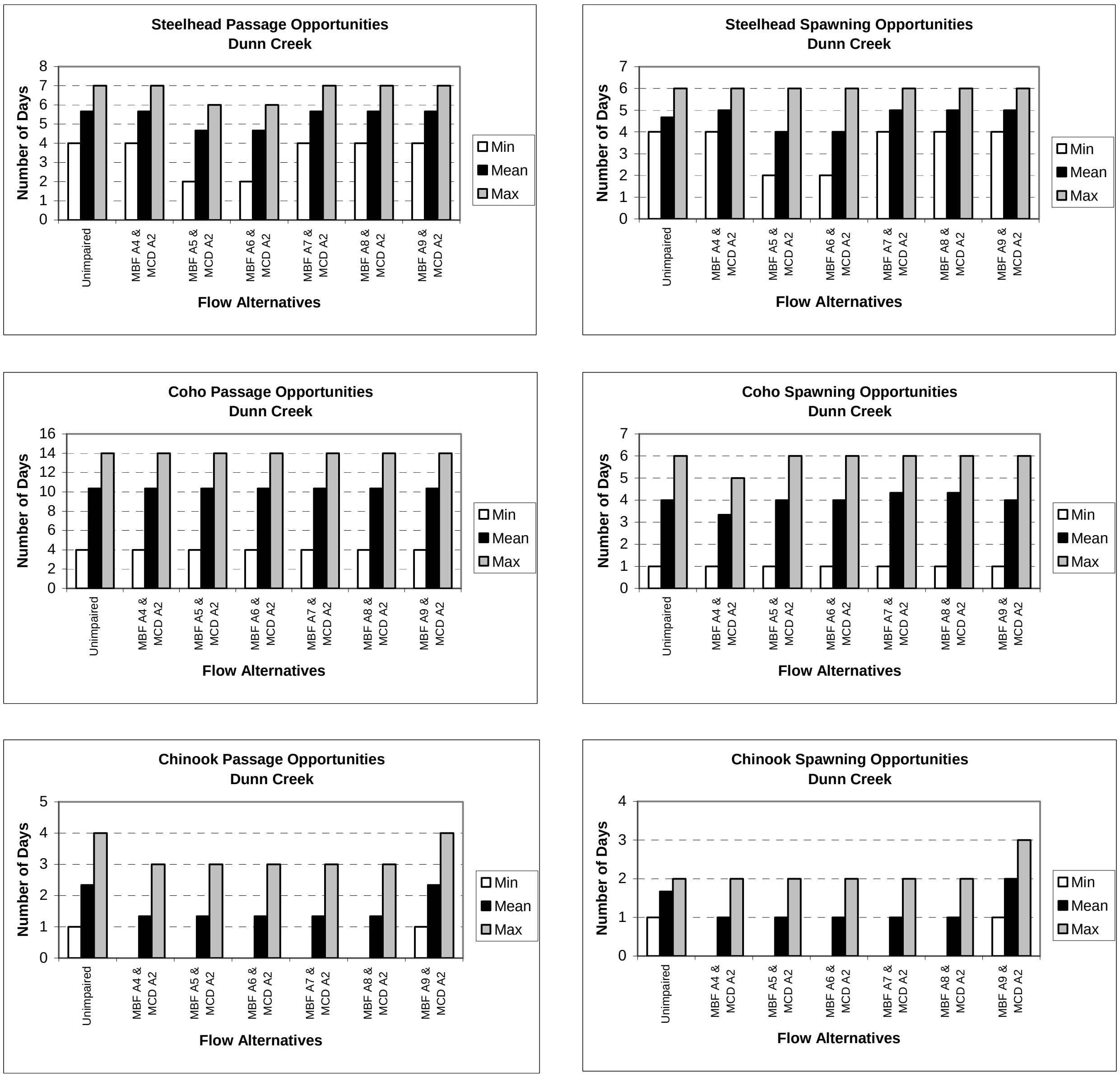

Figure C-3. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in Dunn Creek (drainage area = 1.88 mi^2) expressed as minimum, mean and maximum number of days per water year

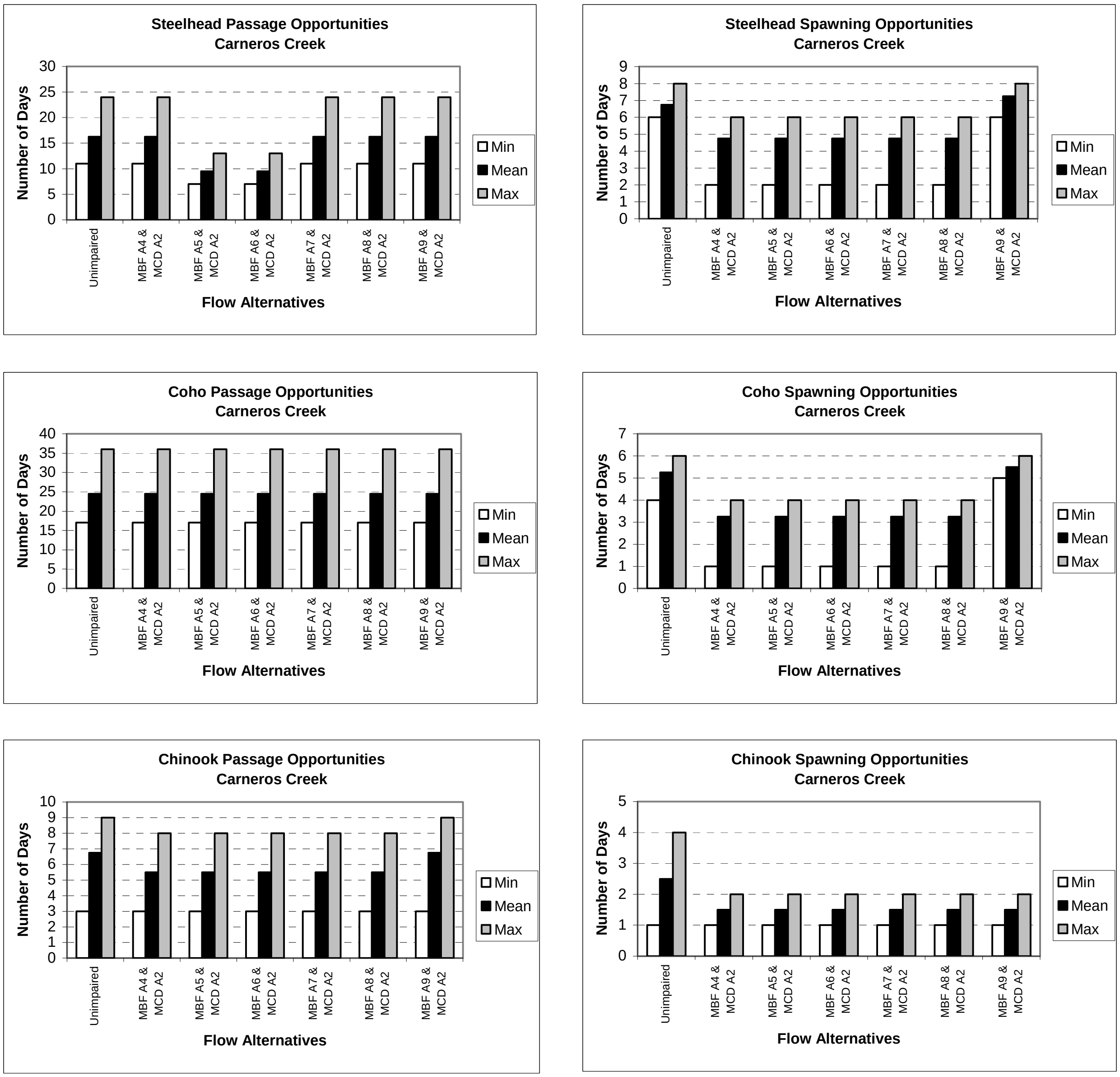

Figure C-4. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in Carneros Creek (drainage area = 2.75 mi^2) expressed as minimum, mean and maximum number of days per water year

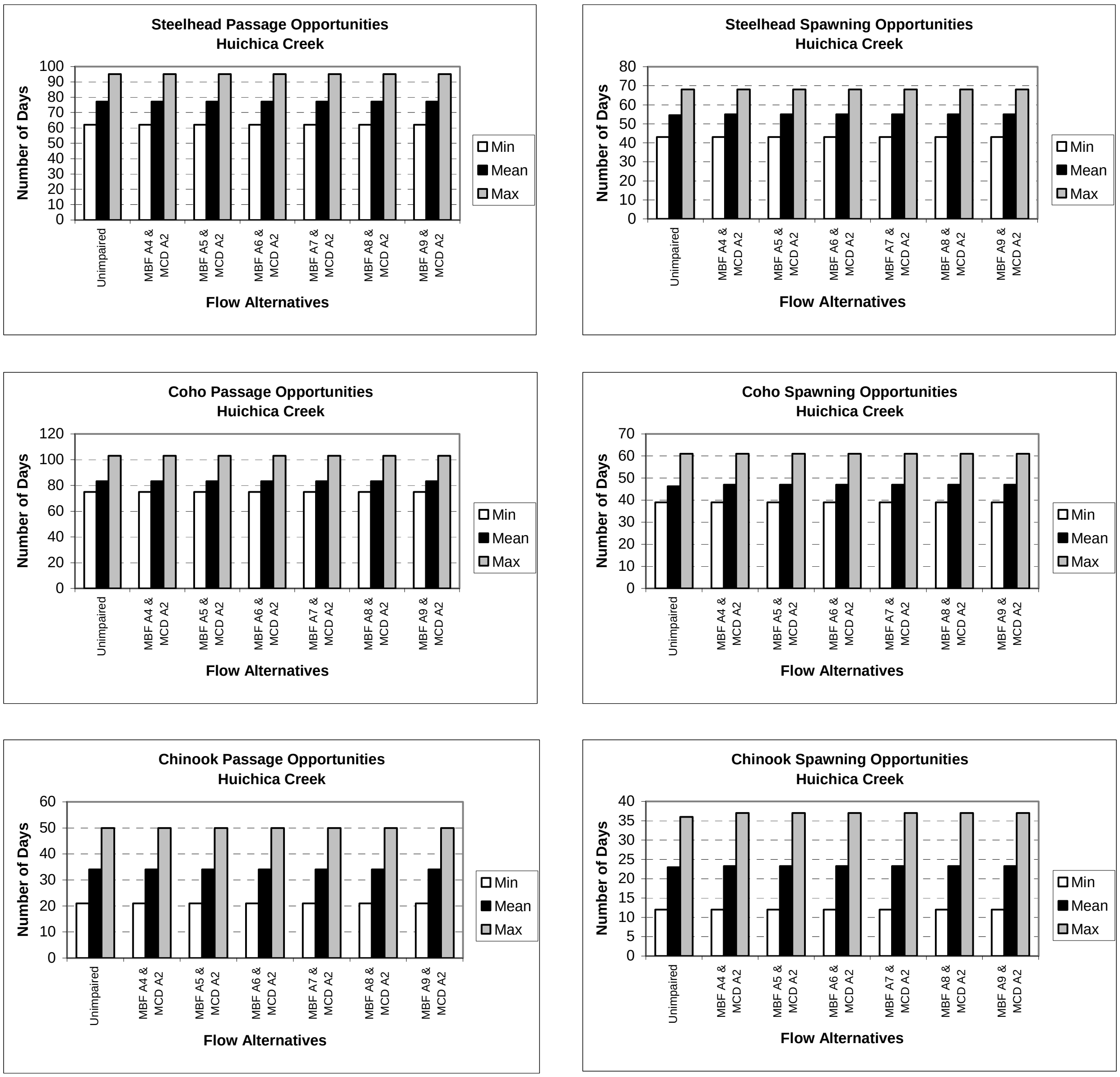

Figure C-5. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in the Huichica Creek (drainage area = 4.92 mi^2) expressed as minimum, mean and maximum number of days per water year

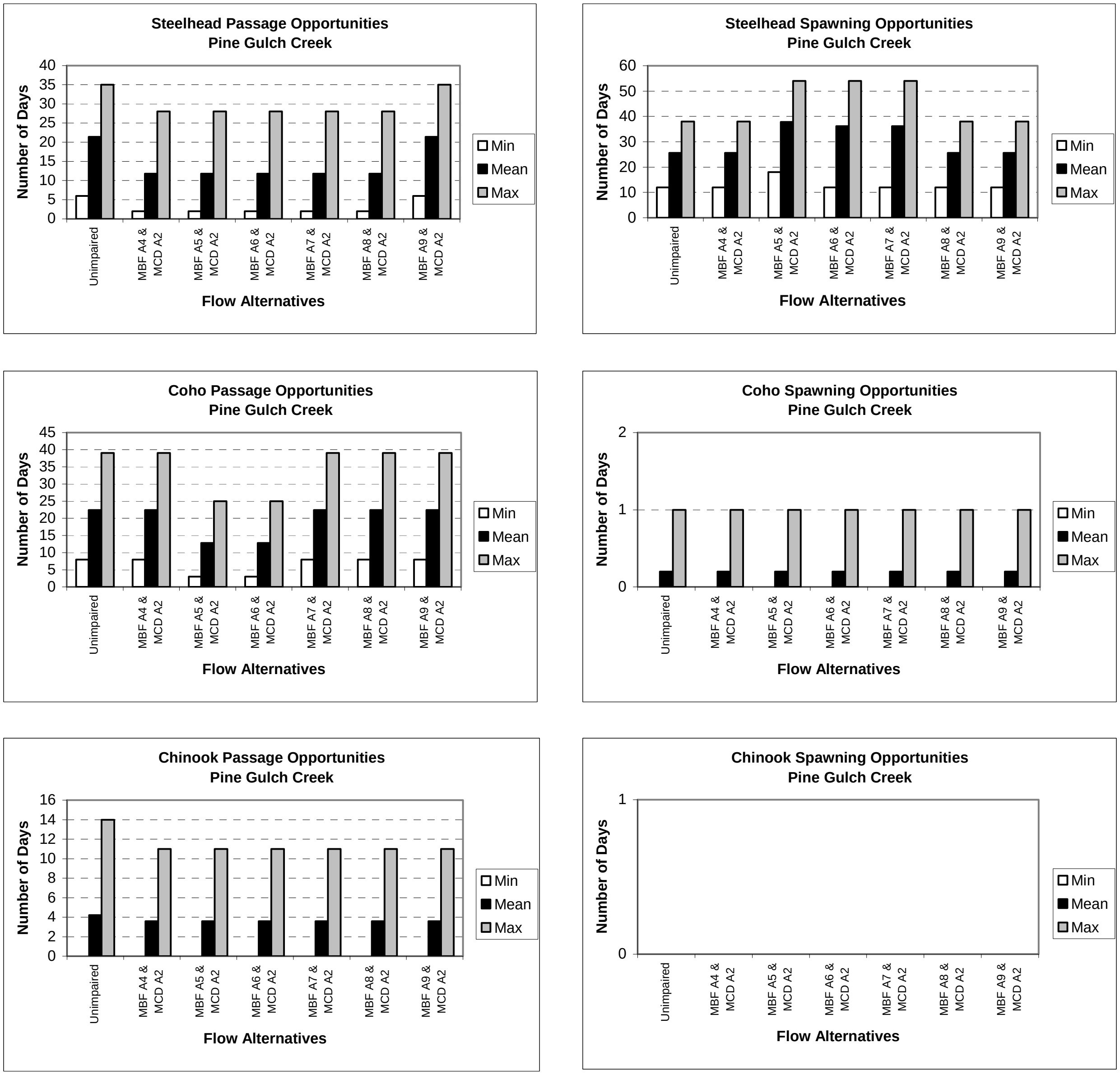

Figure C-6. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in Pine Gulch Creek (drainage area = 7.83 mi^2) expressed as minimum, mean and maximum number of days per water year

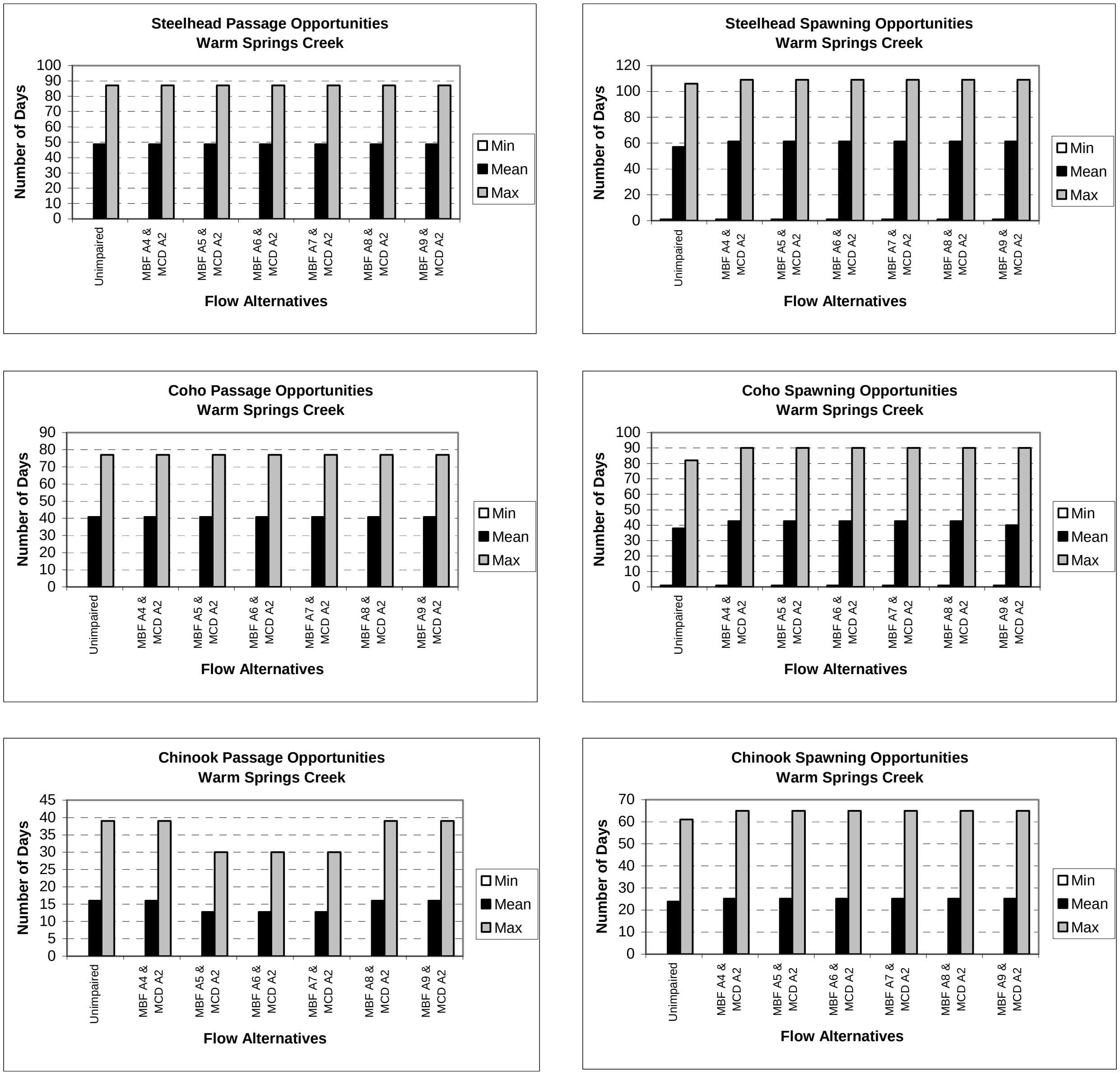

Figure C-7. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in Warm Springs Creek (drainage area = 12.2 mi^2) expressed as minimum, mean and maximum number of days per water year

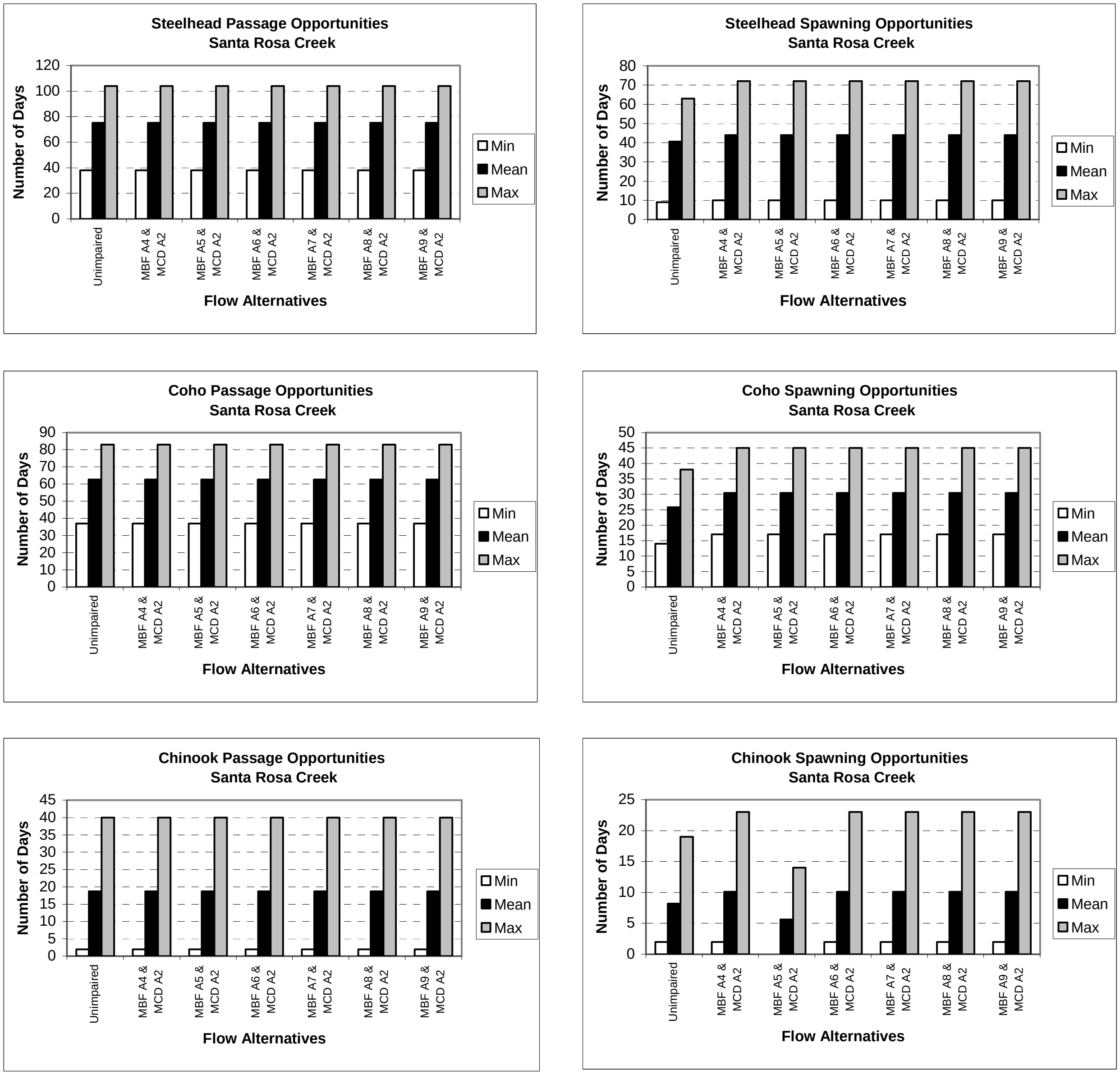

Figure C-8. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in Santa Rosa Creek (drainage area = 12.5 mi^2) expressed as minimum, mean and maximum number of days per water year

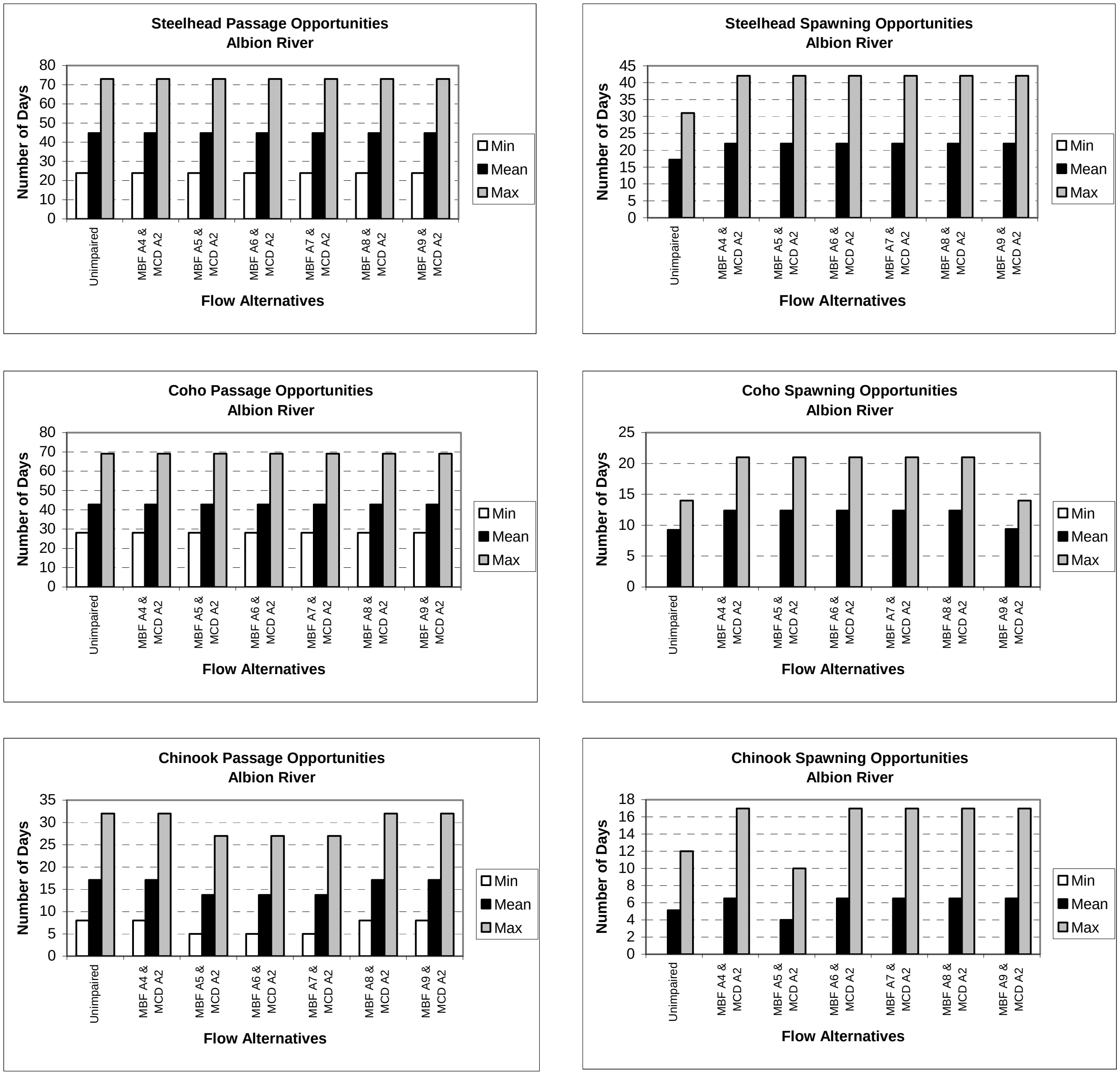

Figure C-9. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in the Albion River (drainage area = 14.4 mi^2) expressed as minimum, mean and maximum number of days per water year

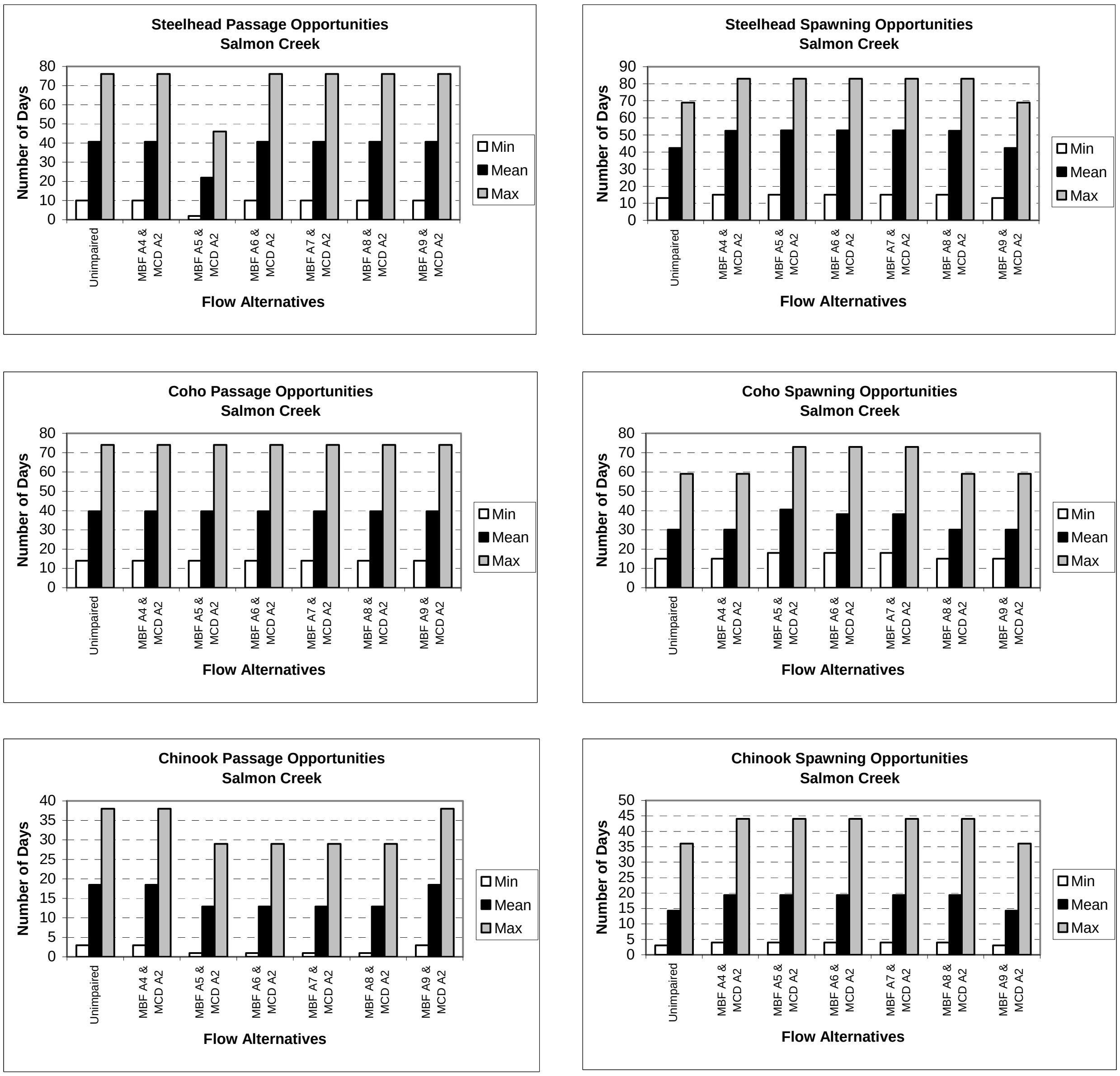

Figure C-10. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in Salmon Creek (drainage area = 15.7 mi^2) expressed as minimum, mean and maximum number of days per water year

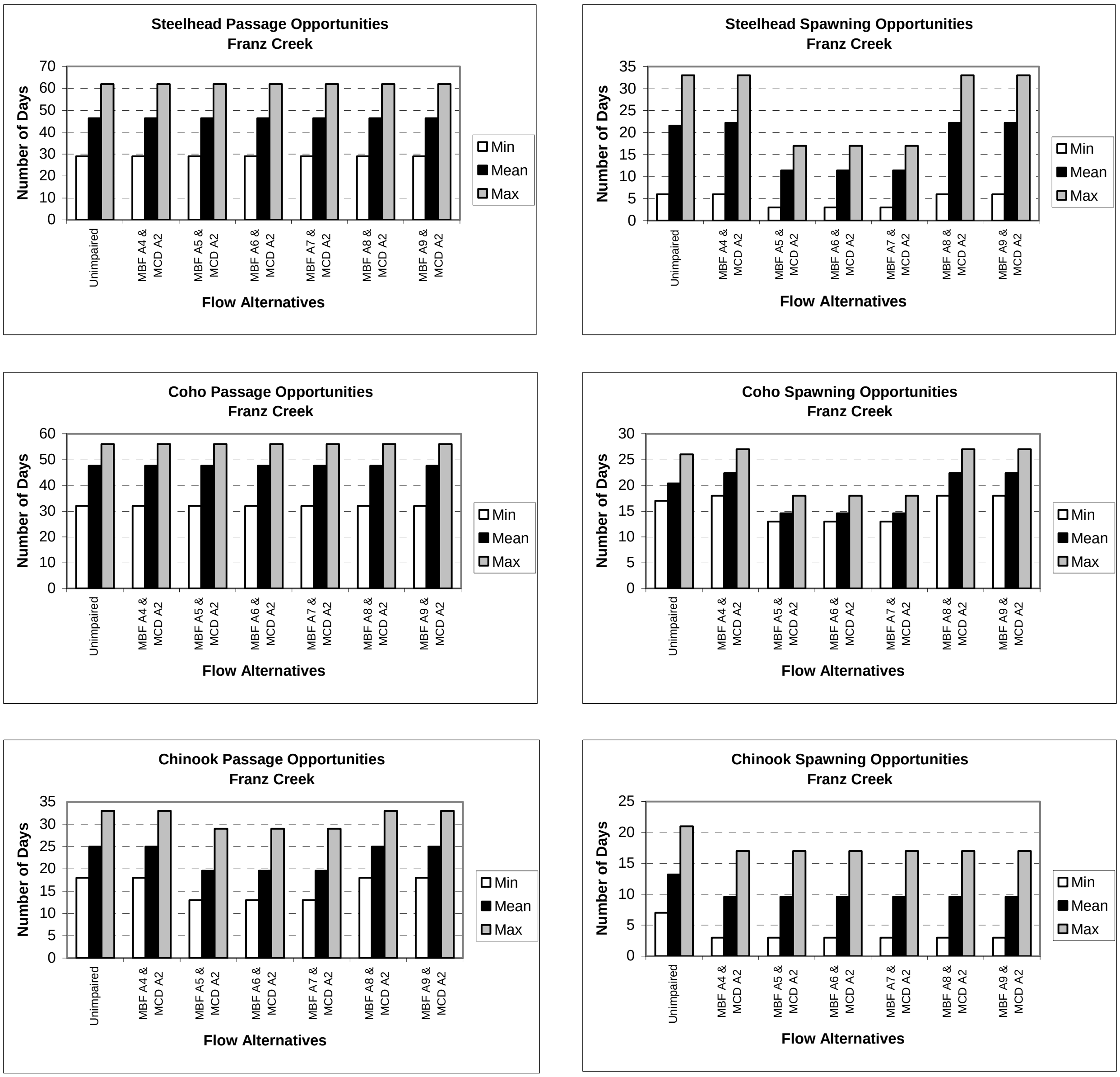

Figure C-11. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in the Franz Creek (drainage area = 15.7 mi^2) expressed as minimum, mean and maximum number of days per water year

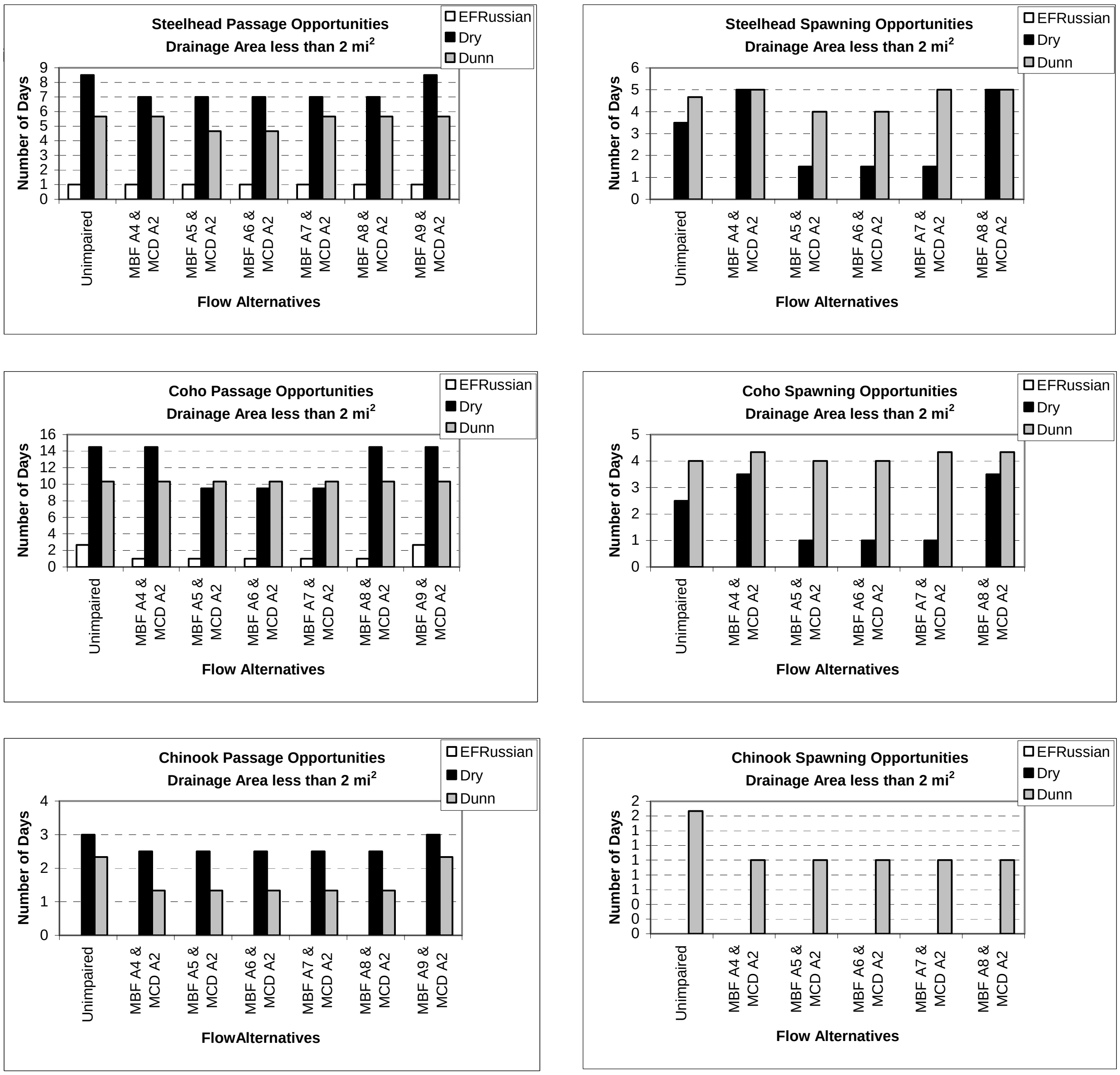

Figure C-12. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in validation sites with drainage area less than 2 mi^2 expressed as mean number of days per water year

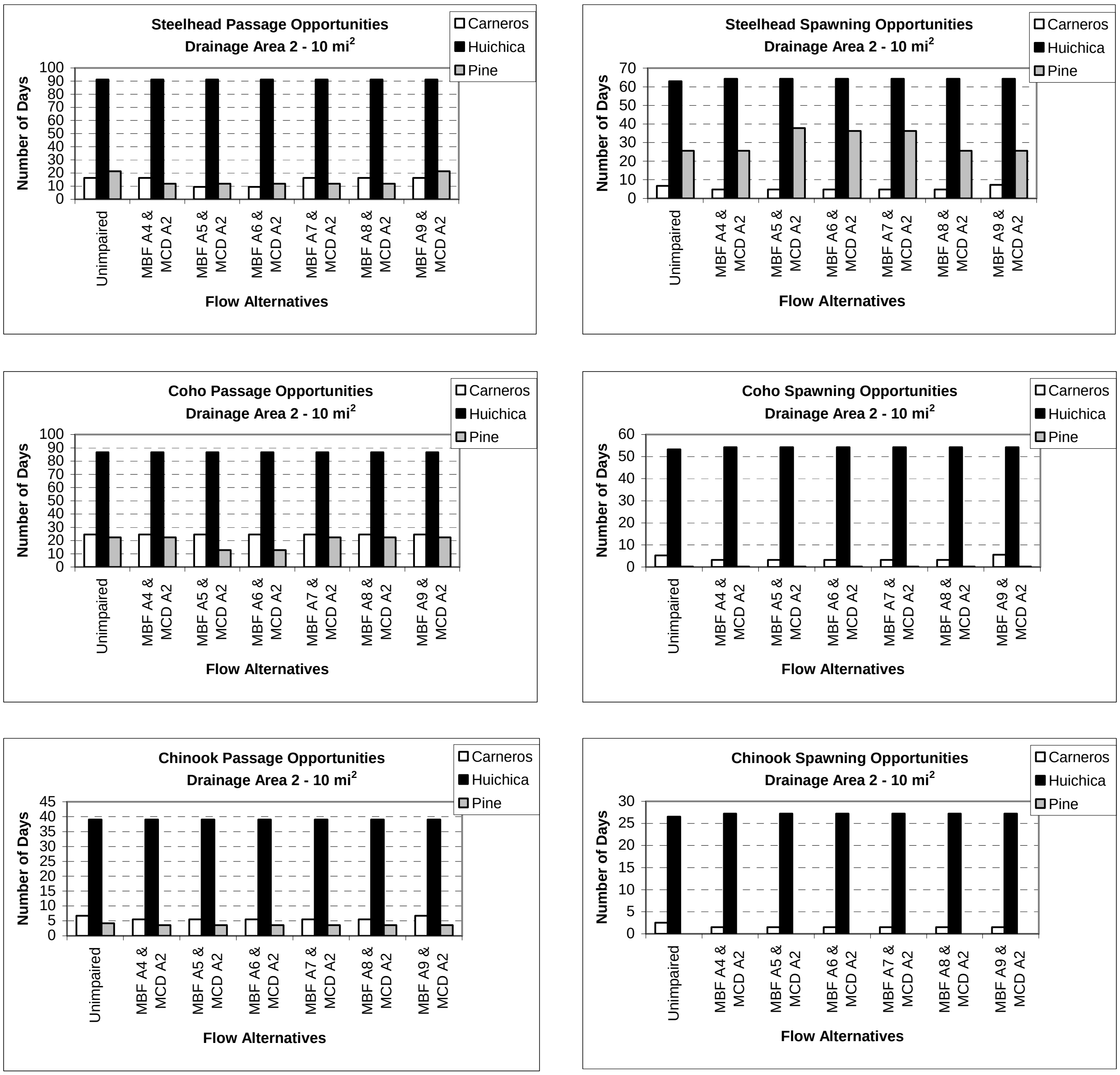

Figure C-13. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in validation sites with drainage area from 2 to 10 mi^2 expressed as mean number of days per water year

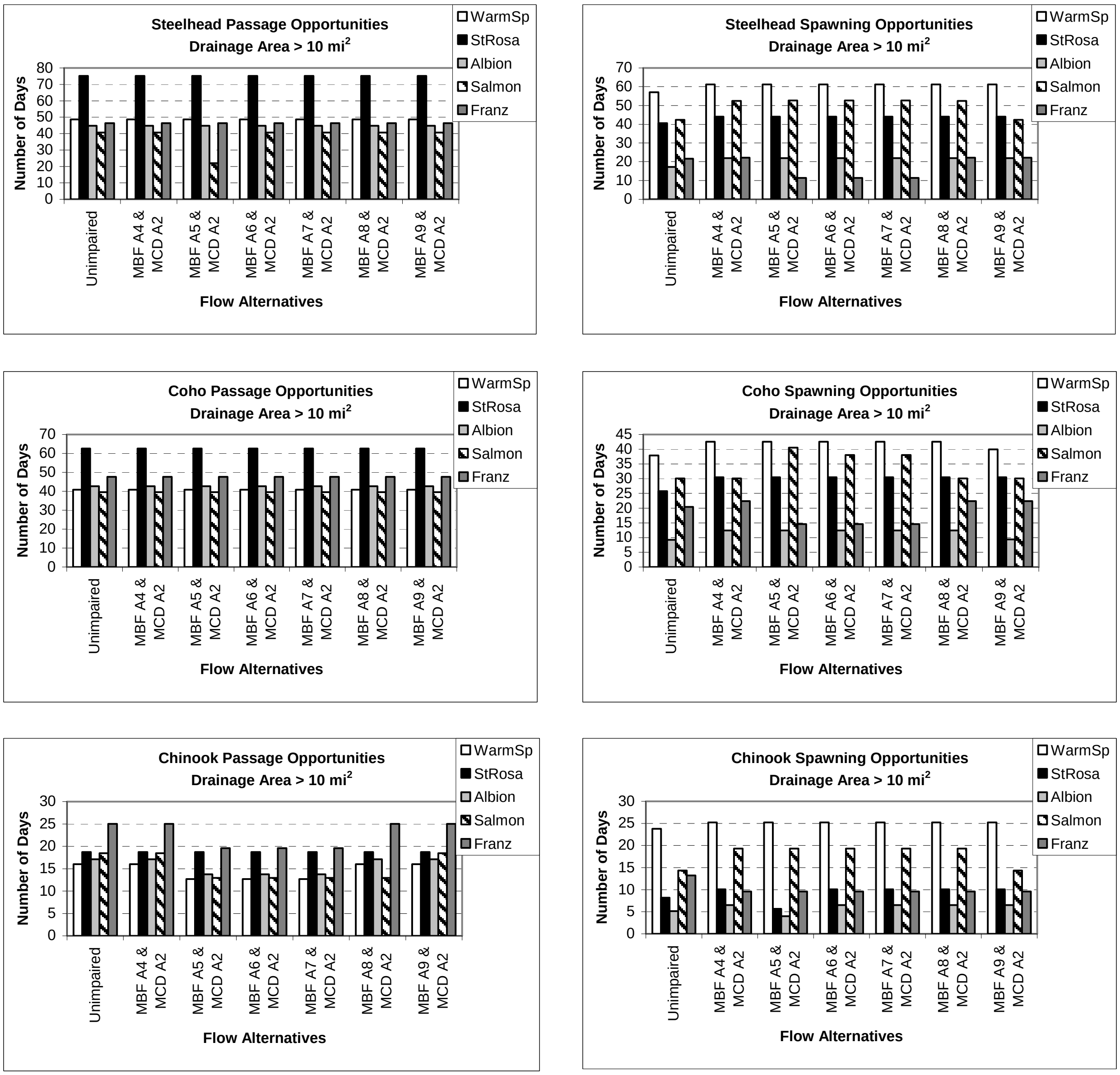

Figure C-14. Comparison of upstream passage and spawning opportunities under unimpaired flow and impaired flow alternatives in validation sites with drainage area greater than 10 mi^2 expressed as average mean of days per water year