CHAPTER 6 Evaluation of the 1981 Secretarial Decision Volumes

This chapter assesses how adequately the annual instream volumes identified in the 1981 Secretarial Decision (140, 220, 287, and 340 TAF [Section 2.5]) protect different life stages of salmonids and provide habitats sufficient to restore the Trinity River salmon and steelhead stocks. Each of these release schedules was assessed for its ability to meet the following factors: fish habitat requirements (Section 5.1), summer/fall temperature criteria (Section 5.5), smolt outmigration and temperature requirements (Section 5.5), and thresholds of physical riverine processes that create and maintain diverse fish habitats necessary to restore anadromous fish populations (Sections 5.3 and 5.4). These factors and the flow criteria to meet these factors (Table 6.1) were prioritized in the following order:

> "This chapter assesses how adequately the annual instream volumes identified in the 1981 Secretarial Decision (140, 220, 287, and 340 TAF [Section 2.5]) protect different life stages of salmonids and provide habitats sufficient to restore the Trinity River salmon and steelhead stocks."

1. Year-round releases of 300 cfs to provide spawning and rearing habitats for salmon and steelhead;

2. Releases of 450 cfs from July 1 to October 14 to meet the summer/fall temperature objectives;

3. Spring/summer releases to provide improved conditions for smolt outmigration (approximately 2,000 cfs); and

4. Releases necessary to meet physical river processes that create and maintain river habitats (approximately 2,000 to 8,500 cfs).

Table 6.1. Physical and biological objectives and corresponding thresholds/criteria used to evaluate a river system's ability to provide, create, and maintain suitable salmonid habitats. Attribute numbers from Section 4.8 corresponding to riverine processes are given in parentheses.

Physical and Biological Objectives:			Thresholds and/or Criteria
Salmonid Habitats	Spawning and rearing flow	Year-round	300 cfs
	Summer/fall temperature objectives	July 1 - Oct 15	450 cfs
	Spring outmigration temperature (°F): optimal/marginal	Apr 22 - May 22	55.4 / 59.0
		May 27 - June 4	59.0 / 62.8
		June 10 - July 9	62.8 / 68.0
Physical Riverine Processes	Sediment transport (5)/a		2,000 - 6,000 cfs
	Bed mobilization (3)/b		3,000 - 6,000 cfs
	Channel perturbation and scour (4, 8)/c		6,000 - 8,500 cfs
	Stream flow fluctuation/variation (2)/d		historical contrast
	Channel migration and floodplain construction (6, 7)/e		historical contrast
	Riparian dynamics (9)/f		empirical data

/a effectiveness at transporting tributary derived sediments downstream.
/b threshold for most mobile deposits is approx. 3,000 cfs (Trinity Restoration Association, 1993). Threshold for channel wide mobility is approx. 6,000 cfs (Wilcock et al., 1995, Trinity Restoration Association, 1993).
/c threshold for $>2D_{84}$ scour on mobile deposits is approx. 6,000 cfs (Wilcock et al., 1995, Trinity Restoration Association, 1993); threshold for $>2D_{84}$ scour on point bar faces on channel rehabilitation sites is approx. 8,500 cfs (McBain and Trush, 1997).
/d the degree of seasonal and inter-annual variation, access to the floodplain.
/e qualitative estimation based on professional judgement.
/f based on riparian response monitoring on pilot restoration sites (McBain and Trush, 1997).

These prioritized flow criteria guided the development of release schedules for each annual instream volume. First, the daily average schedule was developed to determine the maximum, constant daily release possible for the entire year within each volume. If the average daily schedule release met the first criterion of 300 cfs for spawning and rearing habitat, that schedule was manipulated to meet the remaining criteria without sacrificing other criteria. These schedules are provided in Table 6.2. Each criterion represents an important component critical to the survival of salmonids on the mainstem Trinity River and is briefly discussed below.

Fish Habitat Requirements

The minimum release of 300 cfs is necessary to insure suitable depths and velocities for rearing and spawning salmonids. This recommended physical habitat require-

Table 6.2. Weekly Release schedules for each instream volume: Flows by week (in cfs) constituting the Secretarial Decision flow schedules.

		140	220	287	340[a]	340[b]
October	2	194	305	450	450	450
	9	194	305	450	450	450
	16	194	305	300	300	300
	23	194	305	300	300	300
	30	194	305	300	300	300
November	6	194	305	300	300	300
	13	194	305	300	300	300
	20	194	305	300	300	300
	27	194	305	300	300	300
December	4	194	305	300	300	300
	11	194	305	300	300	300
	18	194	305	300	300	300
	25	194	305	300	300	300
January	1	194	305	300	300	300
	8	194	305	300	300	300
	15	194	305	300	300	300
	22	194	305	300	300	300
	29	194	305	300	300	300
February	5	194	305	300	300	300
	12	194	305	300	300	300
	19	194	305	300	300	300
	26	194	305	300	300	300
March	4	194	305	300	300	300
	11	194	305	300	300	300
	18	194	305	300	300	300
	25	194	305	300	300	300
April	1	194	305	300	300	300
	8	194	305	300	300	300
	15	194	305	300	300	300
	22	194	305	300	300	300
	29	194	305	300	543	300
May	6	194	305	2,000	5,357	1,714
	13	194	305	471	729	2,000
	20	194	305	450	450	1,700
	27	194	305	450	450	1,086
June	3	194	305	450	450	1,000
	10	194	305	450	450	450
	17	194	305	450	450	450
	24	194	305	450	450	450
July	1	194	305	450	450	450
	8	194	305	450	450	450
	15	194	305	450	450	450
	22	194	305	450	450	450
	29	194	305	450	450	450
August	5	194	305	450	450	450
	12	194	305	450	450	450
	19	194	305	450	450	450
	26	194	305	450	450	450
September	2	194	305	450	450	450
	9	194	305	450	450	450
	16	194	305	450	450	450
	23	194	305	450	450	450

[a] sediment transport flow [b] spring outmigration flow.

ment was determined by the integration of PHABSIM conclusions (Section 5.1), temperature considerations (Section 5.5), and life-history timing (Section 3.1.1). The full explanation of why this release was selected is presented in Chapters 7 and 8. Daily releases were evaluated on the basis of each schedule's ability to provide the minimum 300-cfs baseflow.

> "The management of dam releases to restore these [physical riverine] processes will address fundamental fish habitat problems, reverse habitat degradation, and provide the maintenance and creation of diverse and complex fish habitats."

Summer/Fall Temperature Objectives

Summer and fall temperature objectives (Section 5.5), established in 1991 to protect holding and spawning adult salmonids, were developed by the CRWQCB-NCR in cooperation with the Service, CDFG, HVT, and NMFS. Releases of 450 cfs are required to meet the CRWQCB-NCR objectives under warm meteorological conditions and likely release temperatures (Section 5.5). Empirical data in recent years indicate that 450 cfs meets these objectives (Section 5.5). Secretarial Decision release schedules were evaluated on the basis of each schedule's ability to provide 450 cfs from July 1 to October 14, which is the period when these objectives must be actively managed.

Spring Outmigration Requirements

Outmigration, a critical life-history stage, occurs during the historical snowmelt period, when increased flows maintained lower water temperatures and reduced the travel time of smolts leaving the river (Sections 3.1.1 and 4.1.5). Releases that mimic the snowmelt hydrograph in the spring and early summer improve conditions for smolt survival. Temperature criteria for spring outmigration were used to assess each release schedule's ability to improve spring outmigration conditions and thereby improve smolt survival (Table 6.1, Section 5.5). Output from the SNTEMP model was used to assess each schedule's ability to meet these spring outmigration temperature objectives under median hydrological and meteorological conditions (Table 6.3).

Physical Riverine Processes

The Trinity River once functioned as a mixed alluvial river (McBain and Trush, 1997). Complex, diverse fish habitats that once were created and maintained by physical riverine processes (listed by attributes in Section 4.8) have degraded because these processes have been altered. The management of dam releases to restore these processes will address fundamental fish habitat problems (Sections 4.3.5 - 4.6), reverse habitat degradation, and provide the maintenance and creation of diverse and complex fish habitats. The flow thresholds necessary to initiate or effectively realize these riverine processes were empirically or qualitatively defined (Table 6.1, Sections 5.3 - 5.4). In evaluating each Secretarial Decision flow regime relative to these thresholds, riverine attributes with similar thresholds/criteria were grouped together (Table 6.1).

6.1 <u>140 TAF Flow Schedule</u>

The 1981 Secretarial Decision to increase fishery flows in the Trinity River established an annual volume of 140 TAF in critically dry water years, which is equal to an average daily flow of 194 cfs. This average daily release cannot meet the first criterion of 300 cfs for spawning and rearing flows. This schedule fails to meet the summer/fall temperature objectives (Table 6.4). Optimal spring outmigration temperatures are met in only 1 of 12 weeks under median conditions (Table 6.3);

> "This average daily release cannot meet the first criterion of 300 cfs for spawning and rearing flows . . . . The river channel and its fish habitats would continue to degrade under this [140 TAF] schedule."

Table 6.3. Spring outmigration temperature analysis: Evaluation of the Secretarial Decision flow schedules against spring outmigration temperature criteria.

Month	Week	Spring Outmigration Temperature Criteria (°F) optimal/marginal	Secretarial Flow Schedule Alternative 140	220	287	340a	340b
April	22	55.4/59	OPT	OPT	OPT	OPT	OPT
	29	55.4/59	M	M	M	OPT	M
May	6	55.4/59	M	M	M	OPT	M
	13	55.4/59	M	M	M	M	M
	20	55.4/59	--	--	--	--	M
	27	59/62.8	M	M	M	M	M
June	3	59/62.8	M	M	M	M	M
	10	62.8/68	M	M	M	M	M
	17	62.8/68	M	M	M	M	M
	24	62.8/68	M	M	M	M	M
July	1	62.8/68	--	--	--	--	--
	8	62.8/68	--	--	--	--	--

Overall Totals	Total # of weeks	Criteria Standard	Total number of weeks criteria are met 140	220	287	340a	340b
	12	optimal	1	1	1	3	1
	12	marginal	9	9	9	9	10

a - sediment transport flow b - spring outmigration flow -- - does not meet criteria
M - meets marginal criteria Opt - meets optimal criteria

marginal outmigration temperatures are met in 9 of the 12 weeks. There would be insufficient water to address any thresholds of the physical riverine processes (Table 6.4).

Although the 140 TAF schedule was not implemented during the TRFE, the influence of such low releases on the river channel and on fishery populations is demonstrated by the historical consequences of releasing an average 162 TAF during the first 10 years of TRD operations (Table 4.4). The diminished releases resulted in the severe habitat degradation previously documented in this report and were largely responsible for the decline of the Trinity River anadromous fishery observed since the 1960's (Section 3.1.2). The river channel and its fish habitats would continue to degrade under this flow schedule.

Table 6.4. Physical and biological objectives analysis: Evaluation of the 1981 Secretarial Decision flow schedules against criteria defining a riverine system able to create and maintain suitable salmonid habitats, and against criteria used to define habitat suitability. Attribute numbers corresponding to riverine processes follow in parentheses.

Secretarial Decision Flow Schedule (TAF)	**Physical and Biological Objectives**									
	Salmonid Habitat				Physical Riverine Processes					
	Spawning and Rearing	Summer/Fall Temperature Objectives	Optimal Spring Outmigration Temperatures	Marginal Spring Outmigration Temperatures	Sediment Transport (fine/coarse) (5)	Bed Mobilization (3)	Channel Perturbation and Scour (4, 8)	Stream Flow Fluctuation/ Variation (2)	Channel Migration and Floodplain Construction (6, 7)	Riparian Dynamics (9)
140	-	-	-	2	-/-	-	-	-	-	-
220	3	-	-	2	-/-	-	-	-	-	-
287	3	3	-	2	1/-	-	-	1	-	-
340a	3	3	1	2	3/1	2	1	1	1	1
340b	3	3	-	2	2/1	1	-	1	-	1

a - sediment transport flow
b - spring outmigration flow.
- - does not meet
1 - usually does not meet
2 - usually meets
3 - always meets

6.2 220 TAF Flow Schedule

When distributed equally throughout the year, an annual volume of 220 TAF would result in an average daily release of 305 cfs. This daily schedule does meet the 300-cfs release recommended for spawning and rearing salmonids. However, there is insufficient water to meet any remaining criteria (Table 6.4). The summer/fall water temperature objectives could be met for a period of 12 days if the extra 5 cfs/day were redistributed: however, the summer/fall objectives span a total period of 106 days because of the extended adult holding period. A total of 94 days with releases at 300 cfs during this time period would result in potential impacts to holding adult salmonids, as well as rearing juvenile coho salmon and steelhead. Optimal spring outmigration temperatures would be met in one of the 12 weeks under median conditions; marginal outmigration temperatures would be met in 9 of 12 weeks (Table 6.3).

> "This [220 TAF] daily schedule does meet the 300-cfs release recommended for spawning and rearing salmonids. However, there is insufficient water to meet any remaining criteria."

While this daily release is over 100 cfs greater than the average daily release available with the 140 TAF flow schedule, these releases would not meet the thresholds of the physical riverine processes that create and maintain fish habitats (Table 6.4). The encroachment of bands of riparian vegetation would continue unabated under such constantly low releases, exacerbating the problems of riparian berm formation and channelization and resulting in continued fish habitat degradation.

6.3 287 TAF Flow Schedule

The 287 TAF flow schedule provides enough volume to meet both the first and second priorities, and, to a minor degree, the third and fourth priorities. This schedule provides the minimum releases of 300 cfs year-round. This schedule also allows an increase to 450 cfs from July 1 to October 14 to assist the upstream migration of adult salmonids and provide appropriate water temperatures for holding and spawning adult salmon. The remaining water is then used to increase releases to 2,000 cfs in early May for 1 week to assist outmigrating smolts (Table 6.2). Releases then decline over the following week to 450 cfs for the rest of May and June.

Although this flow schedule would address a greater variety of objectives than the 220 and 140 TAF schedules, its utility is still limited. The minimum 300-cfs release required during the spawning and rearing periods would be provided. The summer/fall temperature objectives would be met. Optimal spring outmigration temperatures would only be met in 1 week under median conditions, but marginal temperatures would be met in 9 of the 12 weeks (Table 6.3). The highest scheduled release (2,000 cfs) would aid outmigrating smolts, but this peak release would be insufficient to sustain physical riverine processes necessary to create and maintain fish habitat (Table 6.4), other than minimal flushing of fine sediment from the channelbed surface. The River channel and its fish habitats would continue to degrade.

> "Although this [287 TAF] flow schedule would address a greater variety of objectives than the 220 and 140 TAF schedules, its utility is still limited."

6.4 340 TAF Flow Schedule

Annual releases of 340 TAF constitute an increase in annual instream volume nearly three times greater than what occurred immediately following construction of the TRD (Section 2.2). Although this increase appears significant, the 340 TAF volume, when compared with the 84-year period of record, is equivalent to the third driest year on record in the Trinity River (Table 4.4).

"The 340 TAF volume would provide yet more flexibility than the previously described schedules . . . . However, the third and fourth criteria could not be simultaneously met with this volume of water."

The 340 TAF volume would provide yet more flexibility than the previously described schedules. The first and second prioritized criteria would be met. The third and fourth criteria minimally overlap, and therefore two different release schedules were applied to this volume:

1. the sediment-transport release, which is designed to transport and redeposit gravels and transport fine sediment through the river system, and

2. the spring-outmigration release, which is designed to improve conditions for outmigrating juvenile salmonids during the spring and early summer. Releases would increase dramatically in May and slowly taper off, mimicking natural snowmelt hydrology.

However, the third and fourth criteria could not be simultaneously met with this volume of water (Table 6.4).

6.4.1 Fine Sediment Transport Release Scenario - 340 TAF

The sediment-transport release schedule provides a baseflow of 300 cfs from mid-October until late May. Releases are increased to 6,000 cfs for 5 days to flush fine sediments through the river system, then decreased to 1,500 cfs the following week. From mid-June to mid-October, releases are held at 450 cfs, which somewhat improves conditions for outmigrating smolts and addresses the summer/fall temperature objectives.

Both the spawning and rearing release of 300 cfs and the summer/fall temperature objectives would be met with this schedule. Optimal temperatures for spring outmigration would be met in 3 of the 12 weeks, and marginal outmigration temperatures in 9 of the 12 weeks (Table 6.3).

This schedule would provide a 6,000-cfs release for 5 days, capable of removing fine sediment from the bed surface. Although removal of sand to any depth is a positive step, a full rehabilitation effort requires that even higher releases remove finer substrate particles deeper within the riverbed surface (Sections 5.3 and 5.4). On the Trinity River, chinook salmon eggs have been found buried at depths as great as 1.5 feet beneath the surface (USFWS, 1986). The removal of sand deposits from the upper 0.5 foot of the bed is insufficient to cleanse spawning gravels to depths at which eggs are buried. Releases greater than 6,000 cfs are required to support the processes that will fully restore spawning, rearing, and overwintering habitat (Table 6.1, Sections 5.3 and 5.4).

This schedule does transport fine sediment and coarse sediment better than the other schedules. Some bed mobilization occurs, which aids in the cleansing of spawning gravels. However, these releases are not of sufficient duration to flush the existing excessive fine sediments through the system that have accumulated over the years and would not adequately rehabilitate fish habitats. Some other physical riverine process requirements would be minimally met, but this schedule would

"...these releases are not of sufficient duration to flush the existing excessive fine sediments through the system that have accumulated over the years and would not adequately rehabilitate fish habitats."

be insufficient to achieve a dynamic alluvial river system that is necessary to restore and maintain anadromous fisheries.

6.4.2 Spring Outmigration Release Scenario - 340 TAF

In the spring outmigration (or snowmelt) scenario, releases increase to 2,000 cfs during the week of May 6 and remain at this magnitude through May 13. Releases gradually begin to decrease during the week of May 20, mimicking the natural recession of the snowmelt hydrograph. By June 15, releases are stabilized at 450 cfs through October 15. Releases are then decreased to 300 cfs until early May.

This schedule would provide both the spawning and rearing release of 300 cfs and the summer/fall temperature objective release of 450 cfs. It would provide optimal temperatures for spring outmigration in 1 week out of 12, and marginal outmigration temperatures in 10 of the 12 weeks (Table 6.3). This schedule would provide some flushing of fine sediments from the channelbed surface (Table 6.4). Other physical riverine process requirements would be minimally met, but this schedule would be insufficient to achieve a dynamic alluvial river system along the entire mainstem that is necessary to restore and maintain anadromous fisheries.

6.5 Summary of Secretarial Decision Schedules

On the basis of empirical studies and model evaluations of the Secretarial Decision flow schedules and the best available scientific information, the following conclusions were drawn:

- **The criteria are not fully met with the given volumes of water.**

  The first two criteria (spawning and rearing releases and summer/fall temperature objectives) are not both met with flow schedules less than 287 TAF. The remaining criteria cannot be both fully met with the 340 TAF volume.

- **Channel processes would not reach critical thresholds.**

  The largest of the Secretarial Decision volumes, 340 TAF, would initiate only limited surface sediment removal, minimal coarse sediment transport, and very minimal channelbed mobilization. The remainder of the physical channel processes, which were critical to the maintenance of pre- TRD habitats, would not be reestablished to restore and maintain fishery resources.

- **Riparian vegetation would further encroach upon the channel.**

  Under all 1981 Secretarial Decision schedules, riparian vegetation encroachment would continue, as would fine sediment accumulations along the river banks and in the channel, further channelizing water flow and degrading fish habitat.

- **Minimal flushing releases would further reduce already unsuitable spring flows.**

  At best, implementation of release schedules based on 340 TAF provides only enough flow to mimic the natural spring conditions that existed pre-TRD in critically dry water years. These annual release schedules do not provide enough water to allow high spring flows of sufficient duration to ensure optimal conditions for outmigrating salmon and steelhead. The implementation of flushing releases (≥6,000 cfs), a necessary step toward rehabilitation of existing habitats, balancing the sediment budget, and prevention of riparian vegetation encroachment, would further reduce the availability of water necessary to maintain suitable conditions for outmigrating salmon.

"Other physical riverine process requirements would be minimally met, but this schedule [340 TAF] would be insufficient to achieve a dynamic alluvial river system along the entire mainstem."

- **Habitat degradation and sedimentation would continue.**

  Habitat degradation and sedimentation, identified as the primary reasons for the declines of these fishery resources (USFWS, 1983; BLM, 1995), will continue under all 1981 Secretarial Decision schedules, owing to lack of sufficient volumes of water to address multiple needs within a single year.

- **Overall production potential will not be realized.**

  Pre-smolt production was similar for all six release schedules evaluated by SALMOD modeling at intermediate and high spawning escapements (Section 5.6). The SALMOD results suggest that peak pre-smolt production will be reached only at release levels in excess of those represented by any of the releases evaluated under the 1981 Secretarial Decision in conjunction with increasing spawning and rearing habitat.

- **Fisheries resources would decline under all secretarial decision volumes.**

Annual instream flow schedules averaging 162 TAF were released to the Trinity River in the first 10 years of operation and resulted in the severe habitat degradation and drastic decline of the Trinity River anadromous fisheries. The current annual instream flow of 340 TAF (and largest of the Secretarial volumes), while it has more benefits than lesser annual volumes, cannot meet all criteria essential to the restoration and maintenance of fish habitats and dependent salmonid populations. Instream annual flows equal to or less than 340 TAF would result in the continued degradation of the fisheries resources of the Trinity River.

All criteria used to evaluate the 1981 Secretarial Decision schedules are necessary to restore the fishery resources of the Trinity River. Since these 1981 volumes were identified, our understanding of river systems and the processes that maintain rivers has greatly improved. Insufficient water is available within these volumes to meet all criteria necessary to reverse the degradation of the mainstem habitat below the TRD. A restoration strategy specific to the Trinity River incorporating our current understanding of river systems must be developed to guide recommendations to rehabilitate fish habitats and restore fishery populations.

Insufficient water is available within these volumes to meet all criteria necessary to reverse the degradation of the mainstem habitat below the TRD and restore the fishery resources of the Trinity River.

CHAPTER 7 Restoration Strategy

Anadromous salmonids in the Trinity River evolved in a sinuous alluvial channel that has become relatively straight and static since TRD operation. If naturally produced salmonid populations are to be restored and maintained, the habitat on which they depend must be rehabilitated. The most practical strategy to achieve fish habitat rehabilitation is a management approach that integrates riverine processes and instream flow-dependent needs (Figure 7.1). This management approach physically reshapes selected channel sections, regulates sediment input, and prescribes reservoir releases to (1) allow fluvial processes to reshape and maintain a new dynamic equilibrium condition and (2) provide favorable water temperatures. This strategy does not strive to recreate the pre-TRD mainstem channel morphology. Several sediment and flow constraints imposed by the TRD cannot be overcome or completely mitigated. The new alluvial channel morphology will be smaller in scale, but it will exhibit almost all the dynamic characteristics of the 10 alluvial attributes (presented in Section 4.8) necessary to restore and maintain fisheries resources.

The recommended restoration strategy is founded on the following conclusions drawn from the investigations detailed in Chapter 5 and on the best available scientific knowledge of alluvial river channels and riverine ecology:

1. At least a two-fold increase in smolt production is a desirable goal to restore and maintain anadromous salmonid populations toward pre-TRD levels.

2. The carrying capacity for fry and juvenile salmonids cannot be substantially increased within the confined riparian berms of the existing channel through reservoir releases alone. Flows that only mobilize spawning gravels cannot reshape channel morphology to significantly improve spawning habitat and do little to increase rearing habitat.

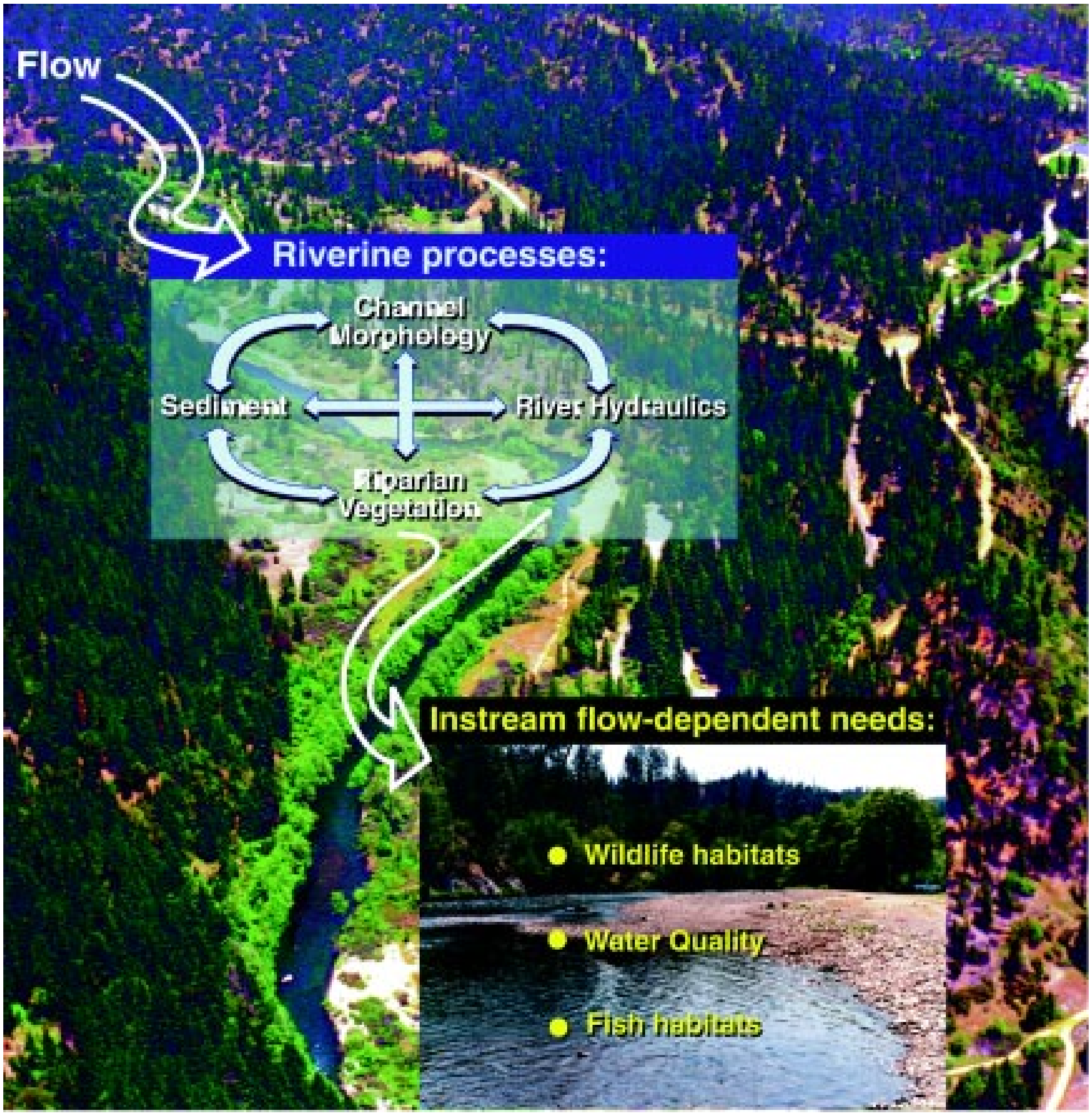

Figure 7.1. A framework for conceptualizing instream flow issues in the Trinity River.

3. Several habitat types are now rare in the mainstem above the North Fork Trinity River confluence as a result of unnatural channel confinement by riparian berms. Specifically, the limited availability of suitable low-velocity habitats severely limits fry survival from mid-winter through spring.

4. Management of TRD releases to provide optimal seasonal temperature regimes within the existing channel as a singular management action cannot increase smolt production necessary to restore and maintain salmonid populations.

5. Only through the combination of mechanical reconstruction, managed releases, and sediment management can the alluvial channel be rehabilitated

and maintained. The anticipated alluvial channel, however, will be a smaller version of the pre-TRD channel.

6. This new, but smaller, channel morphology should increase rearing habitat, allowing at least a doubling of anadromous salmonid smolt production.

7.1 Management Prescriptions

Management prescriptions can be categorized by: (1) increased annual flow regimes and variable reservoir releases; (2) mainstem channel reconstruction; and (3) fine and coarse sediment management. Each has unique objectives within the overall restoration strategy. All prescriptions are evaluated based on an Adaptive Environmental Assessment and Management (AEAM) program (see Section 8.4).

7.1.1 Annual Reservoir Releases

Prescribe flows based on a Water Year Classification to Restore Inter-Annual Flow Variation: No single baseflow can provide all habitat for all salmonid life stages, and no single high flow can create and maintain a dynamic alluvial channel morphology. Therefore, annual releases should be scheduled by water-supply conditions because high-runoff years serve geomorphic and ecological functions differently than do low-runoff years. Water supply forecasting must be based on Trinity River Basin annual runoff to restore inter-annual flow variation. Operational water releases to the Trinity River are officially measured by BOR from April 1 to March 31. Hydrographs in this report are depicted or described from October to September for ease of presentation.

> A primary cause of declining salmonid productivity has been habitat degradation caused by the TRD. Salmonid recovery must be based on a combination of habitat rehabilitation, flow management to improve fluvial processes and water temperatures, and sediment management to improve habitats dependent on alluvial deposits.

Restore Snowmelt Hydrograph Components: Although the downstream tributaries generate sizable winter floods and contribute significant baseflows, they do not mitigate the loss of the pre-TRD snowmelt runoff. Life-history strategies of aquatic and riparian species evolved to cope with and depend on characteristics of the snowmelt hydrograph. Managing reservoir releases to restore the elements of the snowmelt runoff hydrograph, both the snowmelt peak and recession components, is critical to river system integrity.

Prescribe Variable Releases to Rejuvenate and Maintain Alluvial Processes: Physical thresholds (including their magnitude, duration, frequency, and timing) for the alluvial attributes should be provided by the recommended hydrograph components. Each water-year class, Extremely Wet, Wet, Normal, Dry, and Critically Dry, should be assigned a unique annual flow regime. Each must be formulated by assembling hydrograph components capable of achieving specific, quantifiable geomorphic and ecological functions.

Prescribe Releases that Provide Suitable Habitat for All Life Stages of Anadromous Salmonids: Salmonid populations must now rely on the mainstem channel below Lewiston Dam for suitable adult holding, spawning, incubation, and juvenile rearing habitat. The future mainstem channel must substantially increase the availability of suitable microhabitats (depths and velocities) for these life stages from Lewiston Dam to the North Fork Trinity River confluence. Because the depth and velocity preferences vary by life stage and species, a wide range of microhabitats is important for restoration and maintenance of all native fish species and stocks.

Prescribe Releases That Meet Salmonid Temperature Needs: The mainstem below Lewiston Dam must: (1) provide suitable seasonal water temperatures for holding and spawning of anadromous salmonids down to the North Fork Trinity River confluence; (2) improve growth and survival of smolt outmigrants by providing a suitable temperature regime for all three species to Weitchpec; and (3) provide a seasonal thermal regime suitable for year-round rearing of juvenile steelhead and coho salmon.

7.1.2 Selected Mainstem Channel Modifications

Mainstem channel modification will be required in selected reaches to encourage alluvial processes, such as frequent channelbed mobilization and alternate bar formation. The degree of morphological adjustment will depend on channel location. The mainstem from Lewiston Dam to the North Fork Trinity River confluence was divided into four reaches based on present-day alluvial characteristics and future alluvial potential. The two mainstem reaches downstream from the Indian Creek confluence will have greater opportunities for alluvial recovery, as tributaries contribute more flow and coarse sediment. All reaches will require selected removal of the riparian berm down to the original pre-TRD channelbed surface. Closer to Lewiston Dam, channel modification will require selected riparian berm removal and construction of skeletal alternate bars, the latter to encourage rapid deposition and channel readjustment given the limited coarse sediment supply. These projects will also construct functional floodplain surfaces to encourage natural riparian regeneration.

7.1.3 Fine and Coarse Sediment Management

Given that watershed recovery will require a long healing period, as in the Grass Valley Creek watershed, preventing excess fine sediment from entering the mainstem must remain a priority. Coarse bed material supplementation upstream from Rush Creek will be required to rehabilitate a dynamic alluvial channel morphology. The annual volume of supplementation will be a function of peak releases, with wetter water years requiring greater supplementation. To rehabilitate, rather than maintain, mainstem channel morphology above Rush Creek, coarse bed material supplementation must exceed mainstem transport capacity.

7.2 <u>Summary</u>

A dynamic alluvial channel morphology cannot be accomplished solely by prescribing releases. Mechanically removing riparian berms, minimally reshaping the existing channel in selected reaches, introducing coarse bed material above Rush Creek, and reducing or preventing sand input from tributaries also will be necessary. Mechanical intervention functionally simulates a single large winter flood that efficiently eliminates riparian berms and reinstates depositional processes. This evolving alluvial channel morphology at recent channel-rehabilitation projects, and at future projects, can only be sustained with variable annual releases. Otherwise, woody riparian plants will rapidly recolonize these freshly exposed channelbeds, in a manner similar to the rapid encroachment that followed dam closure.

> The riparian berm cannot be removed by TRD dam releases; therefore, habitat rehabilitation must be preceded by a one-time sequence of mechanical berm removal at strategic locations. Subsequent long-term habitat creation and maintenance must be accomplished by flow and sediment management prescriptions rather than mechanical means.

The future mainstem below Lewiston Dam must provide more rearing, holding, and spawning habitat than existed before dam closure. If an alluvial morphology can be rehabilitated for the Trinity River mainstem, salmonid habitat improvement sufficient to at least double smolt production will not be possible without adequate seasonal water temperatures. Past mid-July, the pre-TRD mainstem was a place for salmonids to avoid; afternoon water temperatures could reach the high 70's (°F) to low 80's by Junction City. Since the TRD, hypolimnial dam releases have generated cool water temperatures sufficient to allow juvenile salmonid rearing throughout the summer. Prescribed releases will provide suitable water temperatures for salmonid smolts down the length of the river during the spring. These temperatures will also support increased survival and growth of rearing juvenile salmonids above the North Fork Trinity River confluence, while maintaining appropriate temperatures for holding adult spring-run chinook and summer-run steelhead.

This page was intentionally left blank.

CHAPTER 8 Recommendations

Integration of information collected during studies performed as part of the TRFE and contemporary scientific knowledge of alluvial river channels and riverine ecology have guided the recommendations for restoring and maintaining the fishery resources of the Trinity River. Rehabilitation of the mainstem Trinity River and restoration and maintenance of its fishery resources requires (1) increased annual instream volumes and variable reservoir release schedules, (2) fine and coarse sediment management, and (3) mainstem channel rehabilitation. These actions and resulting recommendations are derived from the best available science. Our achievements will be evaluated over time to document success as well as to make necessary refinements based on our evolving scientific understanding of the consequences of our actions. These refinements will allow us to improve both the rate and efficiency by which we achieve our goals. The process employed to achieve these refinements is described in Section 8.4, Recommended Adaptive Environmental Assessment and Management Program.

> "Rehabilitation of the mainstem Trinity River and the restoration and maintenance of its fishery resources requires (1) increased annual instream allocations and variable reservoir release schedules, (2) fine and coarse sediment management, and (3) mainstem channel rehabilitation."

8.1 Annual Instream Flow Regimes

Recommended flow regimes and release schedules were developed on the basis of a water-year classification and the hydrograph components necessary to meet objectives for each water-year class. Individual hydrograph components were assembled into recommended annual hydrographs on the basis of the targeted fluvial processes and habitat conditions, which often vary by water-year class.

Variability is a keystone to management strategy because no single annual flow regime can be expected to perform all functions needed to maintain an alluvial river system and restore the fishery resources. Inter-annual flow variability (Attribute No. 2, see Section 4.8) is achieved by recommending unique annual flow releases for each water-year class. Unregulated runoff into Trinity Lake will be used to designate the water-year class in each year (Table 8.1), in order that the various targeted fluvial processes will be met with appropriate frequencies. Annual flow regimes vary by water-year class, because they were derived on the basis of the total amount of water necessary to meet the management objectives for each water-year class.

> "...no single annual flow regime can be expected to perform all functions needed to maintain an alluvial river system and restore the fishery resources."

8.1.1 Management Objectives by Water-Year Class

Flow releases must satisfy desired fluvial processes and habitat conditions for each water-year class. The restoration strategy (Chapter 7) broadly describes these release objectives, but it does not assign each of these objectives to a water-year class. Targeted fluvial processes and desired habitat conditions (microhabitat and temperature objectives) were assigned to each water-year class (Tables 8.2 and 8.3). Some processes and habitat conditions, such as favorable spawning and rearing microhabitat, were assigned to all water-year classes. Others, such as floodplain inundation (Attribute No. 7, Section 4.8), were assigned only to the wetter water-year classes.

8.1.2 Hydrograph Components and Releases Necessary to Meet Management Objectives

The studies (Chapter 5) provided three sets of flow-related management objectives: (1) releases to provide suitable salmonid spawning and rearing microhabitat (Table 8.3); (2) snowmelt peak and recession hydrograph components to satisfy fluvial geomorphic and woody riparian objectives that are necessary for the creation and maintenance of diverse salmonid habitats (Table 8.2); and (3) releases to meet appropriate water-temperature objectives for holding/spawning chinook salmon and outmigrating salmonid smolts (Table 8.3). Releases from the TRD were specified that would achieve these management objectives.

8.1.2.1 Rearing and Spawning Microhabitat Management Objectives

On the basis of the analysis of habitat availability in the existing channel, and considering all anadromous salmonid life stages, a release of 150 cfs provides the greatest amount of microhabitat in the mainstem Trinity River from Lewiston Dam to Weitchpec (Chapter 5.1). As with any use of PHABSIM habitat modeling, the weighted usable area indices must be interpreted in the context of fish life-history patterns and habitat needs, streamflow patterns (both existing and historical), water temperature, and changing channel morphology, according to the procedures of the Instream Flow Incremental Methodology (Bovee, 1982). When considering fish life histories and water-temperature needs, specifically holding and spawning temperature preferences (Chapter 5.5), a 300-cfs release provides suitable microhabitat and macrohabitat for spawning and rearing chinook salmon, coho

> "....a 300-cfs release provides suitable microhabitat and macrohabitat for spawning and rearing chinook salmon, coho salmon, and steelhead in the Trinity River above the North Fork Trinity River in the current channel morphology."

Table 8.1. Trinity River water-year classifications and probability of each water-year class occurring.

Water-Year Class	Probability of Occurrence
Extremely Wet	0.12
Wet	0.28
Normal	0.20
Dry	0.28
Critically Dry	0.12

salmon, and steelhead in the Trinity River above the North Fork Trinity River in the current channel morphology (Segment I, Figure 5.1). Recommended releases focus on this segment because it is most affected by releases from Lewiston Dam. Maintaining 300 cfs as the winter baseflow provides spawning habitat throughout the chinook salmon, coho salmon, and steelhead spawning seasons and protects early life stages throughout incubation and emergence periods for all salmonid species (Figure 3.1). Recommendations based on current rearing and spawning microhabitat data will have to be re-evaluated through an adaptive management process (Section 8.4) after channel morphology changes (Section 8.3).

8.1.2.2 Fluvial Geomorphic Management Objectives

Fluvial geomorphic management objectives are based on the alluvial-attribute thresholds (Sections 5.3 and 5.4). The majority of these objectives can be met during the snowmelt peak and snowmelt recession hydrograph. The snowmelt peak and recession hydrograph components historically varied and therefore recommendations also vary for each water-year class (Figure 8.1; Sections 5.3 and 5.4). Recommended snowmelt peak magnitudes were based on threshold shear stresses estimated as necessary for achieving Attribute Nos. 3 and No. 4. Critically Dry years were not expected to achieve either attribute. The 5-day peak release during all water years except Critically Dry provides sufficient duration to transport coarse bed material originating from tributaries in most years (refer to Attribute No. 5 of McBain and Trush (1997) for greater detail). Staggered timing of snowmelt peak runoff was based on historical timing by average water-year class (Figure 5.27).

> "The majority of these [fluvial geomorphic management] objectives can be met during the snowmelt peak and snowmelt recession hydrograph."

Following the snowmelt peak, Extremely Wet and Wet snowmelt hydrographs have two distinct segments to their descending limbs (with distinct differences in rate of change in declining discharge) separated by a short duration "bench" at 6,000 cfs. Both segments (the latter designated the snowmelt recession hydrograph component) mimic the same rate of change as unimpaired snowmelt hydrographs (Figure 8.1, Appendix J). So that cottonwood seedling roots can better follow the declining groundwater table, flow recession rates mimic the unimpaired snowmelt hydrograph, which will likely promote the annual recruitment of cottonwoods (Rood and Mahoney, 1990; Segelquist et al., 1993; Merigliano, 1996). The 6,000-cfs "bench" promotes transport of fine bed material once peak flows have mobilized the surface layer of the channelbed and

Table 8.2. Primary fluvial geomorphic management objectives for the Trinity River by water-year class (Attributes from Section 4.8).

Year Class	Management Objectives
Extremely Wet	• Mobilization of matrix particles (D_{84}) on alternate bar surfaces (Attribute 3) • Channelbed scour greater than 2 D_{84}'s depth and redeposition of gravels on face of alternate bars (Attribute 4) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage (Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Periodic channel migration (Attribute 6) • Floodplain creation, inundation, and scour (Attribute 7) • Channel avulsion (Attribute 8) • Woody riparian mortality on lower alternate bar surfaces and woody riparian regeneration on upper alternate bar surfaces and floodplains (Attribute 9) • Maintain variable water table for off-channel wetlands and side channels (Attribute 10)
Wet	• Mobilization of matrix particles (D_{84}) on alternate bar surfaces (Attribute 3) • Channelbed scour greater than 1 D_{84}'s depth and redeposition of gravels (Attribute 4) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage (Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Periodic channel migration (Attribute 6) • Floodplain creation, inundation and occasional scour (Attribute 7) • Woody riparian mortality on lower alternate bar surfaces and woody riparian regeneration on upper alternate bar surfaces and floodplains (Attribute 9) • Maintain fluctuating water table for off-channel wetlands and side channels (Attribute 10)
Normal	• Mobilization of matrix particles (D_{84}) on general channelbed surface and along flanks of alternate bar surfaces (Attribute 3) • Channelbed scour and redeposition of gravels (Attribute 4) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage (Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Frequent floodplain inundation (Attribute 7) • Woody riparian vegetation mortality along low water edge of alternate bar surfaces and woody riparian regeneration on upper alternate bar surfaces and floodplains (Attribute 9) • Maintain fluctuating water table for off-channel wetlands and side channels (Attribute 10)
Dry	• Channelbed surface mobilization of in-channel alluvial features (e.g., spawning gravel deposits) (Attribute 3) • Transport sand out of the reach at a volume greater than input from tributaries to reduce instream sand storage(Attribute 5) • Transport coarse bed material at a rate near equal to input from tributaries to route coarse sediment, create alluvial deposits, and eliminate tributary aggradation (Attribute 5) • Discourage germination of riparian plants on lower bar surfaces for a portion of the seed release period (Attribute 9) • Maintain variable water table for off-channel wetlands and side channels (Attribute 10)
Critically Dry	• Discourage germination of riparian plants on lower bar surfaces for the early portion of the seed release period (Attribute 9) • Minimally recharge groundwater (Attribute 10)

Table 8.3. Salmonid microhabitat and temperature objectives for the Trinity River by water-year class.

Water Year Class	Microhabitat Objectives	Temperature Objectives
Extremely Wet, Wet, and Normal	Provide the greatest amount of spawning and rearing microhabitat for anadromous salmonids in the existing channel, given the needs of the various life-stages.	Provide suitable temperatures for holding spring chinook and spawning spring and fall chinook by meeting temperature standards of: <60° F from July 1 to September 14 at Douglas City (RM 93.7), <56° F from September 15 to September 30 at Douglas City, and <56° F from October 1 to December 31 at the North Fork Trinity River confluence (RM 72.4). Provide optimal temperatures for anadromous salmonids throughout their outmigration by meeting temperature targets at Weitchpec (RM 0.0) of: <55.4° F prior to May 22 for steelhead smolts, < 59.0° F prior to June 4 for coho salmon smolts, and <62.6° F prior to July 9 for chinook salmon smolts.
Dry and Critically Dry	Provide the greatest amount of spawning and rearing microhabitat for anadromous salmonids in the existing channel, given the needs of the various life-stages.	Provide suitable temperatures for holding spring chinook and spawning spring and fall chinook by meeting temperature standards of: <60° F from July 1 to September 14 at Douglas City (RM 93.7), <56° F from September 15 to September 30 at Douglas City, and <56° F from October 1 to December 31 at the North Fork Trinity River confluence (RM 72.4). Facilitate early outmigration of smolts by allowing water temperatures to warm and provide at least marginal temperatures for anadromous salmonids throughout most of their outmigration by meeting temperature targets at Weitchpec (RM 0.0) of <59.0° F prior to May 22 for steelhead smolts, <62.6° F prior to June 4 for coho salmon smolts, and <68.0° F prior to July 9 for chinook salmon smolts.

alternate bars. The recession hydrograph components in Normal, Dry, and Critically Dry water-year classes also mimic unimpaired receding snowmelt rates (Appendix J).

Another "bench" in Extremely Wet, Wet, and Normal water years at a release of 2,000 cfs has two purposes: (1) to inundate exposed portions of alternate bars when seeds are viable and tributaries are contributing significant baseflows (refer to Attribute No. 9); and (2) to facilitate chinook smolt outmigration through July 9 (Figure 8.2). Similarly, a 36-day bench of 1,500 cfs in Critically Dry water years will discourage seedling germination on alternate bar flanks through inundation and will improve water temperatures for salmonids.

8.1.2.3 Water Temperature Management Objectives

Summer/Fall Temperature Control Flows

In 1991, the CRWQCB-NCR, in conjunction with the Service, CDFG, and the Hoopa Valley Tribe, established water-temperature objectives for the Trinity River to protect holding/spawning spring-run chinook salmon and spawning fall-run chinook salmon (Section 5.5). From July through mid-October a release of at least 450 cfs provides suitable water temperatures for holding and spawning spring-run chinook salmon and spawning fall-run chinook salmon in the Trinity River, above the confluence with the North Fork Trinity River (Figure 8.2; Section 5.5). Under a variety of hydro-meteorological

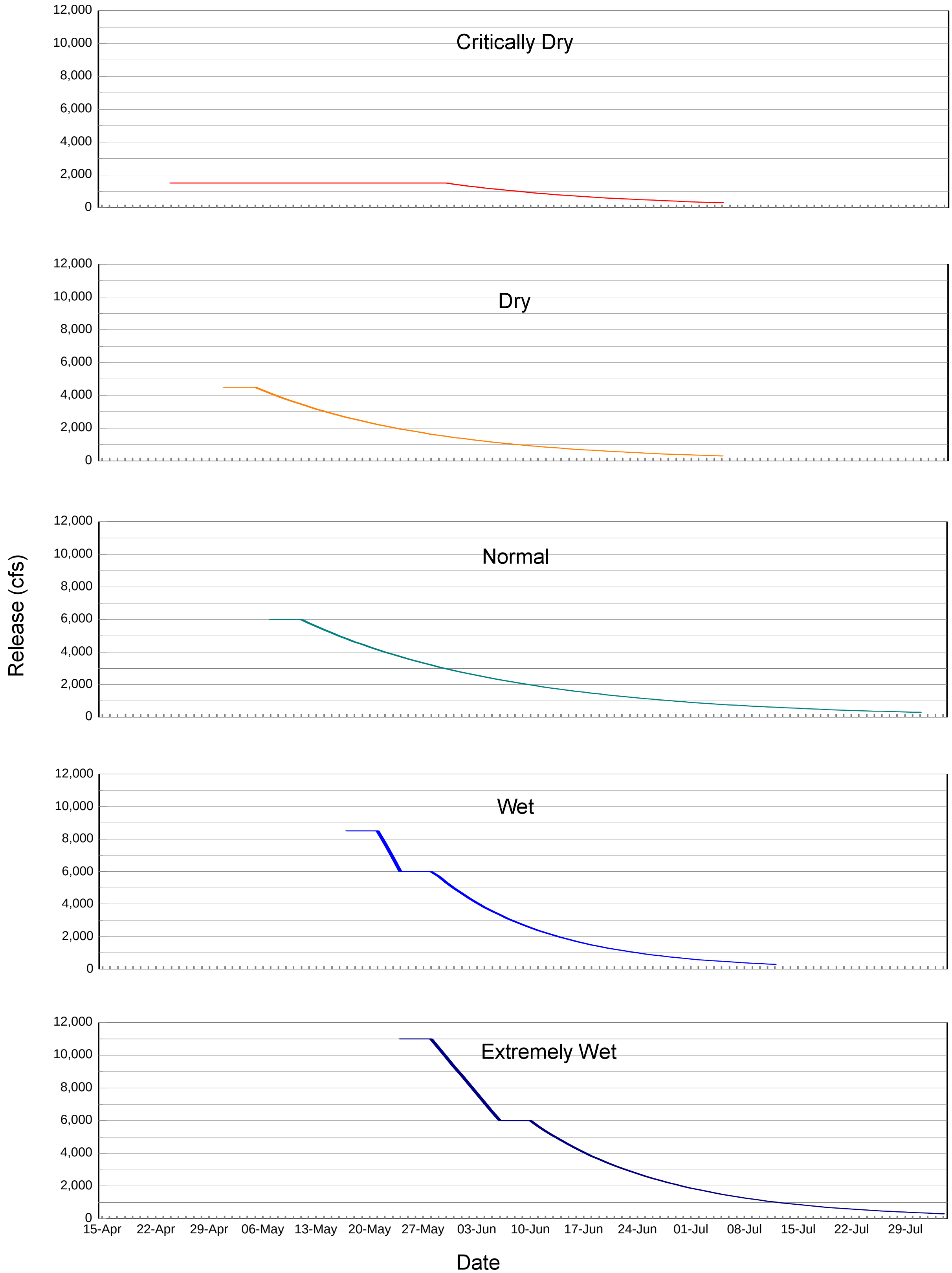

Figure 8.1. Lewiston Dam releases necessary to meet fluvial geomorphic objectives for each water-year class.

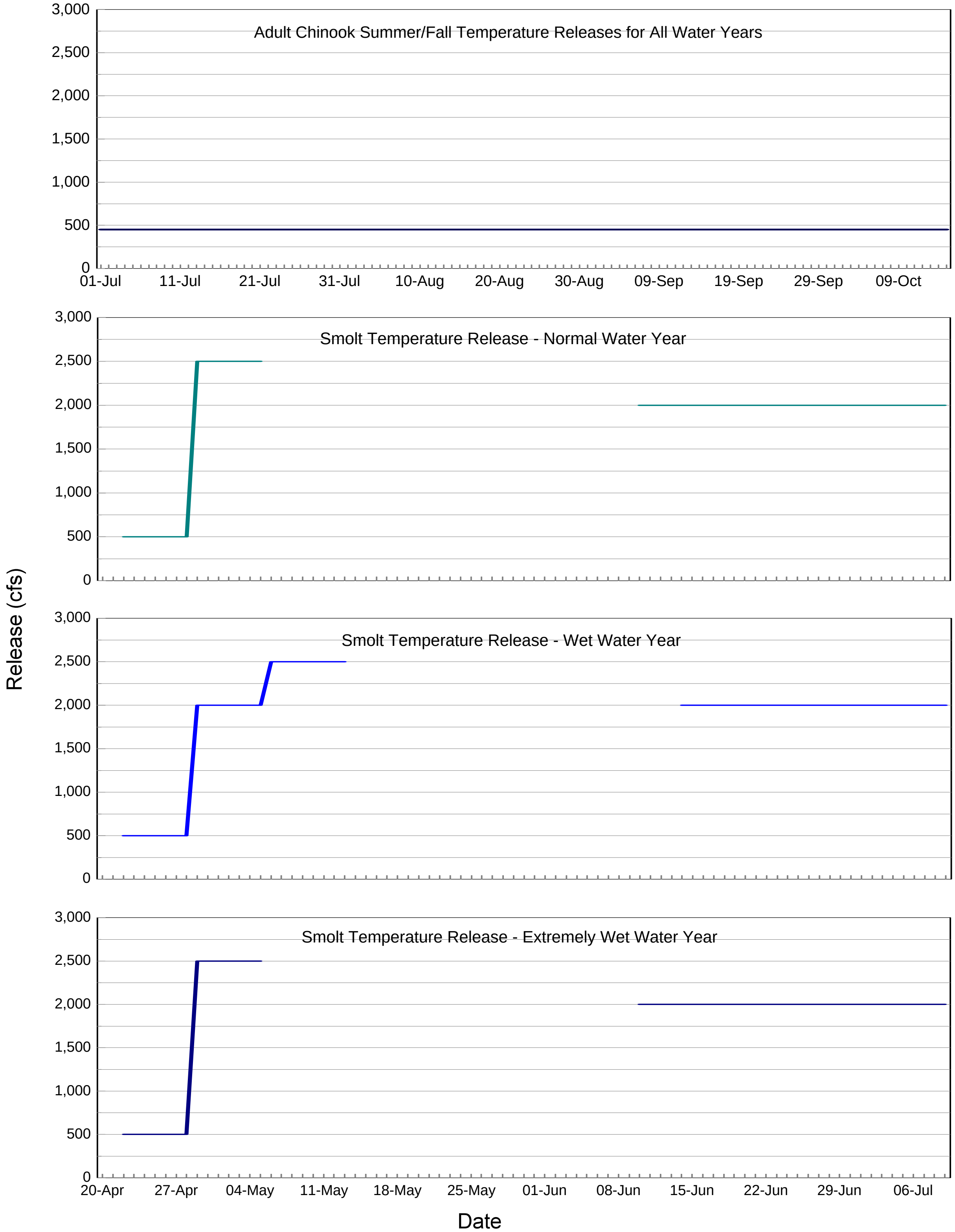

Figure 8.2. Lewiston Dam releases necessary to meet summer/fall adult chinook temperature objectives above the North Fork Trinity River confluence, and releases necessary to meet salmonid smolt temperature objectives at Weitchpec during Normal, Wet, and Extremely Wet water years. Releases for the time periods not graphed are covered by the fluvial geomorphic peaks.

conditions and dam release-water temperatures, releases of 450 cfs have met the temperature objectives established by the CRWQCB-NCR.

Salmonid Smolt Outmigration Flows

Because of the protracted outmigration period of the three anadromous salmonid species in the Trinity River, a variety of outmigrant temperature conditions are necessary throughout the spring/summer hydrographs (Chapter 5.5). Releases for the three water-year classes (Extremely Wet, Wet, and Normal) were scheduled to meet optimum salmonid smolt temperature criteria (Figure 8.2; Chapter 5.5). Because the timing of smolt outmigrations is similar to the timing of the recommended fluvial geomorphic releases, appropriate thermal regimes were provided under the fluvial geomorphic recommendation for much of the fluvial geomorphic hydrograph. Hydrographs were developed to meet optimal smolt temperatures prior to and at the end of the fluvial geomorphic releases during the Extremely Wet, Wet, and Normal water years (Appendix K).

"Under a variety of hydro-meteorological conditions and dam release-water temperatures, releases of 450 cfs have met the temperature objectives established by the CRWQCB-NCR."

Optimal smolt outmigration temperatures will not be provided during Dry and Critically Dry water years. The magnitude and timing of fluvial geomorphic releases during the Dry and Critically Dry water year hydrographs provided at least marginal salmonid smolt temperatures throughout much of the outmigration period (Appendix K). The lower geomorphic releases for these water-year classes provide flow and temperature conditions in the mainstem similar to those that exist lower in the Trinity River and in the lower Klamath River during these year classes (Appendix L). Allowing mainstem water temperatures to warm earlier in the outmigration period will cue salmonids to outmigrate before water temperatures in the lower watershed are likely to become too warm to ensure smolt survival.

"Because of the protracted outmigration period of the three salmonid species in the Trinity River, a variety of outmigrant temperature conditions are necessary throughout the spring/summer hydrographs."

8.1.3 Assembly of Annual Hydrographs for Each Water Year

Annual hydrographs were assembled for each water class on the basis of the targeted microhabitat, fluvial processes (Figure 8.1), and desired temperature conditions (Figure 8.2). Total annual instream volumes, based on the recommended releases for each water-year class, ranged from 369 to 815 TAF (Table 8.4). Stepwise assembly of the Wet water year releases illustrates how management objectives were integrated into a single recommended release schedule (Figure 8.3). Throughout the year, a minimum recommended release of 300 cfs is required for spawning and rearing microhabitat. However, summer/fall temperature objectives require a greater release (450 cfs), which override the rearing microhabitat objectives in the summer and early fall. The benefits of providing suitable temperature regimes (as well as geomorphic processes) outweigh the short-term decrease in the amount of microhabitat. Similarly, smolt temperature objectives and the snowmelt peak and recession override rearing habitat objectives in the spring. The releases required to meet the snowmelt hydrograph also meet most of the smolt temperature objectives. The snowmelt ascending and receding limbs were modified in selected weeks as necessary to meet temperatures for steelhead smolt outmigration that were not initially met by the snowmelt hydrograph releases.

Table 8.4. Recommended annual water volumes for instream release to the Trinity River in thousands of acre-feet (TAF).

Water-Year Class	Instream Volume
Extremely Wet	815.2
Wet	701.0
Normal	646.9
Dry	452.6
Critically Dry	368.6
Average (weighted by water-year probability)	594.5

8.1.4 Recommended Release Schedules for Each Water-Year Class

Recommended daily releases from Lewiston Dam for each water-year class are presented in Appendix M.

8.1.4.1 Extremely Wet Water Year
(Table 8.5; Figure 8.4)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River. Under a variety of hydrometeorological conditions and dam release-water temperatures, releases of 450 cfs have met the temperature objectives established by the CRWQCB-NCR.

A release of 300 cfs from October 16 through April 21 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel (Table 8.5, Figure 8.4). A 300-cfs release provides more microhabitat for most salmonid life-stages than does the 450-cfs release, which is required from July to mid-October for temperature control. Although spawning microhabitat is greater at low releases, reducing releases below 300 cfs would increase the occurrence of dewatering spring-run chinook redds constructed during the preceding 450-cfs release. Maintaining a 300-cfs release protects early life stages of salmonids throughout the protracted period of incubation and emergence that occurs in the mainstem resulting from the successive and extended spawning of chinook salmon, coho salmon, and steelhead.

A release of 500 cfs from April 22 through April 28 provides optimal temperatures for steelhead (<55.4° F), as well as for coho salmon (<59.0° F) and chinook salmon (<62.6° F) smolts.

A release of 1,500 cfs from April 29 through May 5 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

> "Annual hydrographs were assembled for each water class on the basis of the targeted microhabitat, fluvial processes, and desired temperature conditions."

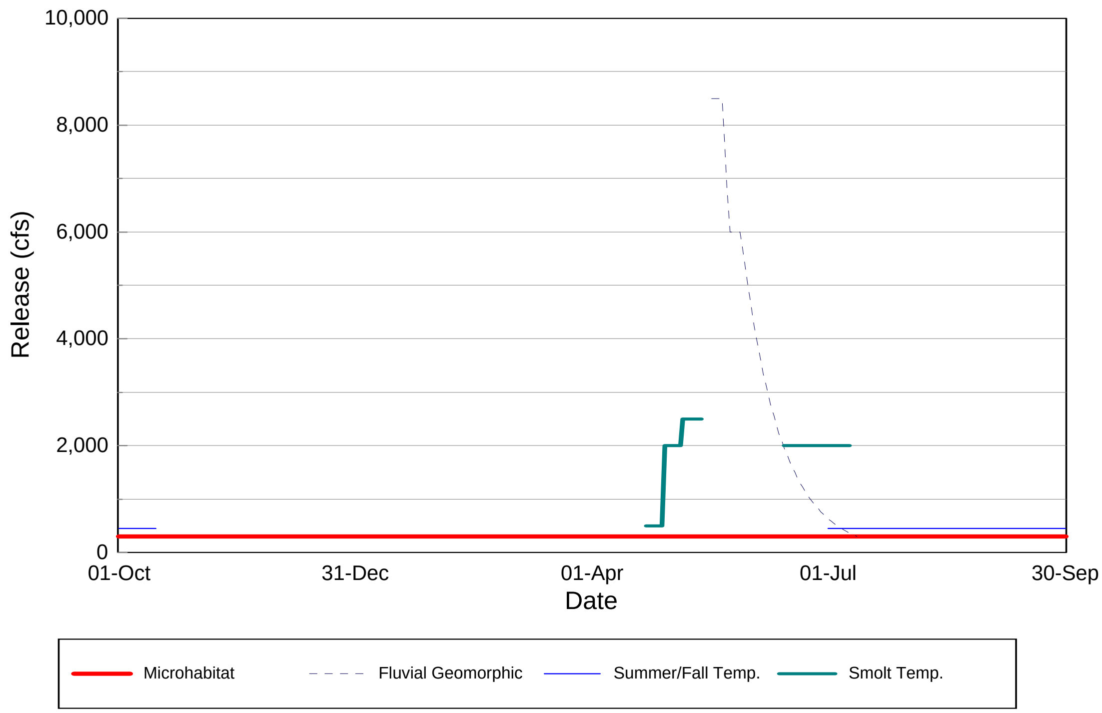

Figure 8.3. Releases necessary to meet microhabitat, fluvial geomorphic, summer/fall temperature, and smolt temperature management objectives during a Wet water year.

A release of 2,000 cfs from May 6 through May 19 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Recommended releases are increased from 2,000 cfs on May 19 to 11,000 cfs on May 24 to meet fluvial geomorphic objectives for the Extremely Wet water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day peak release of 11,000 cfs from May 24 to May 28 targets fluvial geomorphic processes that will create major alterations in the channel and channelbed. This release magnitude and duration will mobilize most alluvial features, scour the channelbed to a depth $>2D_{84}$, transport sediment and route bedload, cause mortality of channel-encroaching plants and prevent germination of riparian plants, promote periodic channel migration and avulsion, and build floodplain features. The timing of the fluvial geomorphic peak release mimics the historical timing of snowmelt peaks during Extremely Wet water years. This release magnitude will also provide optimal temperatures for coho salmon and chinook salmon smolts throughout the mainstem.

> "A 5-day peak release of 11,000 cfs . . . targets fluvial geomorphic processes that will create major alterations in the channel and channelbed."

Recommended releases decrease from 11,000 cfs on May 28 to 6,000 cfs on June 6. This rapid decrease mimics historical conditions that followed spring peak flows.

A 5-day release of 6,000 cfs from June 6 to June 10 facilitates the transport of fine bed material (sand) once higher flows have

Table 8.5. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during an Extremely Wet water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall- run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 21	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 28	500	Spring baseflow	≤ 55.4º F at Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
Apr 29 - May 5	1,500	Spring baseflow/ Ascending limb	≤ 55.4º F at Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
May 6 - May 19	2,000	Spring baseflow/ Ascending limb	≤ 55.4º F at Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production Reduce travel time of outmigrating steelhead smolts
May 19 - May 24	2,000 - 11,000	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
May 24 - May 28	11,000	Snowmelt peak	Peak: Mobilize ≥2 D_{84} deep on flanks of alternate bars (more on lower channel than upper) cleanses gravels and transports all sizes of sediments Initiate channel migration at bank rehabilitation sites Duration: Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to the tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within the surface and subsurface chnnelbed Increase sinuousity through channel migration Create and maintain alternate bar morphology Create floodplains by bar building and fine sediment deposition Encourage establishment and growth of riparian vegetation on floodplains Scour up to 3 yr old woody riparian vegetation along low flow channel margins and scour younger plants higher on bar flanks	Increase fry production through improved egg-to-emergence success Increase fry production by creating and maintaining rearing habitat along channel margins Increase smolt production by increasing year-round rearing habitat quality and quantitiy, and reducing outmigration travel time Increase species and age diversity of riparian vegetation

Table 8.5. Continued.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
May 28 - Jun 6	11,000 - 6,000	Descending limb	Ramp to 6,000 cfs	Reduce fine sediment (<5/16 inch) storage within surface channelbed	Increase fry production through improved egg-to-emergence success
Jun 6 - Jun 10	6,000	Descending limb bench	Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface channelbed while minimizing coarse sediment (>5/16 inch) transport	Improve fry production through improved egg-to-emergence success Discourage riparian vegetation initiation along low water channel margins
Jun 10 - Jun 30	6,000 - 2,000	Descending limb	Descend at a rate mimicking pre-TRD descent	Inundate point bars Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonally variable water surface levels in side channels and off-channel wetlands	Prevent riparian vegetation initiation along low water channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook salmon growth Increase riparian vegetation and future LWD recruitment
Jun 30 - Jul 9	2,000	Descending limb bench	Provide optimal water temperatures (≤ 62.6º F) to Weitchpec for chinook salmon smolts	Provide optimal temperatures for increased survival of chinook smolts Inundate point bars	Improve chinook smolt production Prevent riparian initiation along low water channel margins
Jul 9 - Jul 22	2,000 - 450	Descending limb	Decline to summer baseflow	Minimize stranding of salmonid fry behind berms	Increase survival of steelhead fry Provide outmigration cues for chinook smolts
Jul 22 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

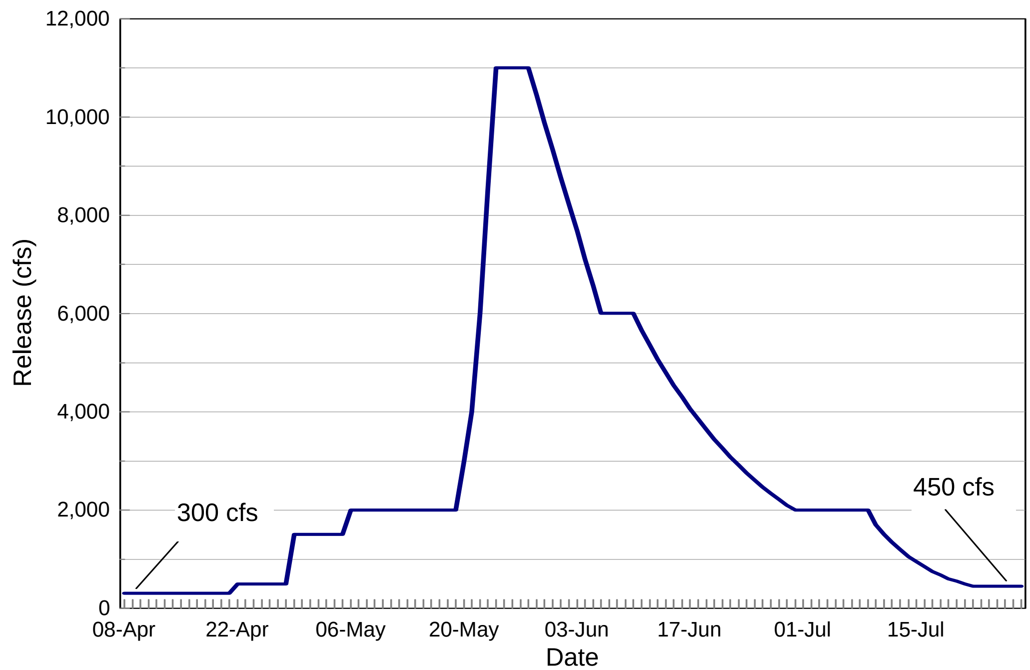

Figure 8.4. Recommended releases during an Extremely Wet water year. Releases are scheduled for 450 cfs from July 22 to October 15. Releases are scheduled for 300 cfs from October 16 to April 21.

mobilized the surface layer of the general channelbed and alternate bars, while minimizing transport of coarse bed material. This release will transport fine sediment (sand), cause mortality of riparian vegetation seedlings, and inundate the flanks of bars to discourage germination and prevent encroachment of riparian plants. This release provides optimal temperatures for chinook salmon smolts throughout the mainstem.

Recommended releases gradually decrease from 6,000 cfs on June 10 to 2,000 cfs on June 30. The rate of this decrease mimics historical conditions that followed spring flows of approximately 6,000 cfs during Extremely Wet water years. Releases during the descending limb of the Extremely Wet water year hydrograph transport fine sediment (sand) and inundate alternate bar features, cause mortality of riparian vegetation seedlings and prevent germination and encroachment on lower bar surfaces, and encourage natural riparian regenerataion on upper bar surfaces and floodplains. These release magnitudes provide optimal temperatures for chinook salmon smolts throughout the mainstem.

> "Releases during the descending limb of the Extremely Wet water year hydrograph transport fine sediment (sand) and inundate alternate bar features, cause mortality of riparian vegetation seedlings and prevent germination and encroachment on bar surfaces."

A release of 2,000 cfs from June 30 to July 9 provides optimal temperatures for chinook salmon smolts throughout the mainstem. Alternate bar features will be inundated, causing mortality of riparian vegetation seedlings and preventing germination of riparian vegetation on lower bar surfaces. Some fine sediment (sand) transport occurs at this release magnitude.

> "The gradual decrease [from 2,000 to 450 cfs] minimizes stranding potential of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts."

Recommended releases decrease from 2,000 cfs on July 9 to 450 cfs on July 22 to reach summer temperature-control releases. The gradual decrease minimizes stranding of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from July through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

8.1.4.2 <u>Wet Water Year</u> (Table 8.6; Figure 8.5)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 21 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

A release of 500 cfs from April 22 through April 28 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout most of the mainstem.

A release of 2,000 cfs from April 29 through May 5 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout most of the mainstem.

A release of 2,500 cfs from May 6 through May 13 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Recommended releases increase from 2,500 cfs on May 13 to 8,500 cfs on May 17 to meet fluvial geomorphic objectives for the Wet water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day peak release of 8,500 cfs from May 17 to May 21 targets several fluvial geomorphic processes. This release magnitude and duration will mobilize most alluvial features, scour channelbed to a depth $>1D_{84}$, transport fine sediment and route bedload, cause mortality of channel-encroaching plants and prevent germination on bar surfaces, initiate periodic channel migration, and inundate/create floodplains. The timing of the fluvial geomorphic peak release mimics the historical timing of the snowmelt peak during wet water years. This release provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

> "A 5-day peak release of 8,500 cfs . . . targets several fluvial geomorphic processes [that will] mobilize most alluvial features, scour channelbed to a depth $>1D_{84}$, transport fine sediment and route bedload, cause mortality of channel-encroaching plants and prevent germination on bar surfaces, initiate periodic channel migration, and inundate/create floodplains."

Recommended releases decrease from 8,500 cfs on May 21 to 6,000 cfs on May 24. This rapid decrease mimics historical conditions that followed spring peak flows.

A 5-day release of 6,000 cfs from May 24 to May 28 facilitates the transport of fine bed material (sand) once higher flows have mobilized the coarse surface layer of the

Table 8.6. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Wet water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall- run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 21	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 28	500	Spring baseflow	≤ 55.4º F to Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
Apr 29 - May 5	2,000	Spring baseflow/ Ascending limb	≤ 55.4º F to Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production
May 6 - May 13	2,500	Spring baseflow/ Ascending limb	≤ 55.4º F to Weitchpec	Provide optimal temperatures for survival of steelhead smolts	Improve steelhead smolt production Reduce travel time of outmigrating steelhead smolts
May13 - May 17	2,500 - 8,500	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
May 17 - May 21	8,500	Snowmelt peak	Peak Threshold : Mobilize ≥1 D_{84} deep on flanks of alternate bars (more on lower channel than on upper) cleanses gravels and transports all sizes of sediments Initiate channel migration at bank rehabilitation sites Duration:Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface and subsurface channelbed Increase sinuousity through channel migration Create and maintain alternate bar morphology Create floodplains by bar building and fine sediment deposition Encourage establishment and growth of riparian vegetation on floodplains Scour up to 2 yr old woody riparian vegetation along low flow channel margins	Increase fry production through improved egg-to-emergence success Increase fry production by creating and maintaining rearing habitat along channel margins Increase smolt production by increasing year-round habitat quality and quantity and reducing outmigration travel time Increase species and age diversity of riparian vegetation

Table 8.6. Continued.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
May 21 - May 24	8,500 - 6,000	Descending limb	Ramp to 6,000 cfs	Reduce fine sediment (<5/16 inch) storage within surface channelbed	Increase fry production through improved egg-to-emergence success
May 24 - May 28	6,000	Descending limb bench	Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface channelbed while minimizing coarse sediment (>5/16 inch) transport	Increase fry production through improved egg-to-emergence success Discourage riparian vegetation initiation along low water channel margins
May 28 - Jun 14	6,000 - 2,000	Descending limb	Descend at a rate mimicking pre-TRD descent Descend at a rate less than 0.1 ft/day	Inundate point bars Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonally variable water surface levels in side channels and off-channel wetlands	Prevent riparian vegetation initiation along low water channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook salmon growth
Jun 14 - Jul 9	2,000	Descending limb bench	Provide optimal water temperatures (≤ 62.6º F) to Weitchpec for chinook salmon smolts	Provide optimal temperatures for increased survival of chinook smolts Inundate point bars	Improve chinook smolt production Prevent riparian initiation along low water channel margins
Jul 9 - Jul 22	2,000 - 450	Descending limb	Decline to summer baseflow	Minimize stranding of salmonid fry behind berms	Increase survival of steelhead fry Provide outmigration cues for chinook smolts
Jul 22 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

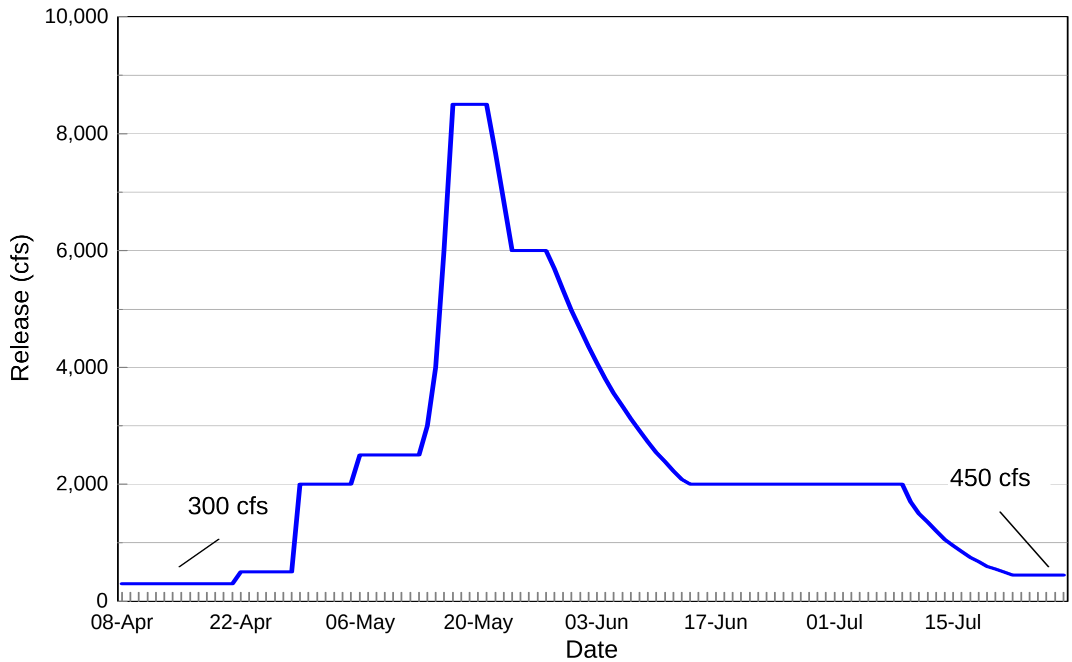

Figure 8.5. Recommended releases during a Wet water year. Releases are scheduled for 450 cfs from July 22 to October 15. Releases are scheduled for 300 cfs from October 16 to April 21.

general channelbed and alternate bars, while minimizing transport of coarse bed material. This release will transport fine sediment (sand), cause mortality of riparian vegetation seedlings, and inundate the flanks of bars to discourage germination and prevent encroachment of riparian plants. This release provides optimal temperatures for chinook salmon smolts throughout the mainstem.

Recommended releases gradually decrease from 6,000 cfs on May 28 to 2,000 cfs on June 14. The rate of this decrease mimics historical conditions that followed spring flows of approximately 6,000 cfs during Wet water years. Releases during the descending limb of the wet water year hydrograph transport fine sediment (sand) and inundate alternate bar features, causing mortality of riparian seedlings and preventing germination and encroachment on bar surfaces. During this period, release magnitudes provide optimal temperatures for coho salmon and chinook salmon smolts throughout the mainstem.

A release of 2,000 cfs from June 14 to July 9 provides optimal temperatures for chinook salmon smolts throughout the mainstem and for salmonid rearing temperatures throughout most of the mainstem. Alternate bar features will be inundated, causing mortality of riparian seedlings and preventing germination of riparian plants on lower bar surfaces. Some fine sediment (sand) transport occurs at this release.

Recommended releases decrease from 2,000 cfs on July 9 to 450 cfs on July 22 to reach summer temperature-control releases. The gradual decrease minimizes stranding potential of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from July 22 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

8.1.4.3 **Normal Water Year** (Table 8.7; Figure 8.6)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 21 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

> "A 5-day release of 6,000 cfs . . . mobilizes most alluvial features, transports fine sediment (sand), causes mortality of riparian seedlings and prevents germination on bar surfaces, and inundates floodplains."

A release of 500 cfs from April 22 through April 28 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts.

A release of 2,500 cfs from April 29 through May 5 provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts.

Recommended releases increase from 2,500 cfs on May 5 to 6,000 cfs on May 7 to meet fluvial geomorphic objectives for the Normal water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day release of 6,000 cfs from May 7 to May 11 targets fluvial geomorphic processes. This release magnitude and duration mobilizes most alluvial features, transports fine sediment (sand), causes mortality of riparian seedlings and prevents germination on bar surfaces, and inundates floodplains. The timing of the fluvial geomorphic peak mimics the historical timing of the snowmelt peak during Normal water years. This release magnitude provides optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Recommended releases gradually decrease from 6,000 cfs on May 11 to 2,000 cfs on June 10. The rate of this decrease mimics historical decreases in flow that followed spring flows of approximately 6,000 cfs during normal water years. Releases during the descending limb of the normal water year hydrograph transport fine sediment (sand) and inundate alternate bar features, causing mortality of riparian seedlings and preventing germination and encroachment on bar surfaces. During this period, releases provide optimal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

A release of 2,000 cfs from June 10 to July 9 provides optimal temperatures for rearing steelhead, and coho salmon and chinook salmon smolts throughout the mainstem. Alternate bar features will be inundated, causing mortality of riparian seedlings and preventing germination of riparian plants on lower bar surfaces. Some fine sediment (sand) transport occurs at this release magnitude.

Recommended releases decrease from 2,000 cfs on July 9 to 450 cfs on July 22 to reach summer temperature-control releases. The gradual decrease minimizes stranding of fry and juvenile salmonids and allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from July 22 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

Table 8.7. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Normal water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall- run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 21	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 28	500	Spring baseflow	≤ 55.4º F at Weitchpec	Provide optimal temperatures for enhanced survival of steelhead smolts	Improve steelhead smolt production
Apr 29 - May 5	2,500	Spring baseflow/ Ascending limb	≤ 55.4º F at Weitchpec	Provide optimal temperatures for enhanced survival of steelhead smolts	Improve steelhead smolt production
May 5 - May 7	2,500 - 6,000	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use Provide optimal temperatures for survival of steelhead smolts	Reduce travel time of outmigrating steelhead smolts Improve steelhead smolt production
May 7 - May 11	6,000	Snowmelt peak	Peak Threshold: Mobilize D_{84} on most alluvial features (general channel mobility) Duration: Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to the tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within the surface channelbed Create and maintain alternate bar morphology Create floodplains by bar building and fine sediment deposition Encourage establishment and growth of riparian vegetation on floodplains Scour up to 1 yr old woody riparian vegetation along channel margins	Increase fry production through improved egg-to-emergence success Discourage riparian vegetation initiation along low water channel margins Increase smolt production by increasing year-round rearing habitat quality and quantity, and reducing outmigration transport time

Table 8.7. Continued.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
May 11 - Jun 10	6,000 - 2,000	Descending limb	Descend at a rate mimicking pre-TRD descent Descend at a rate less than 0.1 ft/day	Inundate point bars to prevent riparian initiation and encroachment along channel margins Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonal variation of water surface levels in side channels and off-channel wetlands	Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook growth Increase riparian vegetation and future LWD recruitment
Jun 10 - Jul 9	2,000	Descending limb bench	Provide optimal water temperatures (≤ 62.6º F) to Weitchpec for chinook salmon smolts	Provide optimal water temperatures for survival of chinook salmon smolts Inundate point bars to prevent riparian initiation along channel margins	Improve chinook smolt production Prevent riparian initiation along channel margin
Jul 9 - Jul 22	2,000 - 450	Descending limb	Decline to summer baseflow	Minimize salmonid fry stranding behind berms	Increase survival of steelhead fry Provide outmigration cues for chinook salmon smolts
Jul 22 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

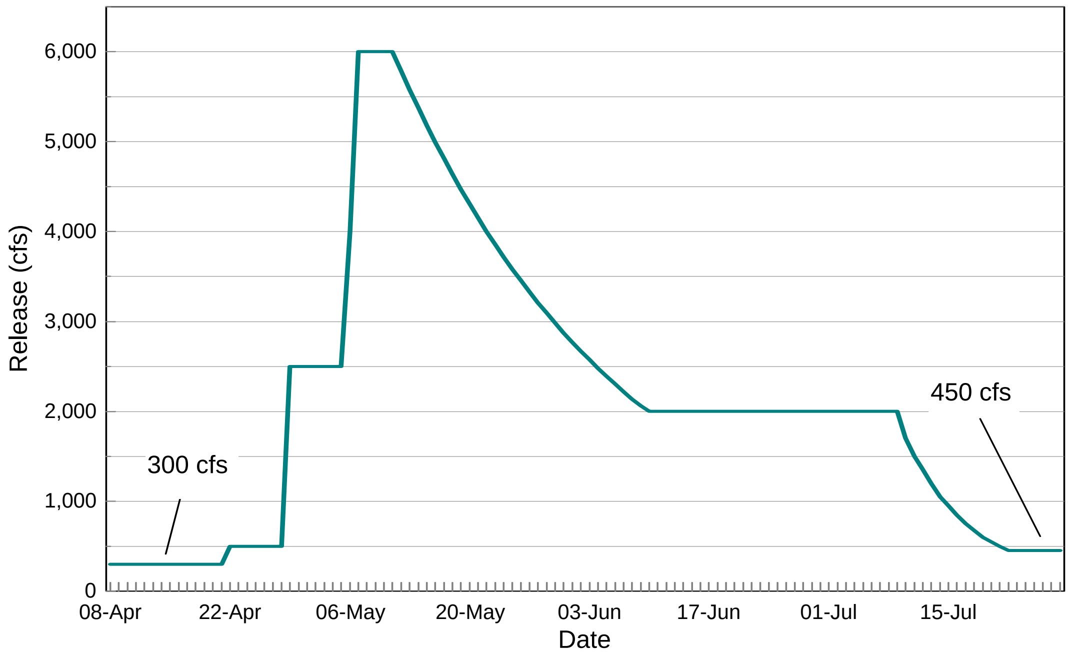

Figure 8.6. Recommended releases during a Normal water year. Releases are scheduled for 450 cfs from July 22 to October 15. Releases are scheduled for 300 cfs from October 16 to April 21.

8.1.4.4 <u>Dry Water Year</u> (Table 8.8; Figure 8.7)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 26 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

Recommended releases increase from 300 cfs on April 26 to 4,500 cfs on May 1 to meet fluvial geomorphic objectives for the Dry water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

A 5-day release of 4,500 cfs from May 1 to May 5 targets fluvial geomorphic processes. This release magnitude and duration mobilizes in-channel alluvial features, transports some fine sediment (sand), causes mortality of riparian seedlings, and prevents germination on bar surfaces. The timing of the fluvial geomorphic peak release mimics the historical timing of the snowmelt peak during Dry water years. This release provides at least marginal temperatures for steelhead, coho salmon, and chinook salmon smolts throughout the mainstem.

Releases gradually decrease from 4,500 cfs on May 5 to 450 cfs on June 26. The rate of this decrease mimics historical conditions that followed spring flows of approximately 4,500 cfs during Dry water years.

> "A 5-day release of 4,500 cfs from May 1 to May 5 targets fluvial geomorphic processes . . . [that] mobilizes inchannel alluvial features, transports some fine sediment (sand), causes mortality of riparian seedlings, and prevents germination on bar surfaces."

Table 8.8. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Dry water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall-run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 26	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 26 - May 1	300 - 4,500	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
May 1 - May 5	4,500	Peak flow	Peak Threshold: Mobilize D_{84} on bar flanks features (median bars, pool tails) Duration: Transport coarse sediment (>5/16 inch) through mainstem at a rate equal to the tributary input downstream of Rush Creek Transport fine sediment (<5/16 inch) through mainstem at a rate greater than tributary input (as measured at Limekiln Gulch Gaging Station)	Reduce fine sediment (<5/16 inch) storage within surface channelbed	Increase salmonid fry production through improved egg-to emergence success Discourage riparian vegetation initiation along low flow channel margins
May 5 - Jun 26	4,500 - 450	Descending limb	Descend at a rate mimicking pre-TRD descent Provide non-lethal water temperatures to Weitchpec for coho smolts (≤ 62.6º F) until June 4 , and for chinook smolts (≤ 68º F) until mid-June	Inundate point bars Minimize river stage change to preserve egg masses of yellow legged frogs Maintain seasonal variation of water surface levels in side channels and off-channel wetlands Improve salmonid smolt production by providing temperatures necessary for survival of steelhead, coho, chinook smolts	Prevent riparian initiation along channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Improve juvenile chinook growth Increase survival of steelhead fry Provide outmigration cues for chinook salmon smolts
Jun 26 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

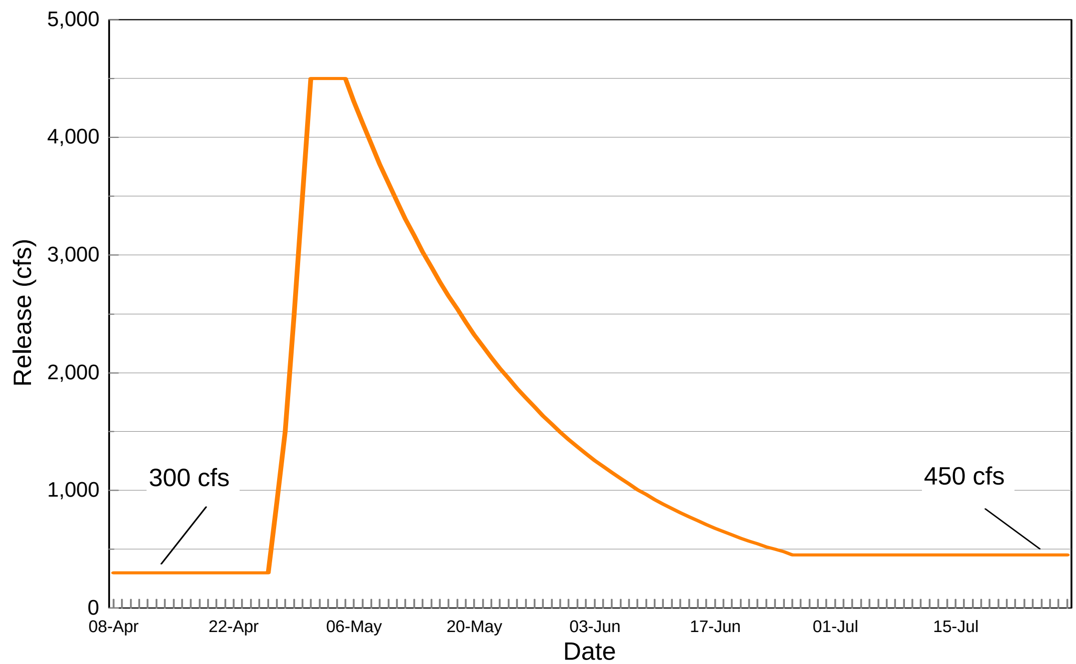

Figure 8.7. Recommended releases during a Dry water year. Releases are scheduled for 450 cfs from June 26 to October 15. Releases are scheduled for 300 cfs from October 16 to April 26.

Releases during much of the descending limb of the dry water year hydrograph inundate alternate bar features, causing mortality of riparian seedlings and preventing germination on bar surfaces, and transport small volumes of fine sediment (sand). The gradual reduction of releases minimizes stranding of fry and juvenile salmonids. Releases during this period provide at least marginal temperatures for coho salmon and chinook salmon smolts throughout the mainstem until mid-June. The gradual reduction of releases allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from June 26 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

“A 36-day peak release of 1,500 cfs . . . inundates most alternate bar surfaces, preventing germination of riparian plants for a portion of the seed-release period.”

8.1.4.5 <u>Critically Dry Water Year</u> (Table 8.9; Figure 8.8)

A release of 450 cfs from October 1 through October 15 maintains water temperatures suitable for spawning spring-run chinook salmon and holding fall-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

A release of 300 cfs from October 16 through April 22 provides suitable microhabitat for spawning and rearing chinook salmon, coho salmon, and steelhead within the existing channel.

Recommended releases increase from 300 cfs on April 22 to 1,500 cfs on April 24 to attain peak release magnitudes for the Critically Dry water year. This ascending limb of the hydrograph is steep, simulating historical rain-on-snow events (McBain and Trush, 1997).

Table 8.9. Recommended releases from Lewiston Dam with management targets, purpose, and benefits during a Critically Dry water year.

Date	Release (cfs)	Hydrograph Component	Management Target	Purpose	Benefits
Oct 1 - Oct 15	450	Fall baseflow	≤ 56º F at confluence of the North Fork Trinity River	Provide optimal holding/spawning temperatures for spring- and fall-run chinook adults	Provide suitable temperatures, reducing pre-spawning mortality and increasing egg viability
Oct 16 - Apr 22	300	Winter baseflow	Provide maximum amount of spawning habitat	Provide best balance of spawning and rearing habitats for all anadromous salmonids in the existing channel	Increase spawning and rearing habitat while minimizing dewatering of redds (dewater less than 5% of redds) of salmonids
Apr 22 - Apr 24	300 - 1,500	Ascending limb	Reach peak flow	Ramp to peak flow (according to OCAP) safely for human use	Reduce travel time of outmigrating steelhead smolts
Apr 24 - Apr 29	1,500	Peak flow	Provide non-lethal water temperatures to Weitchpec for steelhead smolts (≤ 59º F) until May 22 , and for coho salmon smolts (≤ 62.6º F) until May 29 Inundate bar flanks (1,500 cfs)	Sustain steelhead and coho salmon smolt production by providing non-lethal temperatures for survival Discourage riparian vegetation establishment along channel margins	Transport limited amounts of surface fine sediment (<5/16 inch)
May 29 - Jun 26	1,500 - 450	Descending limb	Descend at a rate mimicking pre-TRD descent Provide non-lethal water temperatures to Weitchpec for coho smolts (≤ 62.6º F) until June 4, and for chinook smolts (≤ 68º F) until mid-June	Minimize river stage change to preserve egg masses of yellow legged frogs Inundate point bars Improve salmonid smolt production by providing temperatures necessary for survival of steelhead, coho, chinook smolts	Prevent riparian initiation along low water channel margins Reduce fine sediment (<5/16 inch) storage within surface channelbed Maintain seasonal variable water surface levels in side channel and off-channel wetleands Sustain/ improve salmonid smolt production Provide outmigration cues for chinook salmon smolts
Jun 26 - Sep 30	450	Summer baseflow	Provide water temperatures ≤ 60º F to Douglas City through Sep 14 Provide water temperatures ≤ 56º F to Douglas City from Sep 15 through Sep 30	Increase survival of holding adult spring-run chinook by providing optimal thermal refugia	Increase production of coho salmon and steelhead by providing water temperatures conducive to growth

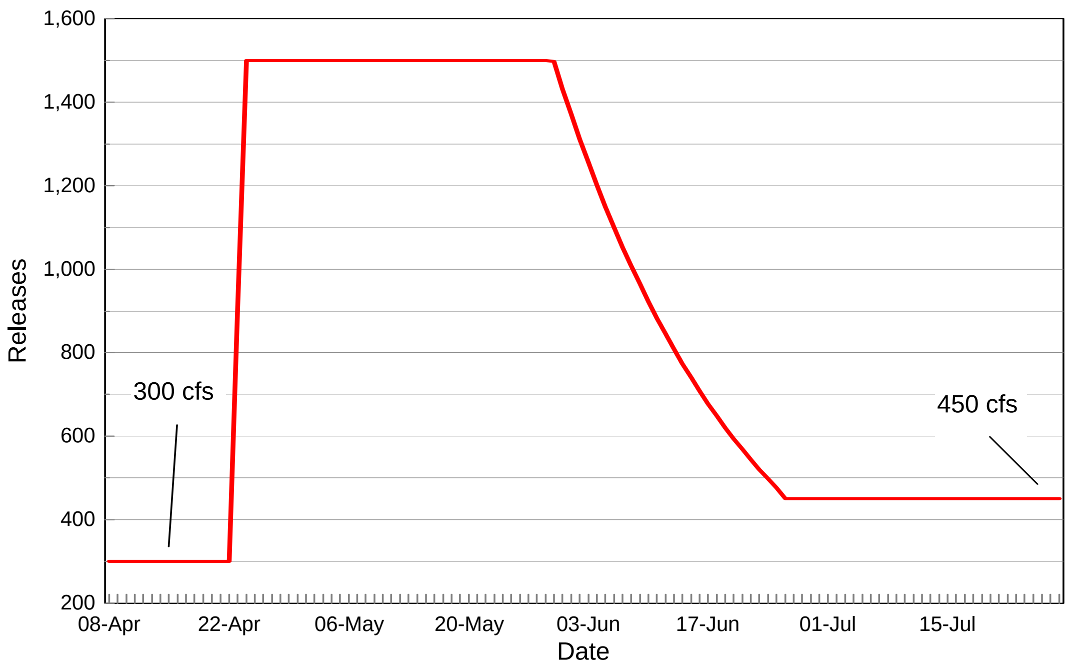

Figure 8.8. Recommended releases during a Critically Dry water year. Releases are scheduled for 450 cfs from June 26 to October 15. Releases are scheduled for 300 cfs from October 16 to April 22.

A 36-day peak release of 1,500 cfs from April 24 to May 29 inundates most alternate bar surfaces, preventing germination of riparian plants for a portion of the seed-release period. The timing of the fluvial geomorphic peak release mimics the historical timing of the snowmelt peak during Dry water years.

Releases gradually decrease from 1,500 cfs on May 29 to 450 cfs on June 26. The rate of this decrease mimics historical conditions during Critically Dry water years (the dry water year descending limb was used because data representing Critically Dry water years were sparse). Releases during part of this period inundate lower alternate bar features, preventing germination of riparian plants on the bars. The gradual reduction of releases will also minimize the probability of stranding of fry and juvenile salmonids. During this period, releases provide at least marginal temperatures for coho salmon and chinook salmon smolts throughout most of the mainstem until late June. The gradual reduction of releases also allows gradual warming of the mainstem to provide outmigration cues to any remaining smolts.

A release of 450 cfs from June 26 through September 30 maintains suitable water temperatures for holding and spawning spring-run chinook salmon in the Trinity River above the confluence with the North Fork Trinity River.

> "Releases during part of this period [the decline from 1,500 to 450 cfs] inundate lower alternate bar features, preventing germination of riparian plants on the bars. The gradual reduction of releases will also minimize the probability of stranding of fry and juvenile salmonids."

"Instead of attempting to mimic winter floods and the associated fluvial processes during winter, these fluvial process requirements are met on a reduced scale during the snowmelt peak . . . . Recommended summer baseflows are stable and comparatively greater than those that historically occurred, but necessary to meet the thermal requirements of holding spring-run chinook salmon and spawning spring- and fall-run chinook salmon."

8.1.5 Comparison of Recommended Releases with Unregulated Hydrographs and Downstream Flows

Release schedules developed for each water-year class show the differences in recommended schedules to unregulated hydrographs at Lewiston (Figures 8.9 to 8.13). Although some components of the recommended hydrographs are similar to unregulated flows (timing of the snowmelt peak and the shape of the descending limb of the snowmelt hydrograph), other components (winter and summer flows) are dissimilar.

Frequent winter storm events, especially during Wet and Extremely Wet water years (Figures 8.9 and 8.10), were responsible for major reshaping of the pre-TRD channel morphology and maintaining the riparian community in an early seral stage, which promoted the alluvial nature of the river. Recommended releases during the winter are comparatively low to meet the microhabitat needs of spawning and rearing salmonids that must spawn and rear in the mainstem below Lewiston Dam. Instead of attempting to mimic winter floods and the associated fluvial processes during winter, these fluvial process requirements are met on a reduced scale during the snowmelt peak. This change in the timing of each year's peak flow decreases the potential of scouring redds and causing mortality of developing eggs and sac fry.

Recommended summer baseflows are stable and comparatively greater than those that historically occurred, but necessary to meet the thermal requirements of holding spring-run chinook salmon and spawning spring- and fall-run chinook salmon. As a result of construction and operation of the TRD, deep thermally stratified pools that provided summer/fall holding habitat no longer exist and releases must now be managed to provide suitable thermal regimes during this period. The lost habitats above Lewiston Dam also historically provided cool refuge because this reach of the river was largely dominated by snowmelt.

Although recommended releases for a water-year class remain the same, intra- and inter-annual flow variability will occur because of flow accretion. The unregulated flow accretion of the tributaries between Lewiston Dam (RM 111.9) and Douglas City (RM 87.7) for water years 1945 to 1951 was determined by subtracting the flow at Lewiston from the flow at Douglas City. The resulting accretion for each water year was then added to the recommended releases of the appropriate water-year class to illustrate the effect of tributary accretion below Lewiston Dam (Figures 8.14A-G). The resulting hydrographs show that substantial intra-annual flow variability will occur within the mainstem. This flow variability, especially during the late fall and winter spawning seasons, will reduce superimposition of redds by distributing spawners as flows fluctuate. Tributary accretion will also help achieve/improve some fluvial geomorphic objectives, as indicated by reduction of recommended channel-rehabilitation sites in reaches farther downstream from Lewiston Dam.

"Although recommended releases for a water year class remain the same, intra- and inter-annual flow variability will occur because of flow accretion."

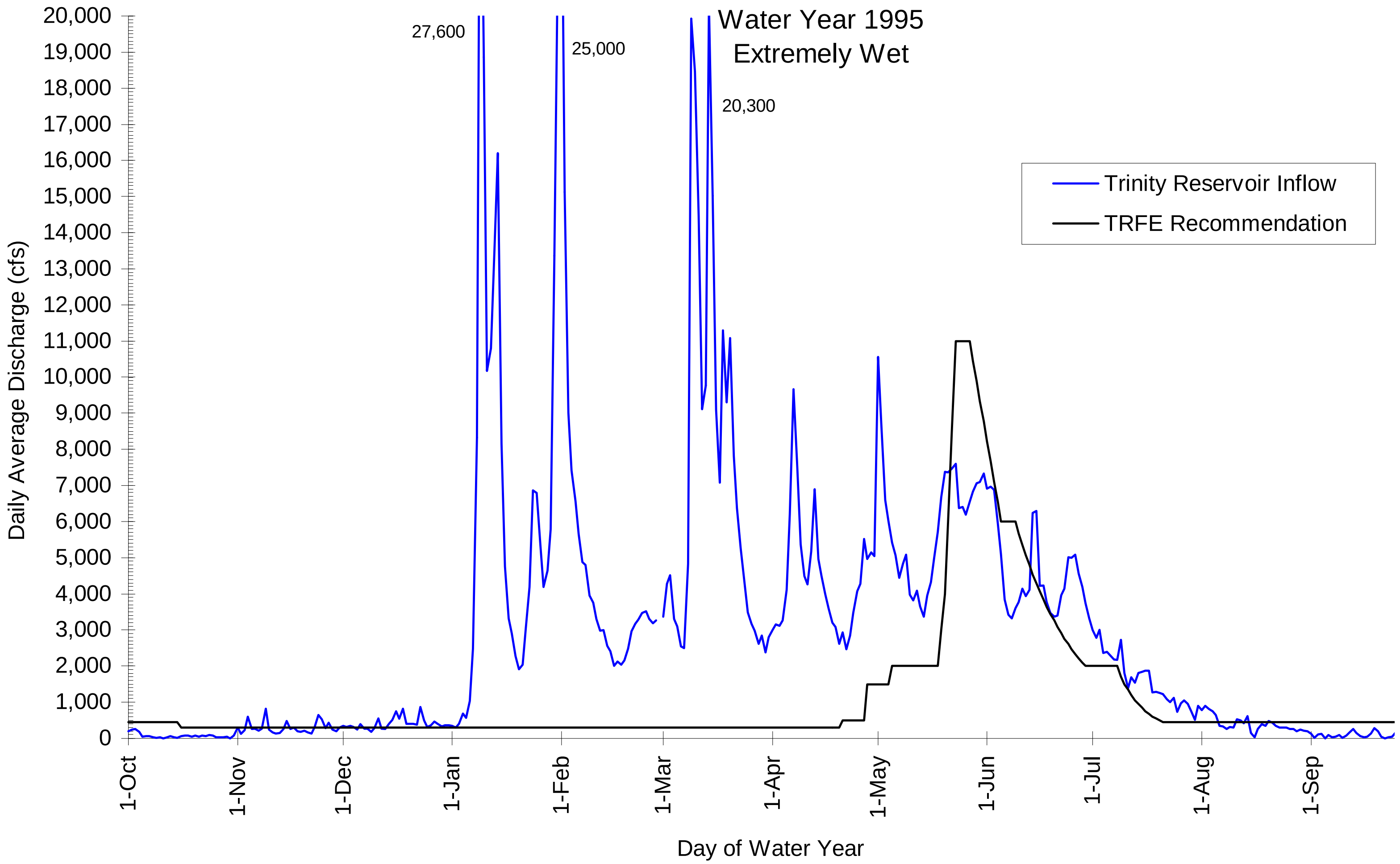

Figure 8.9. Recommended releases during an Extremely Wet water year compared to unimpaired inflow into Trinity Lake for WY 1995. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

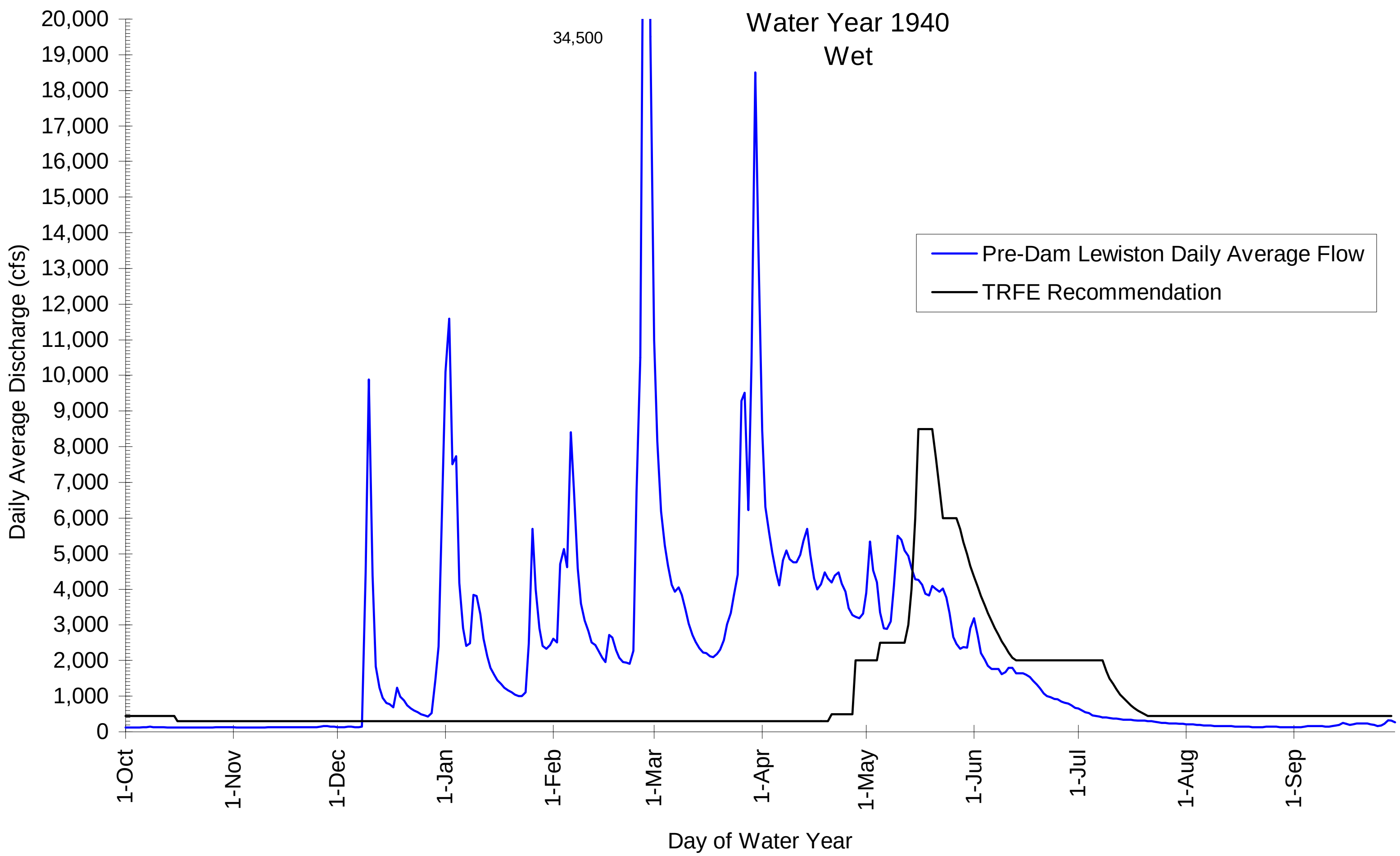

Figure 8.10. Recommended releases during a Wet water year compared to flow in WY 1940. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

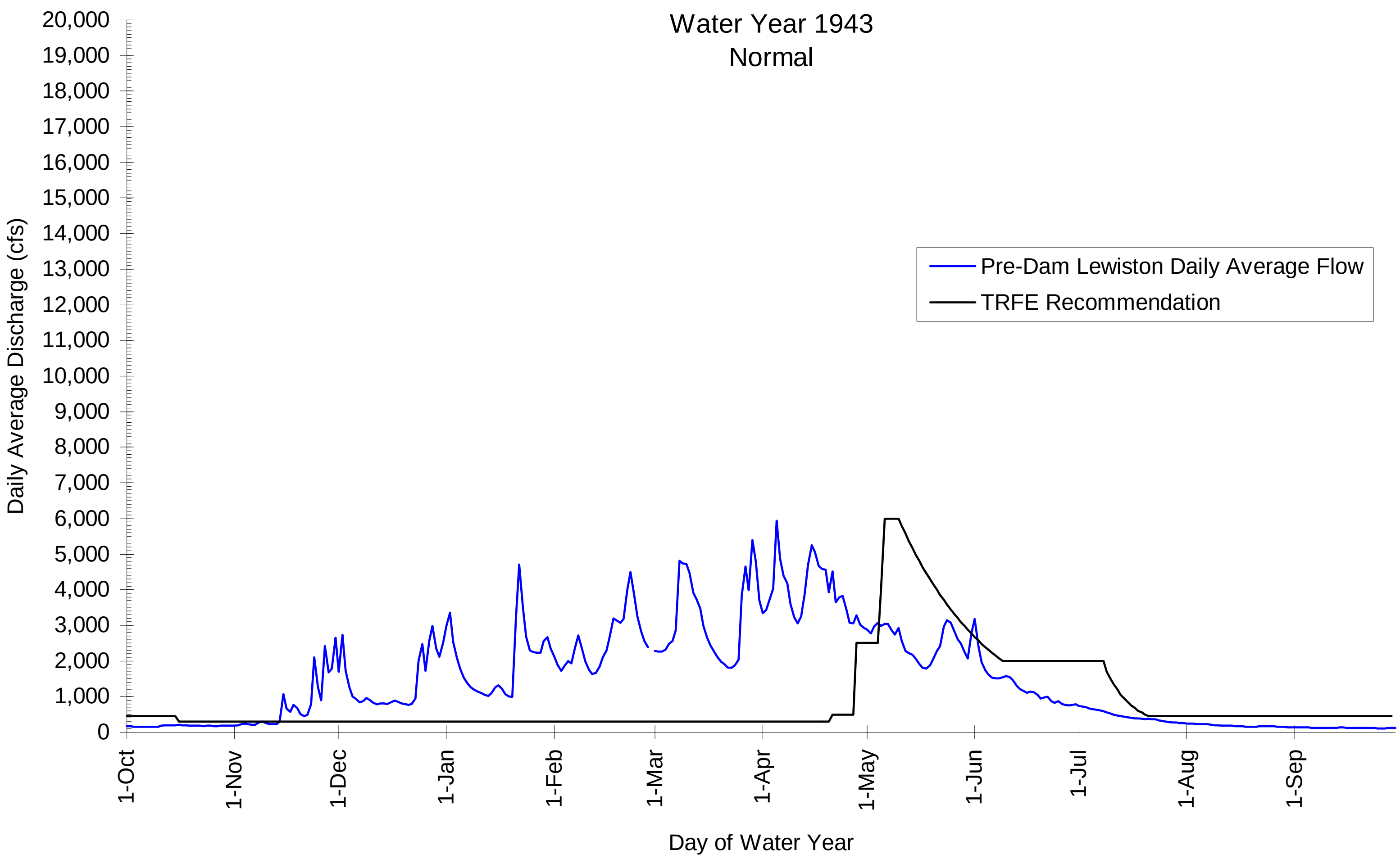

Figure 8.11. Recommended releases during a Normal water year compared to flow in WY 1943.

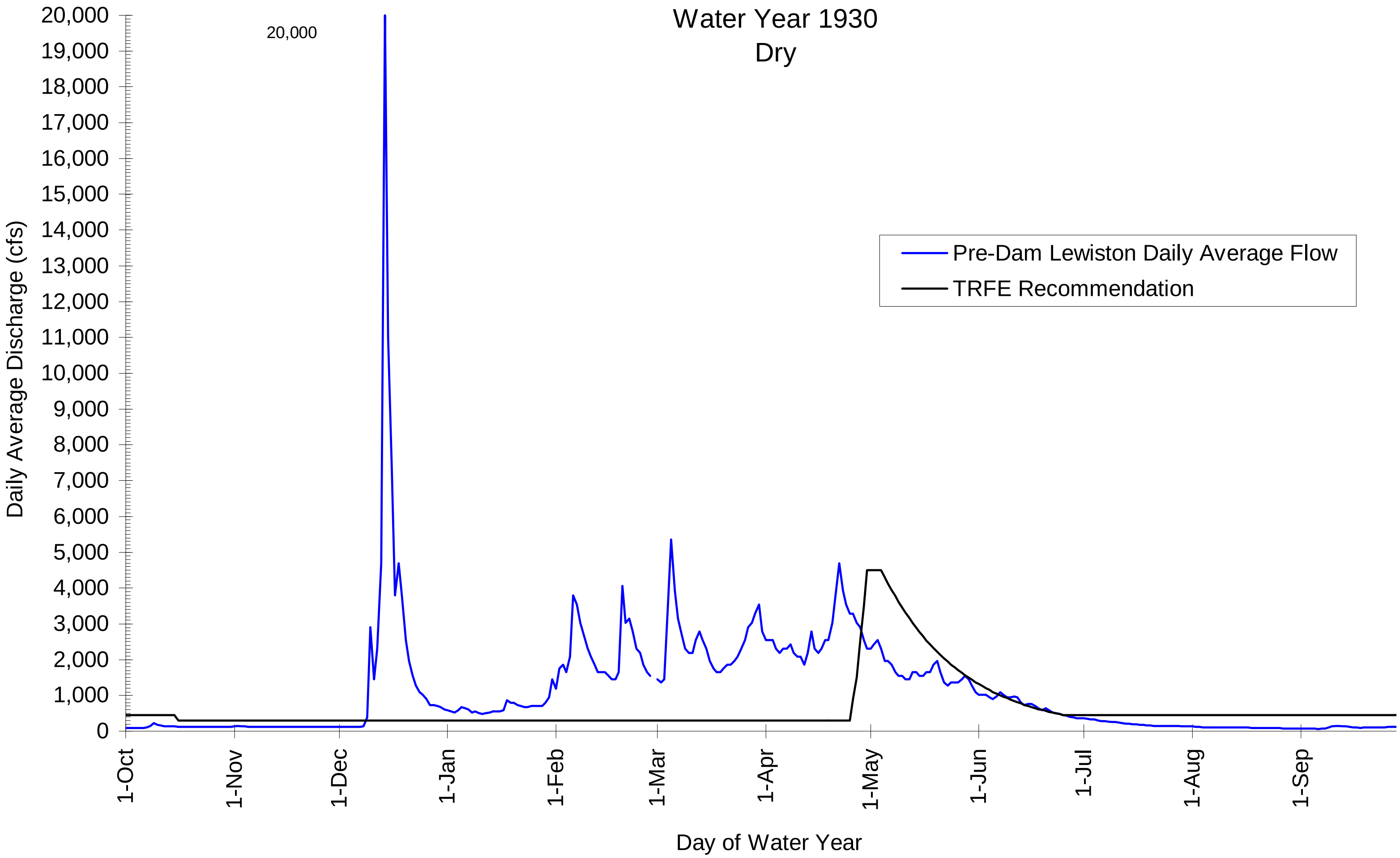

Figure 8.12. Recommended releases during a Dry water year compared to flow in WY 1930. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

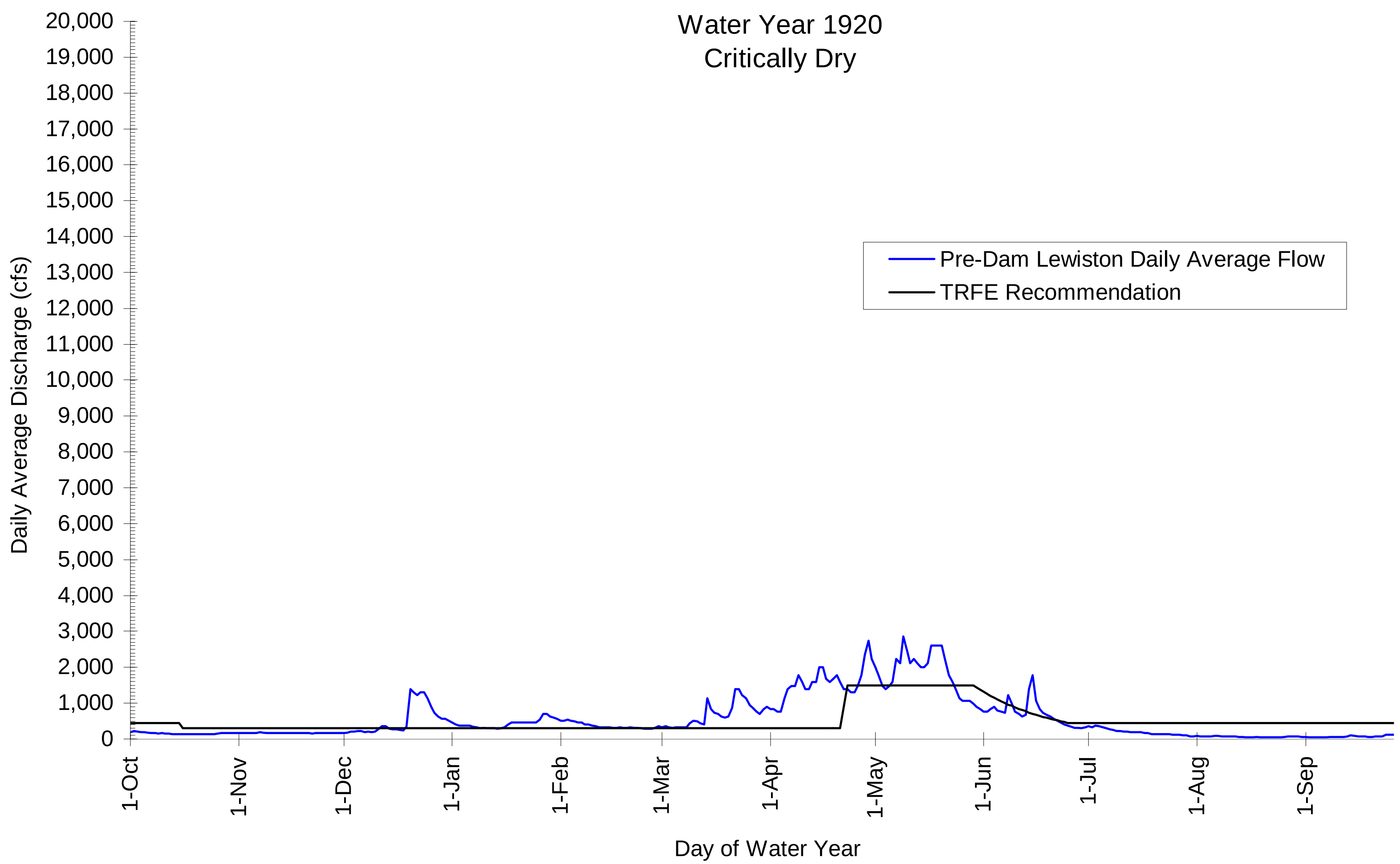

Figure 8.13. Recommended releases during a Critically Dry water year compared to flow in WY 1920.

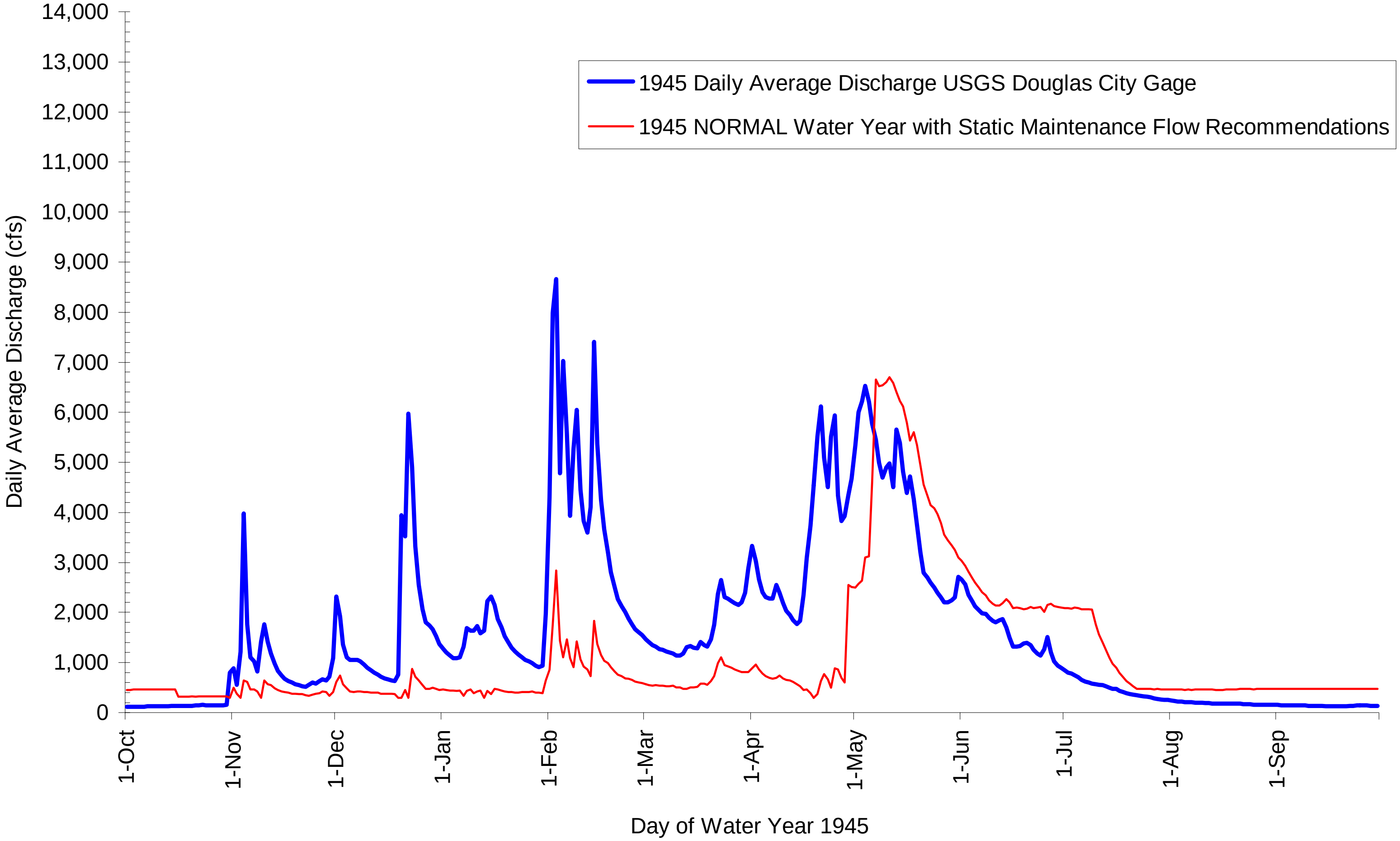

Figure 8.14a. Hypothetical discharge at Douglas City gaging station with normal water-year class release from the TRD and tributary accretion for water year 1945.

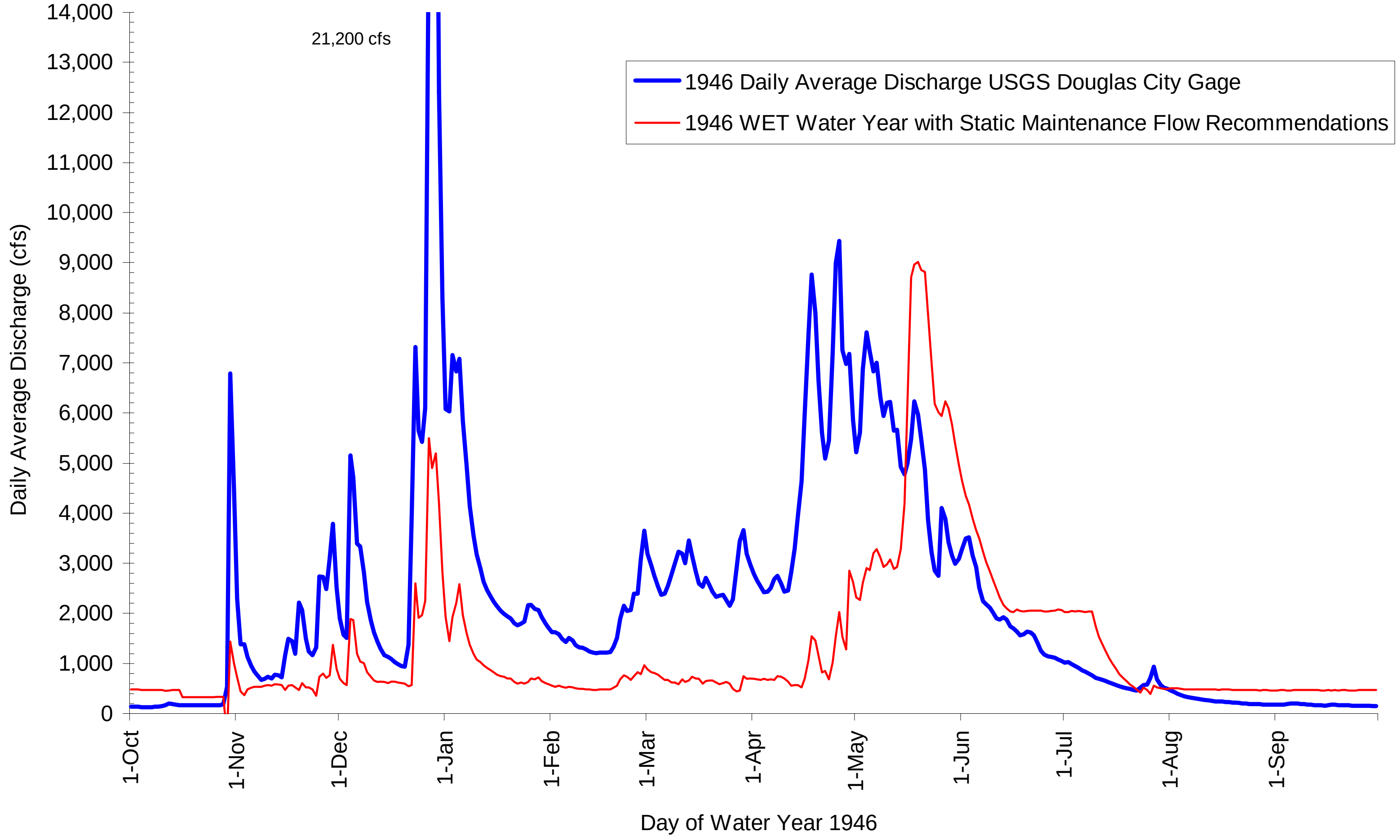

Figure 8.14b. Hypothetical discharge at Douglas City gaging station with wet water-year class release from the TRD and tributary accretion for water year 1946. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

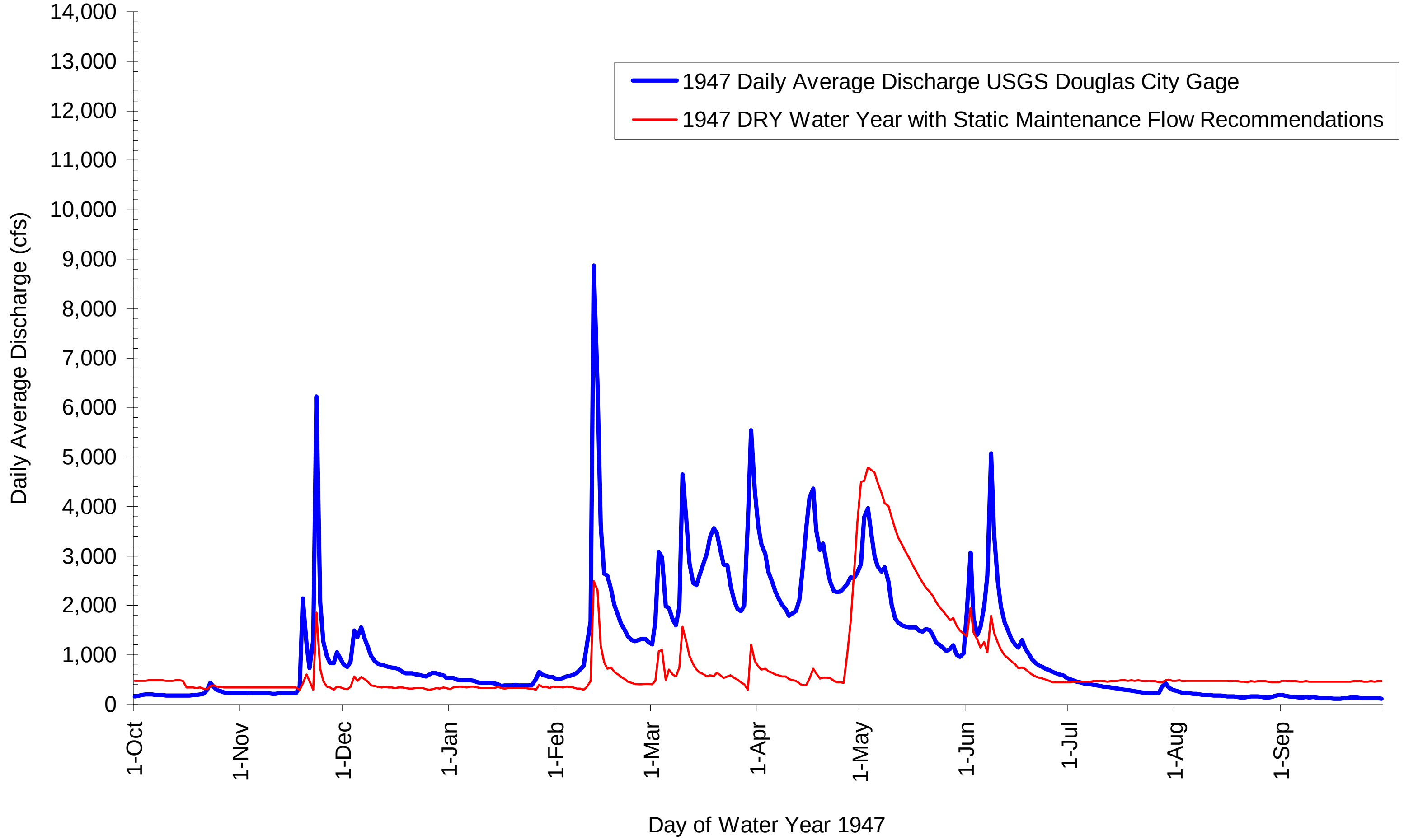

Figure 8.14c. Hypothetical discharge at Douglas City gaging station with dry water-year class release from the TRD and tributary accretion for water year 1947.

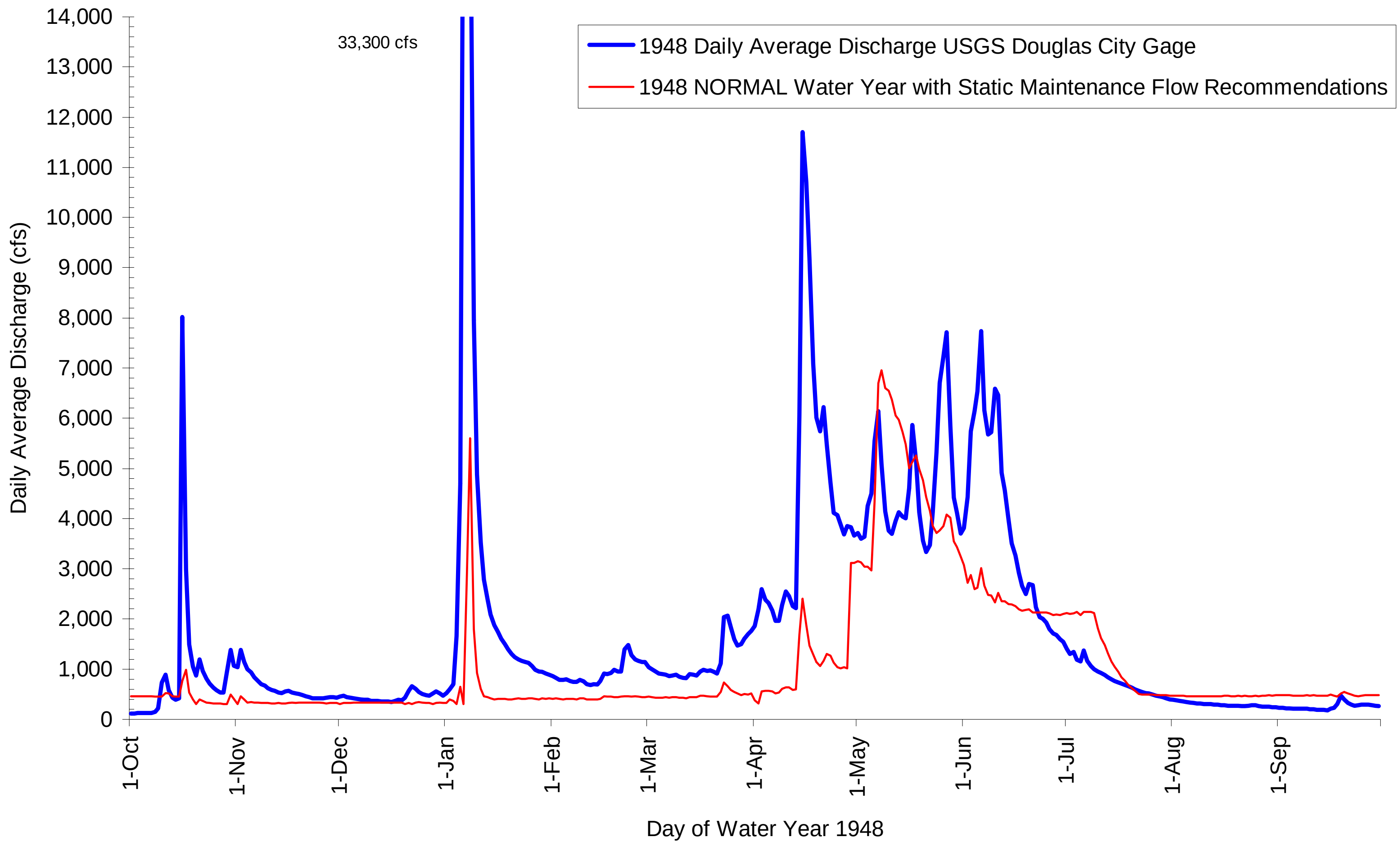

Figure 8.14d. Hypothetical discharge at Douglas City gaging station with normal water-year class release from the TRD and tributary accretion for water year 1948. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

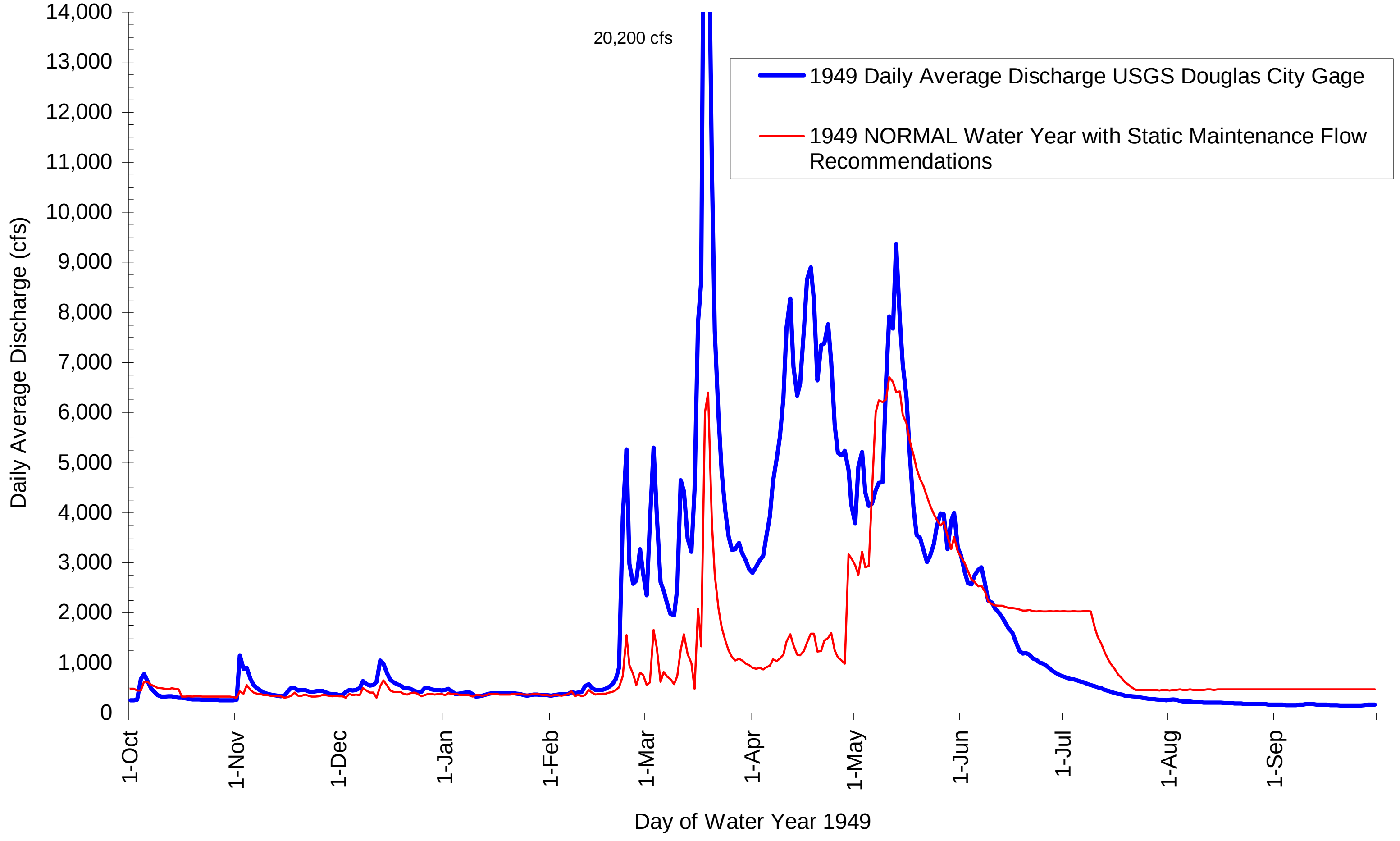

Figure 8.14e. Hypothetical discharge at Douglas City gaging station with normal water-year class release from the TRD and tributary accretion for water year 1949. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

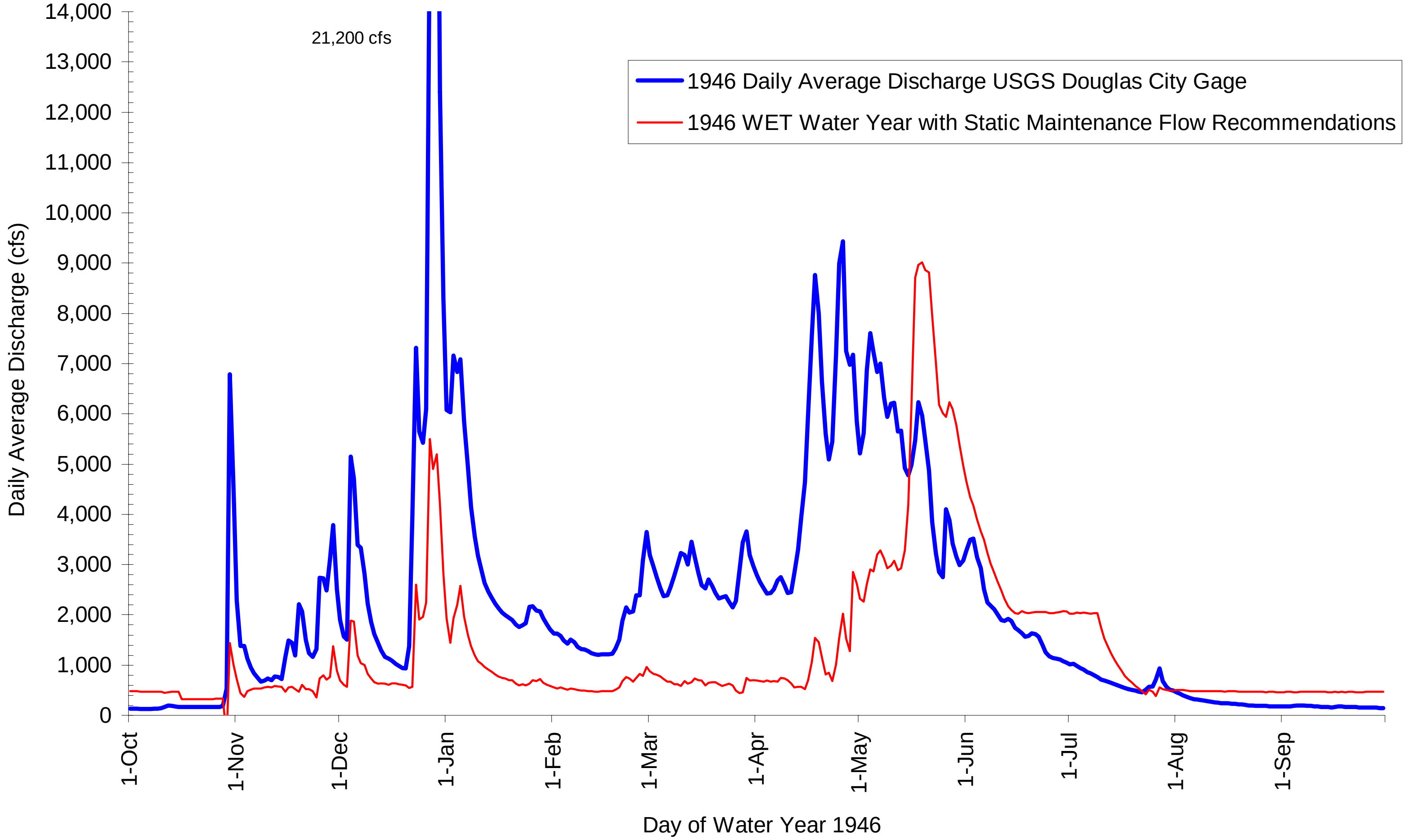

Figure 8.14f. Hypothetical discharge at Douglas City gaging station with wet water-year class release from the TRD and tributary accretion for water year 1946. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

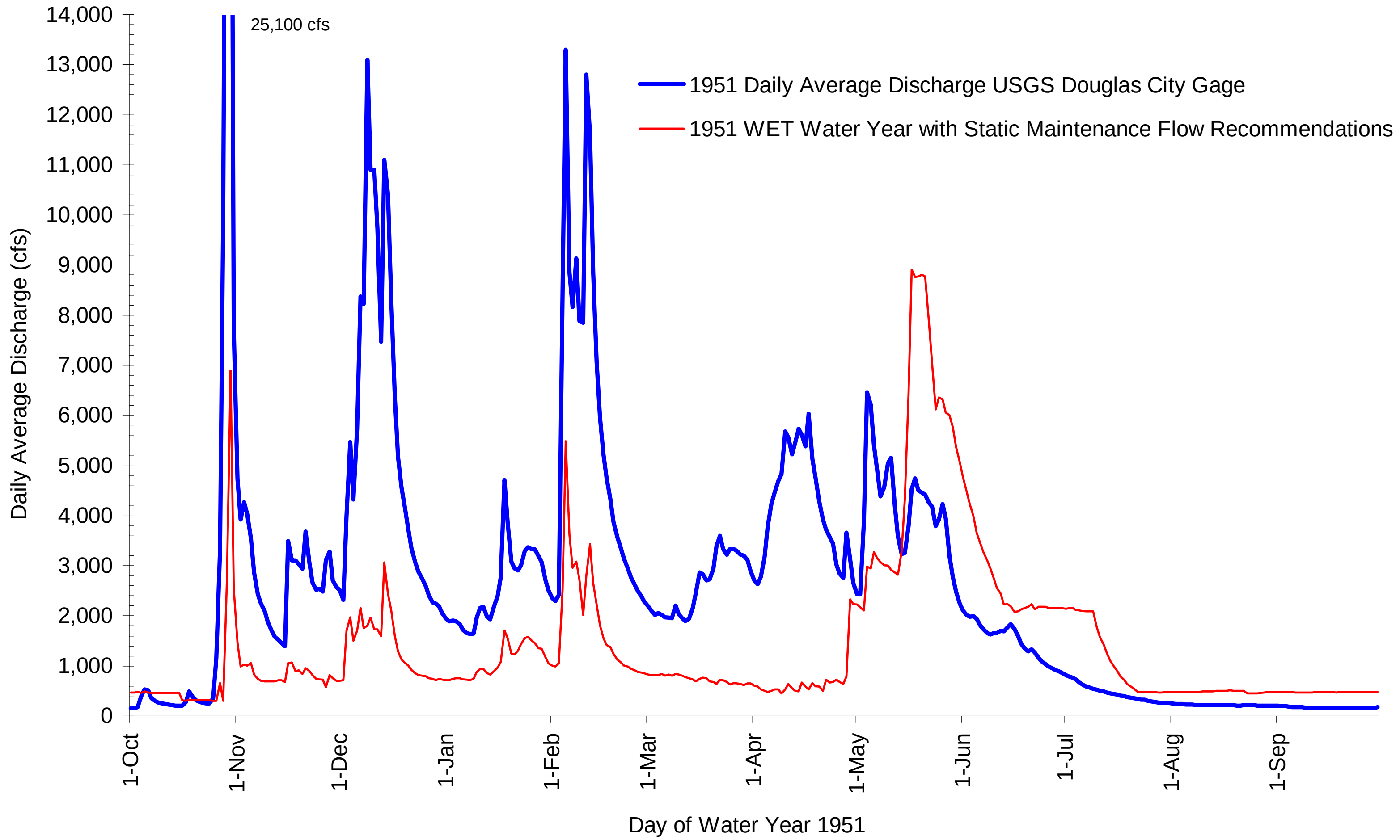

Figure 8.14g. Hypothetical discharge at Douglas City gaging station with wet water-year class release from the TRD and tributary accretion for water year 1951. Instantaneous peak discharges that exceeded the Y-axis maximum are indicated by values (cfs) placed next to the corresponding peak.

8.2 Sediment Management Recommendations

Sediment management recommendations involve four separate actions: (1) immediate placement of coarse sediment (>$^{5}/_{16}$ inch) to restore spawning gravels lost through mainstem transport between Lewiston Dam and Rush Creek; (2) annual supplementation of coarse sediment (>$^{5}/_{16}$ inch) to balance the coarse sediment budget in the Lewiston Dam to Rush Creek reach; (3) fluvial reduction of fine sediment (<$^{5}/_{16}$ inch) storage in the mainstem; and (4) mechanical reduction of fine sediment (<$^{5}/_{16}$ inch) storage in the mainstem. Additionally, recommended channel-rehabilitation projects (Section 8.3) will remove a significant amount of the fine sediment that is now stored (more than 1 million yd^3) in the riparian berms between Lewiston and the North Fork Trinity River confluence. Floodplains created as part of these projects will encourage fine sediment transported during high flows to deposit on the floodplains, thereby reducing in-channel storage.

> "High releases through 1993 to 1998 depleted spawning gravels immediately below Lewiston Dam, causing channelbed degradation . . . "

8.2.1 Short-Term Coarse Sediment Supplementation

There are two sites that require immediate coarse sediment supplementation: a 1,500 foot reach immediately downstream from Lewiston Dam (RM 111.9), and a 750 foot reach immediately upstream from the USGS cableway at Lewiston (RM 110.2) (Figure 8.15). The Lewiston Dam site last received spawning gravel supplementation in 1998. However, supplementation immediately below the Dam has not been sufficient to offset gravel transport. High releases in 1993 through 1998 caused channelbed degradation to a depth of approximately 2 feet. Restoring 2 feet of bed elevation in the Lewiston Dam reach will require approximately 10,000 yd^3 of properly graded gravel material.

The USGS cableway reach has also lost spawning gravels, degrading substantially (approximately 2 feet) over the past several years. Restoring 2 feet of bed elevation in this reach will require approximately 6,000 yd^3 of properly graded gravel material. Because the immediate benefit of gravel added to both sites will be for spawning and rearing habitat, the sizes should range from $^{5}/_{16}$ inch to 5 inches. The first source for gravel should be the 2,000 yd^3 of screened gravel stored at the Old Lewiston Bridge. Additional gravel may be obtained at dredge tailings downstream from Lewiston. Dredge tailings on the south bank near Lewiston (RM 108.5) and on the west bank at Gold Bar (RM 106.3) are the nearest sources. A secondary benefit realized by utilizing these dredge tailings will be the conversion of these areas to functioning floodplains with riparian vegetation.

8.2.2 Annual Coarse Sediment Introduction

Maintaining a coarse sediment balance in the reach from Lewiston Dam to Rush Creek will require annual augmentation to replace sediment transported by peak flows. Estimates of coarse sediment (>$^{5}/_{16}$ inch) transport during high flows for each water-year class were used to calculate replacement volumes (Table 8.10). Dredge tailings downstream from Lewiston (RM 108.5) and Gold Bar (RM 106.3) should again be used as the sediment source. Tailing materials should be screened to a size of $^{5}/_{16}$ to 5 inches to maximize immediate spawning benefits. Two placement methods are recommended: (1) mechanical placement in the two riffles described above in the short-term supplementation sites; and (2) insertion into the large standing wave at the Lewiston Gaging station (RM 110.9) during peak releases. Placement of gravel in the riffles should occur after annual peak releases to replace coarse bed material transported during the peak release. Coarse sediment should be

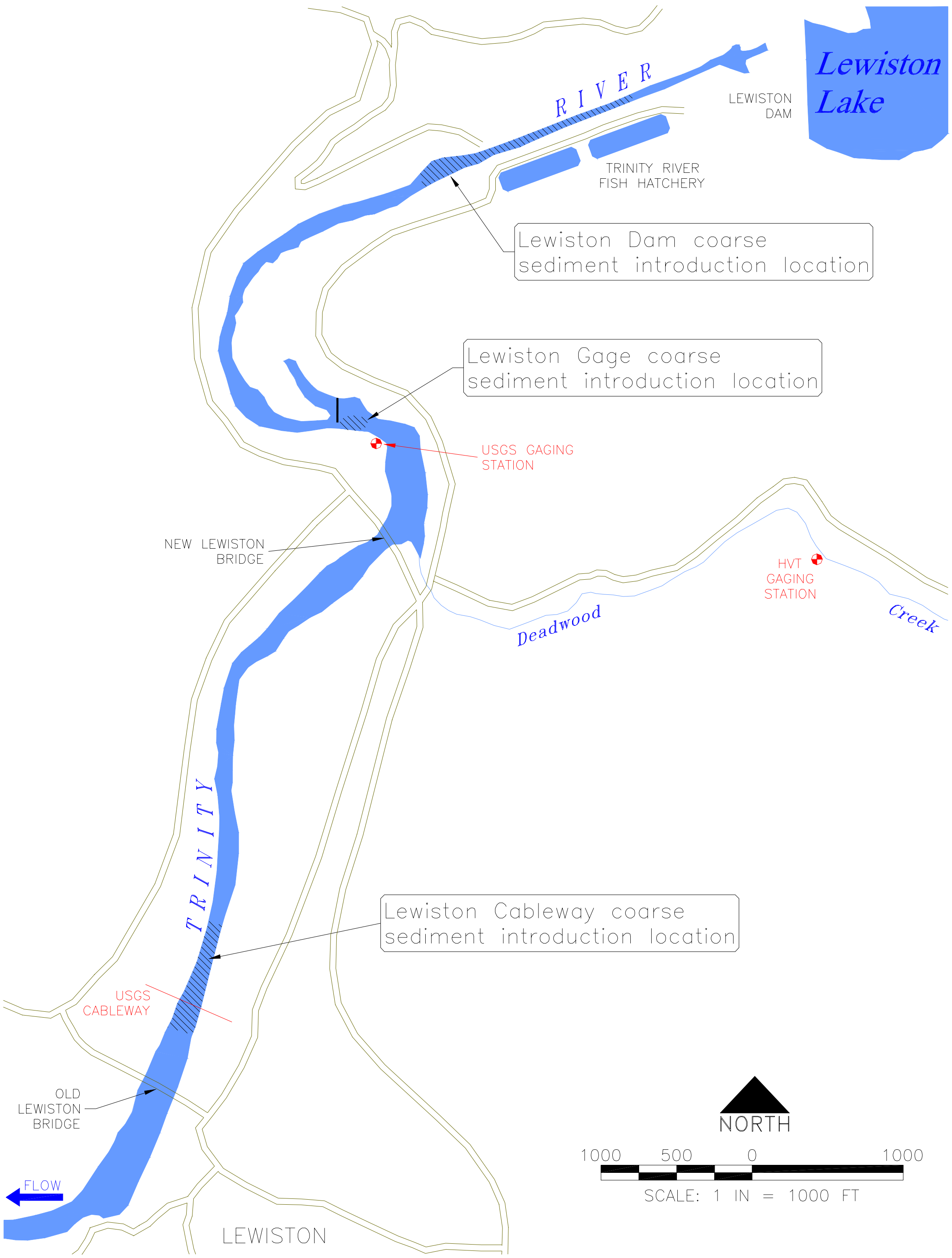

Figure 8.15. Trinity River (RM 109.8 - 111.5) priority coarse sediment supplementation locations.

Table 8.10. Annual coarse sediment replacement estimates for the Lewiston Dam to Rush Creek reach. Actual volume will be determined by modeled and measured transport each year.

Water Year	Coarse Sediment Introduction (yd^3/year)
Extremely Wet	31,000 - 67,000
Wet	10,000 - 18,000
Normal	1,800 - 2,200
Dry	150 - 250
Critically Dry	0

placed into the standing wave at the Lewiston Gaging station during peak releases to facilitate fluvial distribution downstream.

8.2.3 Fine Sediment Reduction: Sedimentation Ponds

Buckhorn Dam and Hamilton Ponds have reduced fine sediment supply from the Grass Valley Creek watershed. Their operation and maintenance should be continued. A fundamental problem, however, has been rapid filling of Hamilton Ponds during high-flow events, and subsequent reduced trapping efficiency, allowing fine sediment to transport into the Trinity River. Funding and a sediment removal contract needs to be continually in place so that sediment deposited in the ponds can be removed during the storm season to maintain trapping efficiency. Most sediment trapped by the Hamilton Ponds is sand; however, the coarse sediment (>$^5/_{16}$ inch) should be screened from deposits and returned to the Trinity River at the mouth of Grass Valley Creek to help maintain adequate coarse sediment supply downstream and reduce the volume of spoils removed from Hamilton Ponds.

Hoadley Gulch (RM 109.8) is a small tributary entering the Trinity River 2 miles downstream from Lewiston Dam that contributes substantial quantities of sand to the Trinity River during large storm events. The volume of sand yielded to the Trinity River from Hoadley Gulch has not been quantified; therefore, no comparison of volume can be made with the sediment-transport capacity of the Trinity River. The relative importance of Hoadley Gulch's sand contribution in comparison with other tributaries (e.g., Rush Creek) should be evaluated to determine if a sedimentation pond is warranted.

8.2.4 Fine Sediment Reduction: Pool Dredging

Measurements and observations in pools downstream from Grass Valley Creek show that fine sediment storage is decreasing. Recommended flow regimes should further decrease in-channel fine sediment storage. Therefore, pool dredging is not recommended, but may be considered under the adaptive environmental assessment and management program (see Section 8.4).

"Funding and a sediment removal contract needs to be continually in place so that sediment deposited in the ponds can be removed during the storm season to maintain trapping efficiency."

8.3 Channel Rehabilitation

Channel-rehabilitation recommendations fall into four categories:

1. Bank rehabilitation on a forced-meander bend (Figure 8.16);
2. Alternate bar rehabilitation over longer reaches (Figure 8.17);
3. Side channel construction over short reaches (Figure 8.18); and
4. Tributary delta maintenance. Local removal of the very coarse sediment (boulders) that causes aggradation and hydraulic backwater effects upstream from deltas.

The Service and Hoopa Valley Tribe identified 44 potential channel-rehabilitation sites (Appendix G, Plate 1), 3 potential side channel-rehabilitation sites (Appendix G, Plate 2), and 2 tributary delta maintenance sites in the reach between Lewiston Dam and the North Fork Trinity River. These sites are located where channel morphology, sediment supply, and high-flow hydraulics would encourage a dynamic, alluvial channel (Table 8.11). A short implementation period for a significant number of these projects and an evaluation of whether they achieve their intended benefits is recommended. Those benefits— increasing quality and quantity of salmonid habitat— need to be balanced by logistics, contractor availability, and construction windows. Therefore, construction of 24 of the 44 channel-rehabilitation sites in the first 3 years is recommended. The remaining projects may proceed following a re-evaluation by the Adaptive Environmental Assessment Management Program (see Section 8.4).

> "These [channel rehabilitation] sites are located where channel morphology, sediment supply, and high-flow hydraulics would encourage a dynamic, alluvial channel."

The Lewiston Dam to Rush Creek and Rush Creek to Indian Creek reaches are distinctly different from those downstream owing to the considerable accretion of flows and sediment downstream from Indian Creek. As a result, unique strategies are recommended for each reach:

Lewiston Dam to Rush Creek (RM 111.9 to RM 107.5)

- Construct bank rehabilitation and alternate bar rehabilitation projects that include building skeletal point bars after riparian berms are removed to encourage development of alternate bars and increase coarse sediment supply in the reach. Skeletal bars would have a framework of large cobbles (> 5 inches), covered by several feet of finer material ($^5/_{16}$ to 5 inches).
- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cottonwood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.
- Maintain existing side channels. Because coarse sediment supply is less than in downstream reaches, plugging by sediment deposition is less likely than for side channels downstream from Indian Creek.
- Remove the coarse fraction (boulders) of Rush Creek delta deposit to lessen backwater effect and improve sediment-routing from upstream reach.
- Construct three bank rehabilitation projects and two alternate bar rehabilitation projects during years 1-3 to increase habitat in this important spawning and rearing reach. Rebuild floodplains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

Rush Creek to Indian Creek (RM 107.5 to RM 95.3)

- Construct bank rehabilitation and alternate bar rehabilitation projects that include building

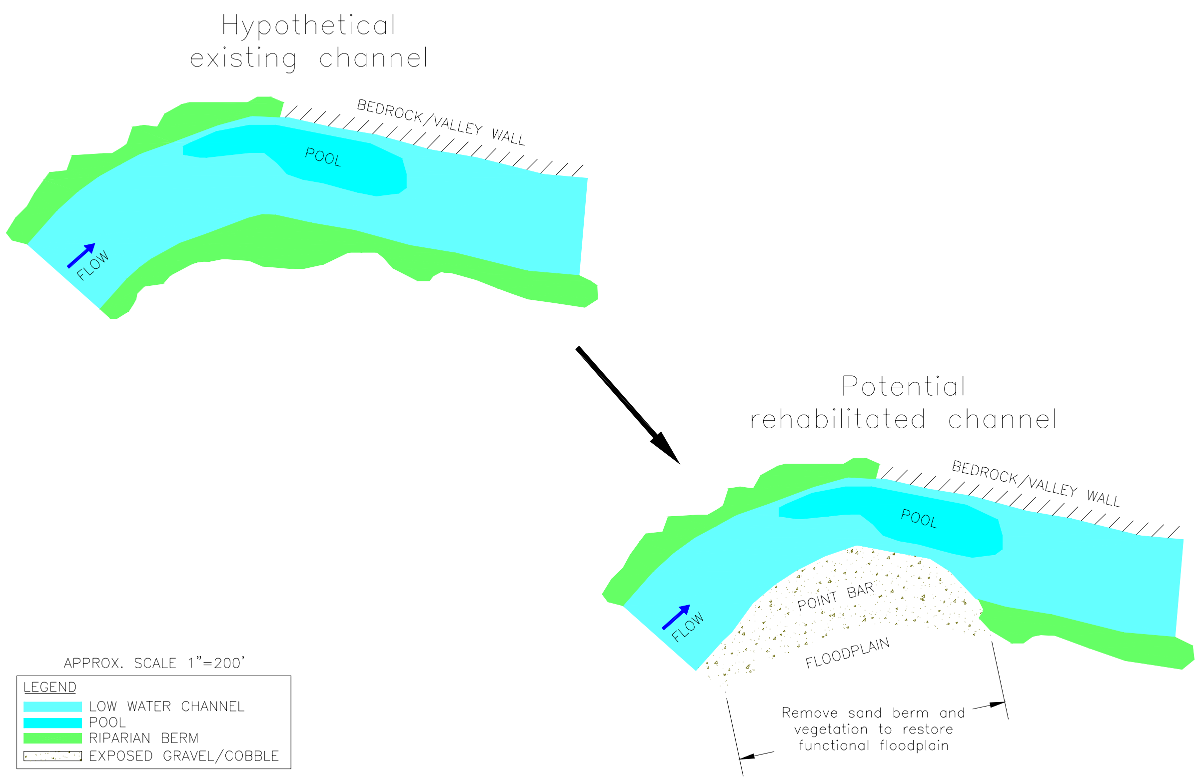

Figure 8.16. Trinity River conceptual single forced meander channel rehabilitations.

skeletal point bars after riparian berms are removed to encourage development of alternate bars and increase coarse sediment supply in the reach. Skeletal bars would have a framework of large cobbles (>5 inches), covered by several feet of finer material ($^{5}/_{16}$ to 5 inches).

- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cotton-wood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.

- Maintain existing side channels. Because coarse sediment supply is less than in downstream reaches, plugging by sediment deposition is less likely than for side channels downstream from Indian Creek.

- Evaluate high-flow hydraulics of the two potential side channel sites, and construct these only if potential for self-maintenance is high.

- Remove the coarse fraction (boulders) of Indian Creek delta deposits to lessen the backwater effect and improve sediment-routing from upstream reach.

- Construct 7 of the 14 bank and alternate bar rehabilitation projects in years 1-3. Rebuild flood-plains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

Indian Creek to Dutch Creek (RM 95.3 to RM 86.3)

- Because coarse sediment supply and tributary flood events are increasing downstream from Indian Creek, construction of skeletal point bars may not be required. Simply removing the riparian berm at key

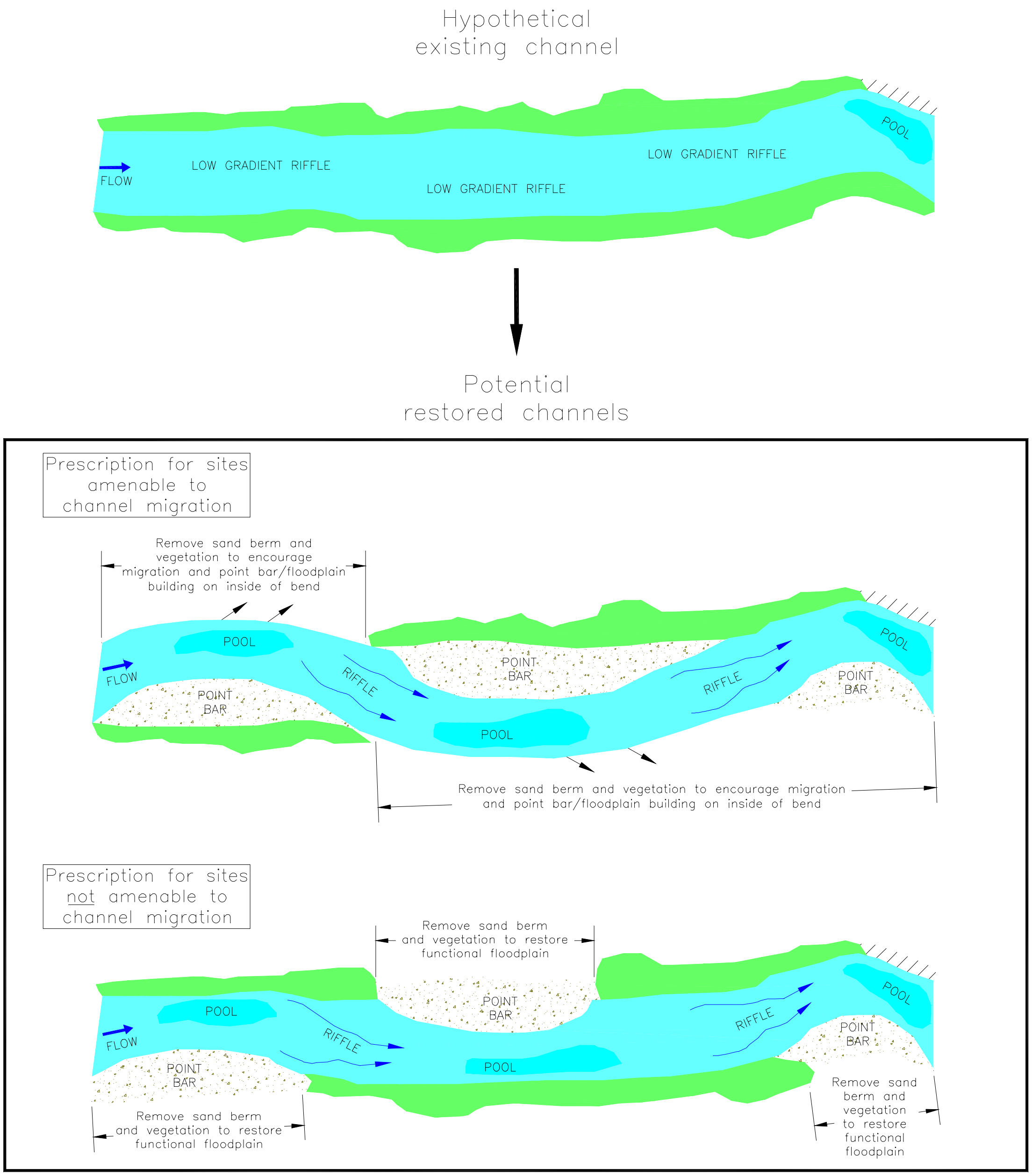

Figure 8.17. Trinity River conceptual alternate bar channel rehabilitation.

locations may induce alternate bars to form during high flows. If bar formation does not occur following first years of high flows, construction of skeletal bars (described above) should be considered in subsequent years.

- Construct five of the seven bank and alternate bar rehabilitation projects in years 1-3. Rebuild floodplains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

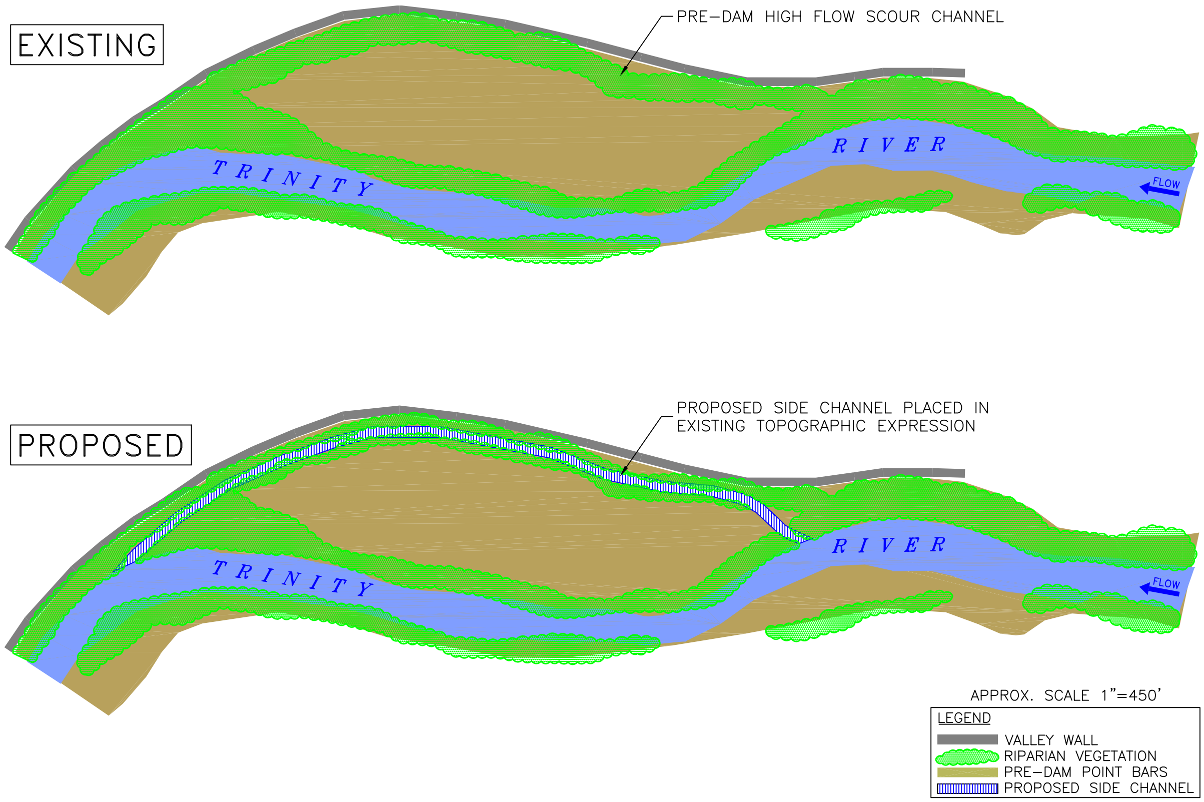

Figure 8.18. Trinity River conceptual side channel rehabilitation.

- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cottonwood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.

- Evaluate high-flow hydraulics of side channel site, and construct only if potential for self-maintenance is high.

- Evaluate whether constructed side channels should be abandoned. Because this mainstem segment is considerably more dynamic than upstream segments, maintenance of side channels will be costly.

Dutch Creek to North Fork (RM 86.3 to RM 72.4)

- Bank and alternate bar rehabilitation projects in this reach are not likely to require skeletal bars to be constructed, because coarse sediment supply and flow accretions increase substantially downstream from Indian Creek. Simply removing the riparian berm at key locations will likely induce alternate bars to form during subsequent high flows. If bar formation does not occur following initial high flows, construction of skeletal bars (described above) should be considered in subsequent years.

- Construct 7 of the 18 bank and alternate bar rehabilitation projects in years 1-3. Rebuild floodplains and point bars to initiate channel migration, allow floodplain inundation, and encourage natural side channel and backwater creation.

Table 8.11. Potential channel-rehabilitation sites between Lewiston Dam and the North Fork Trinity River.

Reach	River Mile	Potential bank rehabilitation sites	Potential alternate bar rehabilitation sites	Potential side-channel sites
Lewiston Dam to Rush Creek	111.9 - 107.5	3	2	0
Rush Creek to Indian Creek	107.5 - 95.3	7	7	2
Indian Creek to Dutch Creek	95.3 - 86.3	3	4	1
Dutch Creek to North Fork Trinity River	86.3 - 72.4	10	8	0
Total		23	21	3

- Evaluate high-flow hydraulics of potential side channel site, and construct only if potential for self-maintenance is high.
- Channel-rehabilitation projects should be larger in this reach than in upstream reaches because of increasing channel size and channel-forming flows. Reshaping floodplain areas and low terraces, especially in areas adjacent to dredge tailings, will be required.
- Revegetate reconstructed floodplains with native woody riparian species, emphasizing black cottonwood (*Populus balsamifera*) and Fremont cottonwood (*Populus fremontia*) to increase the seed source for natural regeneration.
- Abandon constructed side channels and incorporate these areas into floodplains.
- Incorporate constructing off-channel wetlands and oxbow ponds into rehabilitation projects, specifically in projects with adjacent dredge tailings.

8.4 AEAM Recommendations to Monitor and Refine the Annual Operating Criteria and Procedures (OCAP) and Other Recommendations for Restoring and Maintaining the Trinity River Fishery Resources

This Trinity River Flow Evaluation Report concludes that the river channel has degraded to such an extent that simply managing flow releases from the existing reservoirs cannot achieve the salmonid restoration goals mandated by Congress. The primary hypothesis is that a combination of managed high-flow releases, mechanical riparian berm removal, and gravel augmentation will redirect geomorphic processes so that a more complex channel form will evolve, creating the mosaic of aquatic habitats necessary to enhance freshwater salmonid production. Although many of the anticipated changes will be monitored on an annual or semiannual basis, longer-term monitoring and assessment must also occur concurrently due to the prolonged life-histories of salmonids. Over a longer time period, adult returns and the numbers of fish contributing to ocean and inriver fisheries will be a measure of success.

> This Trinity River Flow Evaluation Report concludes that the river channel has degraded to such an extent that simply managing flow releases from the existing reservoirs cannot achieve the salmonid restoration goals mandated by Congress.

Reservoir releases and channel-rehabilitation projects should substantially increase carrying capacity (usable salmonid rearing habitat area) within the rehabilitated channel. What is not known is the rate of change or time frame needed to achieve this new channel equilibrium. AEAM (Appendix N) will facilitate achieving the salmonid restoration goals. The management actions prescribed include channel rehabilitation in combination with annual reservoir releases based on forecasted water supply and the recommended flow regime for the water-year class based on the hydrographs presented in this chapter. These water year flow regimes, each with unique hydrograph components, provide the inter-annual variability necessary to drive the fluvial processes toward a new channel configuration while maintaining the hydraulic and temperature conditions at levels that are greater in quality than those existing since the closure of the dams.

8.4.1 Goals and Objectives for the Trinity River

One of the stated goals for the Trinity River is " . . . the development of recommendations regarding permanent instream fishery flow requirements and Trinity River Division operating criteria and procedures for restoration and maintenance of the Trinity River fishery" (Central Valley Project Improvement Act, Title XXXIV of P.L. 102-575). This report recommends five flow regimes (Appendix M), including operating criteria and procedures for each water-year class. Primary objectives of the recommendations are:

1. Manage the reservoir releases to provide a much improved (near optimum) temperature regime. An optimum temperature regime increases fish residence time and growth rates, resulting in larger smolts exiting the system. Larger smolts have better survival leading to an increase in number of returning adults.

2. Manage the river corridor to increase the shallow-edgewater and backwater habitats necessary for many anadromous young-of-year salmonids.

3. Manage reservoir releases to control vegetation establishment on alluvial features. Schedule reservoir releases to scour seedlings on bars following the seed fall during the spring-summer period. Investigate superimposing reservoir releases on tributary flows when the opportunity is present.

4. Manage reservoir releases within the evolving channel to optimize hydraulic conditions for spawning, incubation, and young-of-year production for a given water year and channel form. As the channel changes from the present trapezoidal form toward the desired alternating point bar configuration, the slope of the hydrograph should be adjusted annually to maximize suitable conditions for a given year.

8.4.2 Hypotheses

The premise of the Trinity River Flow Evaluation Report recommendations is that a combination of mechanical alterations and vegetation removal in addition to

> The primary hypothesis of this flow evaluation is that a combination of managed high-flow releases, mechanical riparian berm removal, and gravel augmentation will redirect geomorphic processes so that a more complex channel form will evolve, creating the mosaic of aquatic habitats necessary to enhance freshwater salmonid production.

managed high-flow releases in the spring will promote geofluvial processes leading to a new channel form that is expected to provide significantly increased spawning and rearing habitat for anadromous salmonids. The assumptions, hypotheses, and logic upon which the recommended management actions presented in this report are based are summarized in Appendix O. Only the most prominent hypotheses are presented.

One of the central hypotheses is that habitat diversity in the upper river, both on the meso- and micro-habitat scale, will increase following the implementation of the recommendations. Although the changes in habitat diversity are expected to be obvious, there will remain a question as to degree of change. A methodology must be embraced to quantify the existing habitat diversity and the annual change created as the management recommendations are implemented. This will enable comparative evaluations to be made and elucidate the effectiveness of specific restoration measures.

A second hypothesis central to the recommendations is that juvenile salmonid rearing habitat, believed to be limiting smolt production in the Trinity River, will increase in both quantity and quality following the creation of a more complex and dynamic channel form. Rearing habitat area, which at present is highly variable depending on streamflow, will increase (at least a doubling) and become more stable over a wide range of flows.

The third central hypothesis is that salmonid smolt survival will improve as a result of better temperature conditions that increase growth and promote extended smoltification and reduced travel time associated with emigration.

Before proceeding with AEAM, this set of hypotheses and series of events is transformed into a set of measurable responses. By way of examples, we offer three initial quantification steps.

First, describe the existing channel geometry in two dimensions by sub-sampling along surveyed transects or grids. Sub-sampling should be sufficient to describe the bathymetry of the alternate bar pool sequences at upper, lower and middle portions of the river from Lewiston Dam to the North Fork Trinity River confluence. Transects should be geo-referenced so that monitoring measurements can be repeated. These measurements are needed to quantify the degree of bar formation, lateral movement, and establishment of woody vegetation attained on an annual basis. The straight trapezoidal channel should evolve toward a more sinuous alternate bar form having increased shallow water area and low-velocity backwaters critical for rearing young salmonids.

Second, the amount of habitat area available to provide suitable spawning and rearing conditions should be measured annually. Geomorphology, vegetation conditions, and salmonid habitat must be quantified using the same sampling strategy. The same strategy allows extrapolation describing 40 miles between Lewiston Dam and the North Fork Trinity River confluence.

Third, the length and weight of chinook salmon young-of-year can be sampled every few weeks from hatching through emigration from the stream study segment. Substantial trapping effort at the downstream end of the study segment is needed to estimate the total number of chinook salmon pre-smolts leaving the segment. These two sets of measurements can be used to estimate growth increments through the season and young-of-year production within the river. In addition to the hypotheses and water year rehabilitation objectives, the state of the knowledge is presented in Appendix O as a solid science foundation for the AEAMP to build upon.

8.4.3 Document Channel Form, Riparian Vegetation, and Salmonid Population Trends

Through comparison of annual measurements and the use of simulation modeling, progress toward the habitat and production objectives can be quantitatively expressed. Progress toward the program objectives and any trends identified should be reported annually to the stakeholders. This report may address the following questions:

Are salmonid population numbers (quantify as population estimates not just abundance indices) improving?

Is anadromous salmonid habitat improving?

Are native riparian communities establishing on different geomorphic surfaces? Are reservoir releases removing germinated vegetation?

Are the riparian berms continuing to build, are they remaining stable, or are they beginning to break down from Lewiston Dam to the North Fork Trinity River confluence?

Are channel reaches migrating laterally and becoming more dynamic?

Are floodplains forming?

Are alternate bars forming?

How does Trinity River water affect water quality of the Klamath River? There is evidence that water-quality conditions in the Klamath River may be, at times,

Causal Analysis – A Complement to Time Series

Monitoring often produces a time-series representation of the changes in a system. However, time is rarely the cause of the changes. AEAM focuses on causal analysis of monitoring data. Ordinarily the object of the monitoring occupies the x-axis, and is plotted against time (y-axis). While indicative of the trends in a system, time-series fail to directly expose the causes of the more obvious trends. Causal analysis replaces time on the abscissa with causative factors (e.g., habitat). A strong functional relationship indicates causation of trends in the system. The figures demonstrate the difference between a time-series and a causal analysis.

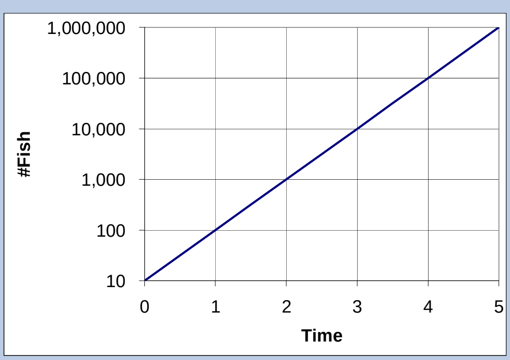

Figure 1. Time Series.

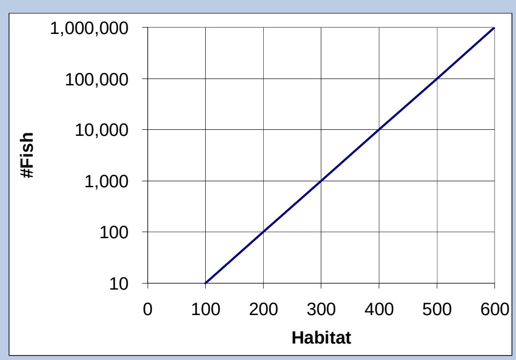

Figure 2. Causal Analysis.

While both figures show an increasing trend in the number of fish, Figure 2 illustrates a direct response in fish numbers given an increase in habitat area. Such causal analyses give management a stronger indication of the system controls.

substantially worse than those in the Trinity River. Will the difference in water quality occur during spring outmigration, especially in dry years? If so, how is this affecting smolt survival? What about other life stages?

8.4.4 Management Actions

The recommendations for management actions incorporate different schedules for flow releases under five defined water-year classes (determined by water-supply conditions measured each spring from mid-February through April). All year classes include a recommendation of high-flow releases in late April to mid-July and a program of gravel placement in the mainstem. These releases are recommended in addition to proposed riparian-berm-removal projects. The intent of riparian-berm-removal projects is to remove the densely vegetated riparian berms at selected sites along the river from Lewiston Dam downstream to the North Fork confluence.

Different April-July flow-release schedules are proposed for Normal, Wet, and Extremely Wet years such that in 6 out of 10 years the channel is predicted to change in cross section and planform. The goal is a meandering alternate bar configuration within the old floodplain. These water-year classes, each with unique hydrograph components, provide the inter-annual variability necessary to affect fluvial processes. A rehabilitated channel, although smaller in scale than the pre-TRD channel, could sustain perhaps two to four times the amount of salmonid rearing habitat now present. Results from SALMOD suggest that young-of-year production can be substantially increased if the rehabilitated channel attains a four-fold increase in the total available rearing habitat throughout the 40-mile reach below Lewiston Dam, all other things being equal (same average ocean survival and number of returning spawners and no further degradation of water quality, etc.).

The current recommendations were made in part, based on microhabitat studies in the existing channel. The existing baseline conditions can be quantitatively expressed as historical time series starting with streamflow and reservoir release records. The resulting hydrologic time series is input for SNTEMP (Theurer et al., 1984), PHABSIM (Milhous et al., 1989), and the Time Series Library (TSLIB) (Milhous et al., 1990) to produce a weekly estimate of the total usable habitat available throughout the study segment. The habitat time series is input to the SALMOD (Bartholow et. al., 1999) to produce a weekly time series of salmonid production estimates. This includes estimates of growth, downstream distribution, and number exiting the study segment.

Although the habitat-response hypotheses could be tested using the one-dimensional hydraulic and habitat models within PHABSIM, an alternative now exists. This alternative utilizes two-dimensional hydraulic models that provide major advancements in riverine habitat assessments. Many in the instream-flow-modeling community believe that two-dimensional hydraulic models are superior to their one-dimensional counterparts for simulating velocity distribution throughout river channel reaches (Ghanem et al., 1994; Leclerc et al., 1995). These advantages are particularly evident in complex river channels of the type it is hypothesized that the Trinity River will become as a result of the proposed management. These models are spatially explicit, allowing calculation of different measures of habitat environmental heterogeneity, and offer the potential to describe both spatial and temporal heterogeneity, in a single habitat metric. This new technology is recommended for evaluating habitat response to the proposed Trinity River AEAM actions.

8.4.5 Implement Actions

The AEAM program (see Section 8.4.2) will initiate its yearly cycle by convening each year in mid-February following initial water-supply forecasts provided by

Reclamation. Along with its other duties, the objective of the AEAM Program is to prescribe the precise magnitude and duration of reservoir releases confirming or modifying the OCAP for that year. These releases are based on the recommendations provided earlier in this chapter as well as other relevant information. The goals of the release schedule include mobilizing alluvial features established the previous year, scouring emergent riparian vegetation, and achieving sediment transport. Physical process modeling will aid the team in optimizing the reservoir release necessary to mobilize alluvial features and optimize lateral bank cutting. After the water year has been declared by Reclamation, these physical process models can simulate the remainder of the water year based upon the OCAP.

The degree of channel change can then be projected using the HEC-6 or other physical process models that predict aggradation or degradation of the channel. Kondolf and Micheli (1995) present a protocol for documenting changes in channel form. Reservoir release temperatures, downstream water temperature, usable habitat, and young-of-year chinook salmon production are all then simulated using the assumed reservoir release schedule and the physical model predicted channel changes. Annual estimates of returning adult chinook salmon spawners and the habitat state during the previous fall are important inputs to these simulations. Therefore, each annual production run is based on the latest empirical data (September-May) and simulated conditions for the remainder of the biological year (May-July).

8.4.6 Monitoring Program

Physical process numerical models are useful in two ways. First they require a systematic collection of data inputs. A well-designed monitoring program will yield the correct type, quality, quantity, and frequency of data. Second, they indicate where significant physical changes may occur, serving to focus monitoring activity in new, and perhaps unexpected, locations.

For example, the run mesohabitat type currently dominates the river above Dutch Creek. These runs are generally long and straight, confined by riparian berms on both sides. At the targeted rehabilitation sites, the removal of the riparian berm on one side of the river and the implementation of the prescribed flow regimes should produce alternate bar morphology with adjacent pools as is described in Section 4.1 of this report. Besides these major mesohabitat features, it is expected that additional mesohabitat types will also result, such as backwaters and riffle-pool transitional habitats. The number of different mesohabitat types and the proportion each represents should change significantly over current conditions, as should the range of hydraulic conditions present.

The annual evaluation of habitat changes at the mesohabitat level is straightforward. The types of pre-project mesohabitats present, the area each encompasses, and the proportion each represents in the reach will be compared with conditions in the previous year. A more detailed evaluation of habitat diversity is needed at the microhabitat scale.

The premise is that all habitat types are potentially important to the health of the anadromous salmonid community. Therefore, the monitoring objective is to quantitatively describe the mix of heterogeneous microhabitat types without regard to which species or life stage may or may not use a particular type. This is done by defining discrete, non-overlapping combinations of microhabitat characteristics and treating these in the same manner as individual species in developing community metrics.

Bain and Boltz (1989) introduced the concept of developing habitat suitability criteria to define habitat use guilds. The same concept can be applied to defining microhabitat types. For example, depth can be classified as shallow, moderate, or deep; likewise, velocities can be partitioned into slow, medium, and fast classifications; cover could be designated by function (e.g., velocity shelter) or simply by presence or absence. Illustrated in Table 8.12 is an example set of divisions that could be

Table 8.12. Example divisions of velocity, depth, and cover to delineate microhabitat types for habitat diversity hypothesis testing.

Microhabitat Attribute	Classification	Range
Velocity	Slow	0.0 - 1.0 fps
	Moderate	1.01 - 2.0 fps
	Fast	2.01 - 4.0 fps
Depth	Shallow	0.1 - 1.0 ft
	Moderate	1.1 - 3.0 ft
	Deep	3.1 - 6.0 ft
Cover	Present	Present
	Absent	Absent

used to delineate sub-classes of variables. Each of the 18 combinations describes a unique microhabitat type (e.g. shallow, slow, no cover).

Because each combination of habitat attributes is unique, it can be treated much the same as a species in traditional community ecology. Thus, for a given streamflow, one could derive values for habitat richness (the number of unique microhabitat types present), habitat diversity (an index of the heterogeneity among microhabitat types present), and habitat evenness (the ratio between calculated microhabitat diversity and the maximum microhabitat diversity possible).

The habitat diversity-discharge relations, displayed graphically, will allow comparative evaluations to determine if microhabitat diversity is increasing in the rehabilitation reaches. These relations will also provide insight into the stability of microhabitat diversity. That would be an indicator of the constancy in abundance of diverse microhabitat conditions as stream discharge changes. A time series analysis will show the temporal variability of habitat diversity. Using the habitat diversity-discharge function and a hydrologic time series, an annual chronology of habitat diversity could be evaluated.

On an annual basis assess the abundance and health (size, growth, diseases, ATPase activity) of smolts utilizing cooler water-temperature conditions. Fish samples for measurement using rotary screw-taps or other capture techniques, at key locations (upper Trinity River, lower Trinity River, and near the estuary), could be taken. On a longer time scale, use adult returns as a measure of success.

Under controlled and natural settings, examine how water temperature affects smoltification of Trinity River parr and smolts. There may also be a need to examine the effects of low dissolved oxygen concentrations on parr and smolts, particularly during Dry and Critically Dry years.

8.4.7 Compare Predictions versus Observations

During early winter, model simulations are run again using the actual preceding 12 months of flow releases and downstream tributary inflows. Seldom do meteorological and precipitation patterns follow seasonal patterns exactly as in the past. Therefore, the physical process and biological models are more fairly tested by comparing outputs (predictions) based on actual (as near as they can be determined) streamflow distribution through the river

An Example

The Stream Network Temperature model (SNTEMP) predicts temperatures in the mainstem of the Trinity River at various points downstream of Lewiston Dam. Inputs into SNTEMP include meteorological data, mainstem and tributary flow rates, and outflow temperatures from Lewiston Dam. The output from SNTEMP is useful in determining if the temperature of the mainstem is within the desirable range for optimal growth rates and outmigration (smoltification) of anadromous fish.

As a water year progresses, management will monitor meteorological and other data prescribed by the monitoring program. In a cooler than average year, the flow in the mainstem will warm slowly compared to an average or warm year. Much of the flow in the late spring and early summer is necessary to maintain desirable temperatures in the mainstem. Meteorological and flow data, processed by the SNTEMP and other models, will reflect the cooler temperature in the mainstem. If predicted temperatures are below the desirable range, then reducing flow should continue to meet temperature requirements. Realizing efficient flow management is a matter of combining predictive models with a directed monitoring program.

segment. Habitat and salmonid production outputs are compared with measured channel form, smolt growth, and production.

8.4.8 Restate System Status

The system state and the degree of progress toward the stated management objectives are determined by comparison with the previous year's observations.

8.4.9 Adapt and Modify Actions as Needed

Scientific evidence is presented to the managers and stakeholders in support of or refuting the original hypotheses. Scientists revisit the hypotheses (or develop new hypotheses if originals are rejected) and recalibrate models awaiting the next round of forecasts, decisions, and simulations. If certain hypotheses are rejected or alternatives are proposed, alternate flow releases or other management actions are designed (within the bounds of the annual water year volume) and submitted to management prior to the winter-spring forecast period. Table 8.13 lists the models and the monitoring-data needs as described for the Trinity River.

8.5 Roles and Responsibilities

Implementation of the AEAMP is critical to the success of the Trinity River fishery restoration and maintenance effort. The authors recognize that all views of stakeholders should be considered in designing an implementation program. Our underlying principles are that "best science" underpin yearly and within-year operating decisions and that all Trinity River AEAM Program activities would comply with applicable laws and permitting requirements. Additionally, independent review must be consistent and panels would provide peer review of all technical studies, analyses, and evaluations generated by the program.

The program would be directed by the Secretary through a designee, who would serve as the principal contact for the AEAM and as the focal point for issues and decisions

Table 8.13. Data, techniques, and models for interdisciplinary analyses.

	Geomorphology	Sedimentation	Temperature	Fish Population	Water Supply	Riparian Vegetation	Dam Safety	Inundation
Data	Bar structure Bar mobilization Bar migration Berm/riparian destruction	X-section & aerial gradations Transport by size fraction Fate: scour/fill	Reservoir boundary condition	Number of spawners Presmolt outmigration Spawning locations Size of outmigrations Rearing habitat	Annual forecast January through May	Density Age Type Germination	Encroachment on rule curve envelope	Water stage recorders Bridges Urban encroachment
Techniques	Annual videography Ground Survey Aerial topography X-section at reference sites Longitudinal water surface & bed profiles Particle size fractions Gradations	Bed load/suspended load Discharge recording Tributary measurements Particle size fractions Gradations	Width/depth Shade Temperature recording Tributary measurements	Estimates of escapement and smolt production Estimates of useable habitat area		Seedling counts Ground survey	Rule curve operational limitations	
Models	HEC-2 (HEC-RAS) HEC-6	HEC-6	SNTEMP BETTER WQRRS	SALMOD	Empirical Forecast PROSIM TRNMOD	Vegetation establishment model, Mahoney and Rood (1998)	DMBRK/ BREACH FLDWAV PROSIM	HEC-2 (HEC-RAS)
Simulation Predictions	Areas of bars/pools by reach	Scour and fill Gravel quality	Longitudinal profile Forecast time series	Weekly number and size leaving specific areas	Updated biweekly	Area of bars w/seedlings Durability by reach	Storage volume Reservoir elevation Number of encroachment events	Flood levels and duration downstream of Trinity

associated with the program. His/her responsibility would include ensuring that the Department of the Interior fulfills its obligations to restore and maintain the Trinity River Fishery.

Components of the Trinity AEAMP include a Trinity Management Council (TMC) supported by a Technical Modeling and Analysis Team (TMAT) and a rotating Scientific Advisory Board (SAB). The program would include consultation with other agencies and interested groups through periodic interaction through a Stakeholders Group. Scientific credibility would be assured through external peer review of operating plans, models, sampling designs, and projections as outlined in Figure 8.19. The general roles and responsibilities of these groups are summarized below.

8.5.1 Trinity Management Council

The TMC would be composed of fishery agency representatives. The Secretary's designee would serve as Executive Director. The TMC would approve fishery restoration plans and any proposed changes to annual operating schedules (described earlier in this chapter) submitted by the Technical Modeling and Analysis Team (see Section 8.5.2). The TMC would be the focal point for issues and decisions associated with the program. The Executive Director's responsibilities would include ensuring that the Department of the Interior fulfills its obligations for streamflow releases and rehabilitation of the river corridor habitats. The Executive Director in consultation with the Council members would review, modify, accept, or remand the recommendations from the TMAT in making decisions about any changes in reservoir releases, dam operations, and other management actions.

8.5.2 Technical Modeling and Analysis Team

The TMAT would consist of a permanent group of 4 to 8 scientists selected to represent the interdisciplinary nature of the decision process. Collectively, they must possess the skills and knowledge of several disciplines: water resources, engineering, geomorphology, water quality, fish population biology, riparian ecology, computer modeling, and data management. Depending upon the number of individuals selected and possible related duties, they may be assigned from 50 to 100 percent time to the TMAT. The TMAT responsibilities include design for data collection, methodology, analyses, modeling, predictions, and evaluating hypotheses and model improvements. This Team would have delegated from the Executive Director a budget and the responsibility for preparing requests for proposals (RFP) to conduct specialized data collections for model input and validation. Spatial coverage and sampling designs for long-term monitoring for status and trends would be developed in consultation with the management agencies and specific recommendations made to the TMC for funding. Funding for the long-term monitoring would remain with the TMC.

8.5.3 Scientific Advisory Board

The SAB would be appointed by the Executive Director. This group would be composed of prominent scientists appointed and appropriately compensated for 2 to 3 year

> "A riverine ecosystem perspective accurately describes the intent to improve anadromous salmonid habitat . . . . [and] to promote alluvial riverine characteristics . . . . These recommendations are intended to shift the ecological role of the mainstem below Lewiston Dam toward one that will provide the habitats necessary to restore the fishery resources of the Trinity River."

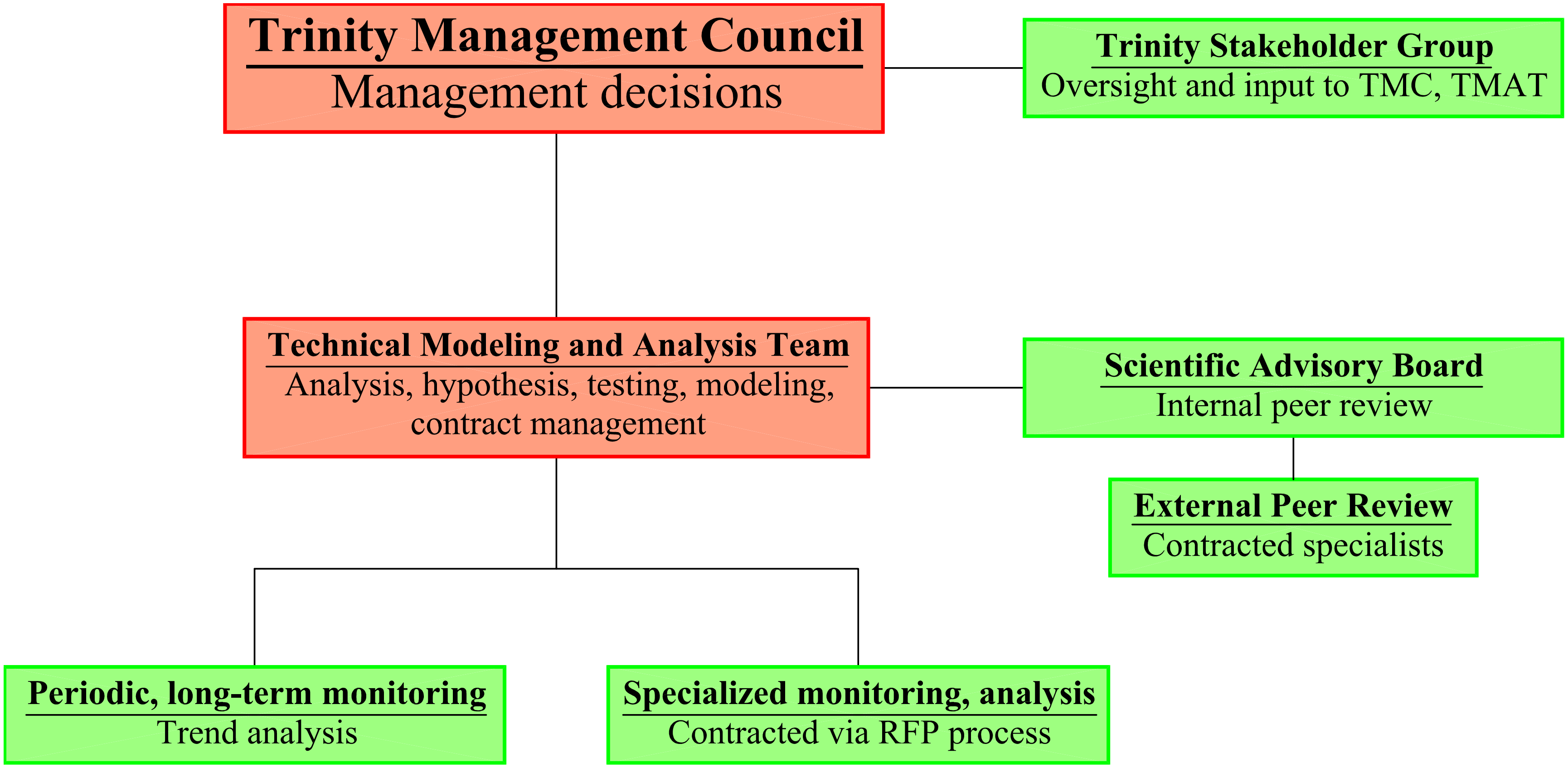

Figure 8.19. Organizational components of a successful Adaptive Environmental Assessment and Management (AEAM) program.

rotating terms. The SAB would be responsible for semiannual review of the analyses, models, and projections of the TMAT as well as providing a science review of the overall management plans and implementation of the annual operating criteria and procedures (described earlier in this chapter) as directed by the TMC. The SAB would also select outside peer reviewers and conduct the review and selection process for any contracted data collection, research, or model development.

8.6 Summary

Allowing the Trinity River to resume its alluvial nature through the integration of increased instream releases, fine and coarse sediment management, and mechanical channel alteration is necessary to restore its anadromous salmonid fishery resources. A riverine ecosystem perspective accurately describes the intent to improve anadromous salmonid habitat in the mainstem by managing releases from Lewiston Dam and supplementing coarse sediment in the mainstem to promote alluvial riverine characteristics in conjunction with flow and sediment inputs from unregulated tributaries.

These recommendations do not target the pre-TRD mainstem as its restoration goal because physical constraints imposed by the TRD cannot be entirely overcome; the primary constraints being the elimination of coarse sediment recruitment from the Basin above Lewiston Dam and the elimination of winter floods. A shift in the mainstem's ecological role occurred the first year of TRD operations to the detriment of the fishery resources of the river. These recommendations are intended to shift the ecological role of the mainstem below Lewiston Dam toward one that will provide the habitats necessary to restore and maintain the fishery resources of the Trinity River.

As the recommendations are implemented, it will be imperative to monitor their success and modify management actions in response to information gained during implementation. To this end, an Adaptive Environmental Assessment and Management (AEAM) program is recommended that is tailored to refine actions consistent with the flow requirement recommendations.

This page was intentionally left blank.

REFERENCES

Aceituno, M.E. and M. Hampton. 1987. Validation of habitat availability determinations by comparing field observations with hydraulic model (IFG-4) output. pp 322-324 in K. Bovee and J. R. Zuboy, eds. Proceedings of a workshop on the development and evaluation of habitat criteria. U. S. Fish and Wildl. Serv. Biol. Rep. 88 (11). 407 pp.

Achord, S. G., M. Matthews, O. W. Johnson, and D. M. Marsh. 1996. Use of passive integrated transponder (PIT) tags to monitor migration timing of Snake River chinook salmon smolts. North American Journal Fisheries Management 16:302-313.

Adams, B. L., W. S. Zaugg, and L. R. McLain. 1973. Temperature effect on parr-smolt transformation in steelhead trout *(Salmo gairdneri)* as measured by gill sodium-potassium stimulated adensosine triphosphatase. Comparative Biochemistry and Physiology 44:1333-1339.

Alderdice, D. F. and F. P. J. Velsen. 1978. Relation between temperature and incubation time for eggs of chinook salmon (*Oncorhynchus tshawytscha*) J. Fish. Res. Bd. Can. 35:69-75.

Allen, K. R. 1969. Limitations on production in salmonid populations in streams, p. 3-18. In. T. G. Northcote, (ed). Symposium on Salmon and Trout in Streams. H. R. MacMillan Lectures in Fisheries. Institute of Fisheries, University of British Columbia, Vancouver.

Anderson, R.M. and R.B. Nehring. 1985. Impacts of stream discharge on trout rearing habitat and trout recruitment in the South Platte River, Colorado, pp 59-64 *In* F.W.Olsen, R.G. White and R.H. Hamre (eds.). Symposium on small hydropower and fisheries. American Fisheries Society, Bethesda, MD.

Armour, C.L. 1991. Guidance for evaluating and recommending temperature regimes to protect fish. U.S. Fish Wildl. Serv. Biol. Rep. 90(22). 13 pp.

BLM (Bureau of Land Management). 1995. *Mainstem Trinity River Watershed Analysis*. U.S. Department of the Interior, Bureau of Land Management, Redding Resource Area, Redding, CA. 237 pp.

Bain, M.B. and J.M. Boltz. 1989. Regulated streamflow and warmwater stream fish: a general hypothesis and research agenda. U.S. Fish and Wildlife Service Biological Report 89(18), Washington D.C.

Baker, P.F, T.P.Speed, and F.K. Ligon. 1995. Estimating the influence of temperature on the survival of chinook salmon smolts (*Oncorhynchus tshawytscha*) migrating through the Sacramento-San Joaquin River Delta of California. Can. J. Fish. Aquat. Sci. 52: 855-863.

Barnhart, R.A. 1986. Species profiles: life history and environmental requirements of coastal fishes and invertebrates (Pacific Southwest)—steelhead. U.S. Fish and Wildlife Service Biological Report No. 82 (11.60), U.S. Army Corps of Engineers, TR EL-82-4. 21 pp.

Barnhart, R.A. and D.C. Hillemeier. 1994. Summer habitat utilization by adult spring chinook salmon and summer steelhead, South Fork Trinity River, CA. Calif. Cooperative Fishery Research Unit. Humboldt State University, Arcata, CA.

Bartholow, J.M. 1996. Sensitivity of a salmon population model to alternative formulations and initial conditions. Ecological Modeling 88(1):215-226.

Bartholow, J. J.L. Laake, C.B. Stalnaker, and S.C. Williamson 1993. A salmonid population model with emphasis on habitat limitations. Rivers, Volume 4, Number 4 pp 265 - 279.

Bartholow, J., J. Sandelin, Coughlan, B.A.K., J. Laake, and A. Moos. Accessed April 29, 199. SALMOD, A Population Model for Salmonids: User's Manual: Documentation files on the World Wide Web at URL <http://www.mesc.usgs.gov/rsm/rsm_download.htm.

Bartholow, J.M. and T.J. Waddle. 1994. A salmon population model for evaluating alternate flow regimes. Pp 887-889 *In* D.G. Fontane and H.N. Tuvel (eds.), Proceedings of the 21st Annual Conference, Water Resources Planning and Management Division, ASCE, Denver, CO. May 23-26, 1994.

Bartholow, J.M. and T.J. Waddle. 1995. The search for an optimum flow regime using a salmon population model. Pp 331-339 *In* Waterpower 95. Proceedings of Water Power '95. ASCE. San Francisco, CA. July 25-28, 1995.

Bell, M. 1991. Fisheries handbook of engineering requirements and biological criteria. U.S. Army Corps of Engineers, Fish Passage Development and Evaluation Program, 290 pp.

Beschta, R.L. and W.S.Platts. 1986. Significance and function of morphological features of small stream. Water Resources Bulletin 22(3): 369-379.

Bisson, P.A., K. Sullivan, and J.L. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead, and cutthroat trout in streams. Trans. Am. Fish Soc. 117:262-273.

Bjornn, T.C. and D. W. Reiser 1991. "Influences of forest and rangeland management on salmonid fishes and their habitats." *American Fisheries Society Special Publication* 19: 83-138.

Boles, G.L. 1976. Effects of riffle degradation on aquatic invertebrate populations in the Trinity River, California Department of Water Resources, Northern District.

Boles, G. 1988. Water temperature effects on chinook salmon (*Oncorhynchus tshawytscha*) with an emphasis on the Sacramento River - a literature review. California Department of Water Resources publication, Northern District. 43 pp.

Bovee, K. D. 1982. A guide to stream habitat analysis using the Instream Flow Incremental Methodology. Instream Flow Information Paper 12. U.S. Department of the Interior Fish and Wildlife Service, Office of Biological Services. FWS/OBS-78/33. 131 pp.

Bovee, K.D. and Cochnauer. 1977. Development and evaluation of weighted criteria, probability-of-use curves for instream flow assessments: Fisheries. Instream Flow Information Paper No. 3. U.S. Fish Wildl. Serv. FWS/OBS-77/63.

Bovee, K.D., B.L. Lamb, J.M. Bartholow, C.B. Stalnaker, J. Taylor, and J. Henriksen. 1998. Stream habitat analysis using the instream flow incremental methodology. U. S. Geological Survey, Biological Resources Division Information and Technology Report USGS.BRD/ITR—1998—0004. vii + 129 pp.

Boyd, C.E. 1990. Water quality in ponds for aquaculture. Alabama Agricultural Experiment Station, Auburn University, Alabama. Birmingham Publishing Co. 482 pp.

Bradley, C. and D. Smith. 1986. Plains cottonwood recruitment and survival on a prairie meandering river floodplain, Milk River southern Alberta and northern Montana. Can J. Bot. 64:1433-1442.

Brege, D. A., R. F. Absolon, and R. J. Graves. 1996. Seasonal and diel passage of juvenile salmonids at John Day Dam on the Columbia River. North American Journal of Fisheries Management 16:659-665.

Brett, J. R. 1952. Temperature tolerance in young Pacific salmon, Genus *Oncorhynchus*. J. Fish Res. Bd. Can., 9 (6).

Briggs, J.C. 1953. The behavior and reproduction of salmonid fishes in a small coastal stream. Calif. Dep. Fish Game Fish. Bull. 94. 62 pp.

Bugert and T.C. Bjornn. 1991. Habitat use by steelhead and coho salmon and their responses to predators and cover in laboratory streams. Trans. Am. Fish. Soc. 120:486-493.

Burner, C.J. 1951. Characteristics of spawning nests of Columbia River salmon. Fish Bull. Fish Wild. Serv. 61: 97-110.

Bustard, D. R. and D. W. Narver. 1975. Aspects of the winter ecology of juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri)* J. Fish. Res. Bd. Can. 32: 667-680.

CDFG (California Department of Fish and Game). 1992a. Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1989 - 1990 season. Inland Fisheries Division, Sacramento, CA. 140 pp.

CDFG (California Department of Fish and Game). 1992b. Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1990 - 1991 season. Inland Fisheries Division, Sacramento, CA. 186 pp.

CDFG (California Department of Fish and Game). 1994a. Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1991 - 1992 season. Inland Fisheries Division, Sacramento, CA. 235 pp.

CDFG (California Department of Fish and Game). 1994b. Amphibian and reptile species of special concern in California. 255 pp.

CDFG (California Department of Fish and Game). 1995. Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1992 - 1993 season. Inland Fisheries Division, Sacramento, CA. 235 pp.

CDFG (California Department of Fish and Game). 1996a. Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1993 - 1994 season. Inland Fisheries Division, Sacramento, CA. 266 pp.

CDFG (California Department of Fish and Game). 1996b. Annual Report, Trinity River Basin salmon and steelhead monitoring project, 1994 - 1995 season. Inland Fisheries Division, Sacramento, CA. 197 pp.

CDFG (California Department of Fish and Game). 1996c. Klamath River Basin Fall Chinook Salmon Run-Size, Harvest, and Spawner Escapement - 1996 Season.

CRWQCB-NCR (California Regional Water Quality Control Board - North Coast Region). 1994. Water Quality Control Plan for the north coast region. Santa Rosa, CA.

Cada, G. F., M. D. Deacon, S. V. Mitz, and M. S. Bevelhimer. 1997. Effects of water velocity on the survival of juvenile salmon and steelhead: A review with emphasis on the Columbia River Basin. Reviews in Fisheries Science, 5(2): 131-183.

Chapman, D.W. 1962. Aggressive behavior in juvenile coho salmon as a cause of emigration. *Journal of the Fisheries Research Board Canada* 19(6):1047-1080.

Chapman, D.W. and T.C. Bjornn 1969. Distribution of salmonids in stream with special reference to food and feeding. Pages 153 - 176 in T.G. Northcote, editor. Symposium on salmon and trout in streams. H. R. MacMillan Lectures in Fisheries, University of British Columbia, Vancouver, B.C.

Chapman, D. W., D. E. Weitcamp, T. L. Welsh, M. B. Dell, and T. H. Schadt. 1986. Effects of river flow on the distribution of chinook salmon redds. Trans. Am. Fish. Soc. 115: 537-547.

Cheslak, E.F., and Garcia. 1987. Sensitivity of PHABSIM model output to methods for fitting functions of curves to species preference data. In K.D. Bovee and J. Zuboy (eds.) Proceedings of a workshop on the development and evaluation of habitat criteria. U.S. Fish Wildl. Serv. Biol. Rep. 88 (11). 407 pp.

Chien, N. 1985. Changes in river regime after the construction of upstream reserviors. Earth Surface Processes and Landforms 10: 143-159.

Clarke, W. C. 1992. Environmental factors in the production of Pacific salmon smolts. *World Aquaculture,* (23)4,40-42.

Clarke, W. C., and J. E. Shelbourn. 1985. Growth and development of seawater adaptability by juvenile fall chinook salmon (*Oncorhynchus tshawytscha*) in relation to temperature. Aquaculture 45:21-31.

Clarke, W. C., Shelbourn, J. E., and Brett, J. R. 1981. Effect of artificial photoperiod cycles, temperature, and salinity on growth and smolting in underyearling coho *(Oncorhynchus kisutch)*, chinook *(Oncorhynchus. tshawytscha)* and sockeye *(Oncorhynchus nerka)* salmon. Aquaculture, 22, 105-116.

Coots, M. 1957. The spawning efficiency of king salmon (*Oncorhynchus tshawytscha*) in Fall Creek, Siskiyou County: 1954-55 investigations. Calif. Dep. Fish Game Inland Fish Admin. Rep. 57-1. 15 pp.

Craig, J. L., and T. S. Fletcher. 1994. Klamath River fisheries assessment program, Annual Report 1992. U.S. Fish and Wildlife Service, Coastal California Fishery Resource Office, Arcata, CA., Report No. AFF1-FRO-94-03.

Cramer, S. P., and J. A. Lichatowich. 1978. Factors influencing the rate of downstream migration of juvenile chinook salmon in the Rogue River. Pages 43-48 in B. C. Shephard and R. M. J. Ginetz (editors). Proceedings of the 1977 Northwest Pacific chinook and coho salmon workshop. Fish. Mar. Ser. (Can.) Tech. Rep. 759.

Crisp, D.T. 1981. A desk study of the relationship between temperature and hatching time for the eggs of five species of salmonid fishes. *Freshwater Biology* 11(4):361-368.

DEQ (Department of Environmental Quality). 1995. 1992 - 1994 water quality standards review. Standards and Assessment Section, Portland, Oregon.

DOI (Department of the Interior). 1993. Memorandum Opinion to the Secretary on the Fishing Rights of the Yurok and Hoopa Valley Tribes M-36979 (October 4, 1993).

Dethlefsen, E.S. 1948. A subterranean nest of the Pacific giant salamander, *Dicamptodon ensatus*. The Wasmann Collector. 7:81-84.

Dill, L.M. 1969. Food abundance and territory size in juvenile coho salmon (*Oncorhynchus kisutch*). Can. J. Zool. 59:1801-1809.

Edmundson, E. H., F. H. Everest, and D. W. Chapman. 1968. Permanence of station in juvenile chinook salmon and steelhead trout. J. Fish. Res. Bd. Can. 25: 1453-1464.

Edwards, T.K., and G.D. Glysson. 1988. Field methods for measurement of fluvial sediment. U.S. Geological Survey Techniques of Water-Resources Investigations, TWRI 3-A2.

Emmett, R. L., S. L. Stone, S. A. Hinton, and M. E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Volume II: species life history summaries. ELMR Rep. No 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD, 329 pp.

Evans, J. F. 1980. Evaluation of Riparian Vegetation Encroachment, Trinity River, California. Annual Evaluation Reports, Trinity River Basin Fish and Wildlife Comprehensive Action Program. U.S. Department of the Interior, Water and Power Reclamation Service, Sacramento, CA.

Everest, F.H., and D.W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook and steelhead trout in two Idaho streams. J. Fish. Res. Board Can. 29:91-100.

Everest, F. H., and J. R. Sedell. 1983. Evaluation of fisheries enhancement projects on Fish Creek and Wash Creek, 1982 and 1983. Pacific Northwest Forest and Range Experiment Station. Corvallis, Oregon. Annual Report, 1983.

Folmar, L. C., and W.W. Dickhoff 1980. The parr-smolt transformation (smoltification) and seawater adaptation in salmonids: A review of selected literature. Aquaculture, 21, 1-37.

Foott, J.S., and R.L. Walker. 1992. Disease survey of Trinity River salmonid smolt populations. U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA. 35 pp.

Fredericksen, Kamine, and Associates. October 1980. Proposed Trinity River Basin Fish and Wildlife Management Program, Appendix B - sediment and related analysis., Report prepared for Bureau of Reclamation by Trinity River Basin Fish and Wildlife Task Force, Sacramento, CA.

Free, D., J.S. Foott, W. Talo, and J.D. Williamson. 1997. Physiological effects of *Nanophyetus* Metacercaria Infection in Chinook Salmon Smolts (Trinity River). U.S. Fish and Wildlife Service, California-Nevada Fish Health Center, Anderson, CA. 35 pp.

Gallagher, S. P. 1995. Evaluation of the feathered edge restoration projects on the Trinity River: Fish use and physical habitat. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, California. 28 pp.

Gangmark, H.A., and R. G. Bakkala. 1960. A comparative study of unstable and stable (artificial channel) spawning streams for incubating king salmon at Mill Creek. Calf. Fish Game 46:151-164.

Gard, M. 1996. Simulation of physical habitat for anadromous salmonids in the Trinity River. U.S. Fish and Wildlife Service, Ecological Services, Sacramento, California. 55 pp.

Gard, M. 1997. Simulation of physical habitat for anadromous salmonids in the lower Trinity River. U.S. Fish and Wildlife Service, Ecological Services, Sacramento, California. 30 pp.

Giorgi, A. E., Willman, T. W., Stevenson, J. R., Hays, S. G., and C.M. Peven. 1997. Factors that influence the down-stream migration rates of juvenile salmon and steelhead through the hydroelectric system in the Mid-Columbia River basin. North American Journal Fisheries Management 17:268-282.

Ghanem, A., P. Steffler, F. Hicks, and C. Katapodis. 1994. Two-dimensional finite element flow modeling of physical fish habitat. Pages 84-89 *in* Proceedings of the 1st International Association for Hydraulic Research Sympo-sium on Habitat Hydraulics. Norwegian Institute of Technology, Trondheim, Norway.

Glase, J. D. 1994a. Monitoring juvenile salmon and steelhead outmigrants produced in the upper Trinity River, Northern California, 1991-1993 progress report. U.S. Fish and Wildlife Service, Trinity River Restoration Program, progress report. 27 pp.

Glase, J. D. 1994b. Progress Report, Evaluation of Artificially Constructed Side Channels as Habitat for Salmonids in the Trinity River, Northern California, 1991-1993. U.S. Fish and Wildlife Service, Trinity River Fishery Resource Office, Weaverville, CA. pp. 46.

Godin, J.J. 1981. Migrations of salmonid fishes during early life history phases: daily and annual timing. Pages 22-50 *in* E. L. Brannon and E. O. Salo (eds.). Proceedings of a symposium on salmon and trout migratory behavior. University of Washington Press, WA.

Groot, M. C., and L. Margolis (editors). 1991. Pacific Salmon Life Histories. UBC Press, Vancouver, Canada.

Guy and Norman. 1970. Field methods for measurement of fluvial sediment. Techniques of Water -Resources Investigations of the United States Geological Survey. Chapter C2: 1-59.

HVT (Hoopa Valley Tribal Fisheries Dept.). 1996. Results of Trinity River Mainstem Spawner surveys conducted from 1992 to 1995 by Hoopa Valley Tribal Department of Fisheries. 21 pp.

Haley, K.B. 1990. Operational research and management in fishing. Pages 3-7 in A.G. Rodrigues (ed.). Operations research and management in fishing. NATO ASI Series. Series F.:Applied Sciences, Vol. 189. Kluwer Academic, Dordrecht, The Netherlands.

Hall, D.W., 1997. Project Director of the Darby Creek Watershed-Columbus, Ohio.

Hamilton, A. 1987. PREFSORT - a turbo PASCAL 4.0 program to calculate weighted usable area from direct hydraulic and structural measurements. U.S. Fish and Wildlife Service, Weaverville, CA.

Hampton, M. 1988. Development of habitat preference criteria for anadromous salmonids of the Trinity River. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 93 pp.

Hampton, M. 1992. Evaluation of the Junction City side channels, U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, CA. 12 pp.

Hampton, M. 1997. Microhabitat suitability criteria for anadromous salmonids of the Trinity River. T. Payne (ed). U.S. Fish and Wildlife Service, Arcata, California. 24 pp.

Hartman, G. F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*Salmo gairdneri*). J. Fish. Res. Bd. Can. 22: 1035-1081.

Healey, M. C. 1980. Utilization of the Nanaimo River estuary by juvenile chinook salmon, *Oncorhynchus tshawytscha*. Fish. Bull. 77:653-668.

Healey, M.C. 1991. Life History of Chinook Salmon. *In* C. Groot and L. Margolis (eds.), Pacific Salmon Life Histories. UBC Press, Vancouver, Canada.

Helley, E. J., and E. J. Smith (1971). Development and calibration of a pressure-difference bed-load sampler. U. S. Geological Survey Open-File Report 8037-01. 18 pp.

Hewes, Gordon. 1942. "Economic and geographical relations of aboriginal fishing in northern California." California Department of Fish and Game 28(2). pp. 103-110.

Hill, M.T., W.S. Platts, and R.L. Beschta. 1991. Ecological and geomorphological concepts for instream and out-of-channel flow requirements. Rivers 2:198-210.

Hoar, W. S. 1988. The physiology of smolting salmonids. Pages 275-323 *in* W. S. Hoar, editor. Fish Physiology, Vol IXB. Academic Press, New York.

Hokanson, K.E.F., C.F.Kleiner, and T.W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth rate and mortality rates and yield of juvenile rainbow trout, Salmo gairdneri. J. Fish. Res. Bd. Can. 34: 639-648.

Holling, C.S. 1977. Adaptive environmental assessment and management. University British Columbia, Vancouver, B.C. 57 pp with appendices.

Holling, C.S. 1978. Adaptive environmental assessment and management. John Wiley and Sons, New York.

Hubbel, P. 1973. A program to identify and correct salmon and steelhead problems in the Trinity River Basin. California Department of Fish and Game.

International Institute for Applied Systems Analysis. 1979. Expect the Unexpected: An Adaptive Approach to Environmental Management. Executive Report 1, International Institute for Applied Systems Analysis, Laxenburg, Austria. 16 pp.

Johnson, W.C. 1994. Woodland expansion in the Platte River, Nebraska: patterns and causes. Ecol. Monographs 64: 45-84.

KRTAT (Klamath River Technical Advisory Team). 1986. Recommended spawning escapement policy for Klamath River fall-run chinook. 73pp.

Kamman, G. 1998. Temperature analysis of proposed Trinity River restoration flow alternatives using the BETTER model, Trinity River Mainstem Fishery Restoration EIS/EIR.

Kerstetter, T. H., and Keeler, M. 1976. Smolting in steelhead trout (*Salmo gairdneri*): a comparative study of populations in two hatcheries and the Trinity River, northern California, using gill Na, K, ATPase assays. Humboldt State University, Sea Grant Program. 35 pp.

Kjelson, M., and P. Brandes. 1989. The use of smolt survival estimates to quantify the effects of habitat changes on salmonid stocks in the Sacramento-San Joaquin Rivers, California. P. 100 - 115. *In* C. D. Levings, L. B. Holtby, and M. A. Henderson (editors) Proceedings of the National Workshop on Effects of Habitat Alteration on Salmonid Stocks Can. Spec. Publ. Fish. Aquat. Sci. 105.

Knighton, D. 1984. Fluvial forms and processes. Edward Arnold, New York, NY, 218 pp.

Know Your Watershed, www.ctic.purdue.edu/KYW/TipsAndHints/Observations.html.

Kondolf, G. M., and W.V.G. Matthews. 1993. Management of coarse sediment on regulated rivers. Univ. Calif.: Water Resource Center.

Kondolf, G. M., and E. R. Micheli. 1995. Evaluating stream restoration projects. Environmental Management Vol. 19, No. 1, pp. 1-15.

Krakker, J. 1991. Evaluation of artificially constructed side channels as habitat for salmonids in the Trinity River, Northern California. U.S. Fish and Wildlife Service, Trinity River Restoration Program, Weaverville, CA. pp 54.

La Faunce, D. A. 1965. A steelhead spawning survey of the upper Trinity River System. California Department of Fish and Game, Marine Resources Administration Report No. 65-4. 5 pp.

Lane, E.W. 1955. The importance of fluvial geomorphology in hydraulic engineering. Proceedings of the ASCE 81(1):1-17.

Larkin, P. A. 1977. Pacific salmon, P. 156-186. *In*: J. A. Gulland, (ed.). Fish Population Dynamics. J. Wiley & Sons, New York.

Leclerc, M., A. Boudreault, J.A. Bechara, and G. Corfa. 1995. Two-dimensional hydrodynamic modeling: a neglected tool in the Instream Flow Incremental Methodology. Transactions of the American Fisheries Society 124(5):645-662.

Leidy R.A., and G.R. Leidy. 1984. Life stage periodicities of anadromous salmonids in the Klamath River Basin, northwestern California. U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, CA. 21 pp.

Leonard, W.P., H.A. Brown, L.L.C. Jones, K.R. McAllister, and R.M. Storm. Amphibians of Washington and Oregon. Seattle Audubon Society, Seattle, Washington. 168pp.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. *Fluvial Processes in Geomorphology*. W. Freeman & Sons, San Francisco.

Lestelle, L.C., L.E. Mobrand, J.A. Lichatowich, and T.S. Vogel. 1996 Ecosystem Diagnosis and Treatment (EDT), Applied Ecosystem Analysis - A Primer. Prepared for US Dept. of Energy, Bonneville Power Administration, Environmental Fish and Wildlife. Portland, Oregon. 95 pp.

Ligon, F.K., W.E. Deitrich, and W.J. Trush. 1995. Downstream ecological effects of dams: a geomorphic perspective. BioScience 45(3):183-192.

Lind, A.J., H.H. Welsh, Jr., and R.A. Wilson. 1996. The effects of a dam on breeding habitat and egg survival of the foothill yellow-legged frog (Rana boylii) in northwestern California. Herpetological Review 27:62-67.

Lind, A.J., R.A. Wilson, and H.H. Welsh, Jr. 1992. Distribution and habitat associations of the willow flycatcher, western pond turtle, and foothill yellow-legged frog on the main fork Trinity River. Interim Report, submitted to: Wildlife Working Group, Trinity River Restoration Project, USDI Fish and Wildlife Service and Bureau of Reclamation. Weaverville, California. (September). 48 pp.

Lind, A.J., D.A. Reese, and H.H. Welsh, Jr. March 1995. An assessment of habitat quality of man-made side channels and bank feathering projects for the western pond turtle and foothill yellow-legged frog (1993-1994). Final report to Wildlife Working Group, Trinity River Restoration Program, U.S. Fish and Wildlife Service and Bureau of Reclamation, Weaverville, California, 21 pp. (March).

Lister, D. B., and C. E. Walker. 1966. The effect of flow control on freshwater survival of chum, coho, an chinook salmon in the Big Qualicum River. Can. Fish Cult. 37: 3-25.

Macedo, R.A. 1992. Evaluation of Side Channels for Increasing Rearing Habitat of Juvenile Salmonids, Trinity River, California. Masters Thesis, Humboldt State University, Arcata, CA. 142 pp.

Mahoney, J.M. and S.B. Rood. 1998. Streanflow requirements for cottonwood seedling recruitment - an integrative model. Wetlands 18(4). pp 634-645.

Major, R. L., and J. L. Mighell. 1969. Egg-to-migrant survival of spring chinook salmon (*Oncorhynchus tshawytscha*) in the Yakima River, Washington. Fish. Bull. 67: 347-359.

McBain, S.M., and W.J. Trush. 1995. Channel bed mobility and scour on a regulated gravel bed river. pp1941-1950 in J.J. Cassiday, (ed.) International Conference on Hydropower ASCE, San Francisco, CA.

McBain, S., and W. Trush. 1997. *Trinity River Channel Maintenance Flow Study Final Report.* Prepared for the Hoopa Valley Tribe, Trinity River Task Force.

McDonald, J. 1960. The behavior of Pacific salmon fry during their downstream migration to freshwater and saltwater nursery areas. *Journal of the Fisheries Research Board Canada* 17(5):655-676.

McLain, R.J., and R.G. Lee. 1996. Adaptive management: promises and pitfalls. Environmental Management. 20(4):437-448.

McMahon, T.E. 1983. Habitat suitability index models: coho salmon. FWS/OBS-82/10.49.

McNeil, W.J. 1967. Randomness in the distribution of pink salmon redds. Journal of the Fisheries Research Board Canada. 24(7):1629-1634.

Merigliano, M. 1996. Ecology and management of the South Fork Snake River cottonwood forest. Idaho BLM Technical Bulletin 96-9. Bureau of Land Management Id. 79 pp.

Mesick, C.F. 1988. Effects of food and cover on numbers of Apache and brown trout establishing residency in artificial stream channels. *Transactions American Fisheries Society* 117(5):421-431.

Milhous, R.T., D.L. Wegner, and T. Waddle. 1984. User's guide to the Physical Habitat Simulation System (PHABSIM). Instream Flow Information Paper 11. U.S. Fish and Wildlife Service. FWS/OBS-81/43. 475 pp.

Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. *Physical Habitat Simulation System Reference Manual, Version II.* U.S. Fish and Wildlife Service Biological Report 89(16), Washington D.C.

Milhous, R. T., J. M. Bartholow, M. A. Updike, and A. R. Moos. 1990. Reference Manual for Generation and Analysis of Habitat Time Series-Version II. U. S. Fish and Wildlife Service Biological Report 90(16). 249 pp.

Moffett, J.W., and S.H. Smith. 1950. Biological investigations of the fishery resources of the Trinity River, California. Special Scientific Report No. 12. U.S. Fish and Wildlife Service. 71 pp.

Morhardt, J. E, D. F. Hanson, and P. J. Coulston. 1983. "Instream flow: increased accuracy using habitat mapping." In *Waterpower "83" An International Conference on Hydropower*. Conference Proceedings Vol 3: Environmental Impacts. pp. 1294-1304. Tennessee Valley Authority.

Morhardt, J.E., and D.F. Hanson. 1988. Habitat availability considerations in the development of suitability criteria. In K.D. Bovee and J. Zuboy (eds.) Proceedings of a workshop on the development and evaluation of habitat criteria. U.S. Fish Wildl. Serv. Biol. Rep. 88 (11). 392-407 pp.

Moyle, P. 1976. Inland Fishes of California. University of California Press. Berkeley and Los Angeles. 404 pp.

Muir, W.D., W.S. Zaugg, A.E. Giorgi. 1994. Accelerating smolt development and downstream movement in yearling chinook salmon with advanced photoperiod and increased temperature. Aquaculture 123, pp 387 - 399.

NMFS (National Marine Fisheries Service). 1994. Status review for Klamath Mountains Province. NOAA Technical Memorandum NMFS-NWFSC-19. 130 pp.

Nelson, R.W., J.R. Dwyer, and W.E. Greenberg. 1987. Regulated flushing in a gravel-bed river for channel habitat maintenance: A Trinity River Fisheries Case Study. Environmental Management Vol 11.4:479-493.

Nussbaum, R.A., E. D. Brodie, and R.M. Storm. 1983. Amphibians and Reptiles of the Pacific Northwest. University of Idaho Press, Moscow. 332pp.

Nussbaum, R.A., and G.W. Clothier. 1973. Population structure, growth, and size of larval *Dicamptodon ensatus*. Northwest Science 47:218-227.

Ordal E. J., and R. E. Pacha. 1963. The effects of temperature on disease in fish. Proc. 12th Sym. On Water Poll. Res., Pac. N. W. Water Lab., Corvallis, Oregon.

PFMC (Pacific Fishery Management Council). 1988. Review of 1987 Ocean Salmon Fisheries.

PFMC (Pacific Fishery Management Council). 1995. Review of 1994 Ocean Salmon Fisheries.

Packer, W.C. 1960. Bioclimatic influences on the breeding migration of *Taricha rivularis*. Ecology. 41:510-517.

Pelzman, R.J. 1973. Causes and possible prevention of riparian plant encroachment on anadromous fish habitat. California Department of Fish and Game, Environmental Services *Branch Administrative Report No. 73-1*, 26 pp.

Pereira, D.L. and I.R. Adelman. 1985. Interactions of temperature, size, and photoperiod on growth and smoltification of chinook salmon (*Oncorhynchus tshawytscha*). Aquaculture 46: 185-192.

Platts, W.S., W.F.Megahan, G.W. Minshall. 1983. Methods for Evaluating Stream, Riparian, and Biotic Conditions. Intermoutain Forest and Range Experiment Station. Odgen UT. General Technical Report INT-138. 78 pp.

Poff, N. L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks, and J.C. Stromberg. 1997. The Natural Flow Regime: A paradigm for river conservation and restoration. BioScience 47(11):769-784.

Propper, C.R. 1991. Courtship in the rough-skinned newt *Taricha granulosa*. Animal Behavior 41:547-554.

Raymond, H. L. 1968. Migration rates of yearling chinook salmon in relation to flows and impoundments in the Columbia and Snake rivers. Trans. Am. Fish. Soc. 97:356-359.

Raymond, H. L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966 to 1975. Transactions of the American Fisheries Society 108:505-529.

Reese, D.A. 1996. Comparative demography and habitat use of western pond turtles in northern California: the effects of damming and related alterations. Unpubl. PhD Diss., University of California, Berkeley.

Reese, D.A., and H.H. Welsh. 1998. Habitat use by western pond turtles in the Trinity River, California. Journal of Wildlife Management 62(3):842-853.

Reese, D.A., and H.H. Welsh. *In Press*. Comparative demography of western pond turtle populations (*Clemmys marmorata*) in two forks of the Trinity River of California in the context of dam-induced alterations. Journal of Herpetology.

Reeves, G.H. L.E. Benda, K.M. Burnett, P.A. Bisson and J.R. Sedell. 1996. A disturbance-based ecosystem approch to maintaining and restoring freshwater habitats of evolutionary significant units of anadromous salmonids in the Pacific Northwest. American Fisheries Society Symposium 17:334-349.

Reimers, P. E. 1968. Social behavior among juvenile fall chinook salmon. J. Fish. Res. Bd. Can. 25: 2005-2008.

Rich, A. A. 1987. Report on studies conducted by Sacramento County to determine the temperatures which optimize growth and survival in juvenile chinook salmon *(Oncorhynchus tshawytscha)*. Prepared for: McDonough, Holland & Allen, 555 Capital Mall Sacramento, California 95814.

Richter, B.D., J.V. Baumgartner, R. Wigington, D.P. Braun. 1997. How much water does a river need? Freshwater Biology 37:231-249.

Richards. 1982. Rivers: Form and Process in Alluvial Channels. Methuen and Company. 354 pp.

Ritter, J.R. 1968. Changes in the channel morphology of the Trinity River and eight tributaries, 1961-1965. USGS Open File Report, 60p.

Roberts, R. 1996. Grass Valley Creek sediment basin inventory and evaluation-revised draft. Natural Resource Conservation Service, Weaverville, CA. 14p.

Rogers, D. W. 1973. A steelhead spawning survey of the tributaries of the upper Trinity River and upper Hayfork Creek drainage, 1972. California Department of Fish and Game, Anadromous Fisheries Administrative Report No. 73-5A. 8 pp.

Rood, S.B. and J.M. Mahoney. 1990. Collapse of riparian poplar forests downstream from dams in western prairies: probable causes and prospects for mitigation. Environmental management 14(4):451-464.

Sandercock, F.K. 1991. Life history of coho salmon (*Oncorhynchus kisutch*). *In* C. Groot and L. Margolis (editors), Pacific Salmon Life Histories. UBC Press, Vancouver, Canada. pp 397 - 445.

Scott, M.L., M.A. Wondzell, and G.T. Auble. 1993. Hydrograph characteristics relevant to the establishment and growth of western riparian vegetation. In: Proceedings of the Thirteenth Annual American Geophysical Union Hydrology Days, Morel-Seytoux, H.J. (ed.), Hydrology Days Publications, Atherton, 237-246p.

Sear, D.A. 1994. River restoration and geomorphology. Aquatic Conservation: Marine and Freshwater Ecosystems. 4:169-177.

Sear, D.A. 1995. Morphological and sedimentological changes in a gravel-bed river following 12 years of flow regulation for hydropower. Regulated Rivers: Research and Management 10:247-264.

Segelquist, C.A., M.L. Scott, and G.T. Auble. 1993. Establishment of *Populus deltoides* under simulated alluvial groundwater declines. Am. Midl. Nat. 130:274-

Shaw, P. A., and J. A. Maga. 1943. The effect of mining silt on yield of fry from salmon spawning beds. Calif. Fish Game 29: 29-41.

Shelbourne, J.E., J.R. Brett, and S. Shirahata. 1973. Effect of temperature and feeding regime on specific growth rate of sockeye salmon fry (*Oncorhynchus nerka*), with a consideration of size effect. *Journal of the Fisheries Research Board Canada* 30(8):1191-1194.

Shelton, J. M. 1955. The hatching chinook salmon eggs under simulated stream conditions. Prog Fish Cult. 17: 20-35.

Shelton, J. M., and R. D. Pollock. 1966. Siltation and egg survival in incubation channels. Trans. Am. Fish. Soc. 95: 183-187.

Sill, D. M. 1973. An action program to compensate for wildlife losses resulting from construction of Trinity River Division project. Trinity River Basin Fish and Wildlife Task Force. 63 pp.

Smith, G. 1975. Anadromous salmonid escapement in upper Trinity River, California. 19679. California Department of Fish and Game, Anad. Fish. Br. Admin Rep. 75-7.

Snyder, J.O. 1931. "Salmon of the Klamath River, California." *Fish Bulletin No. 34*.California Division of Fish and Game.

Stanford, J.A. J.V. Ward, W.J.Liss, C.A. Frissell, R.N. Williams,J.A. Lichatowich, and C.C. Coutant. 1996. A general protocol for restoration of regulated rivers. Regulated Rivers: Research and Management 12: 391-414.

Stebbins, R.C. 1985. Western Amphibians and Reptiles. Houghton Mifflin Company, Boston. 336pp.

Stemple, M. 1988. Possible implications of integrating hatchery and natural production of salmon and steelhead in the Trinity River Basin. U.S. Fish and Wildlife Service. Trinity River Restoration Project Office. Weaverville, CA. 8 p.

Sullivan, K., T.S. Lisle, C.A. Dolloff, G.Z. Grant, and L.M. Reid. 1987. Stream Channels: the link between forests and fishes. Pp. 39-97 *In* E.O. Salo and T.W. Cundy (eds.) Streamside Management: forest and fishery interactions. College of Forest Resources. Univ. of Washington Seattle. Contribution No. 57. Proceedings of a Symposium held at Univ. of Washington, Feb12-14, 1986.

TRBFWTF (Trinity River Basin Fish and Wildlife Task Force). 1977. Framework guide for Trinity River Basin Fish and Wildlife Management Program. 87 pp.

Tagart, J.V. 1984. Coho salmon survival from egg deposition to fry emergence, p. 173-181. *In*: J. M. Walton and D. B. Houston (eds). Proceedings of the Olympic Wild Fish Conference, March 23-25, 1983. Fisheries Technology Program, Peninsula College, Port Angeles, Washington.

TCRCD and NRCS (Trinity County Resource Conservation District and Natural Resources Conservation Service). 1998. Grass Valley Creek Watershed Restoration Project: Restoration in Decomposed Granite Soils. 107 pp.

Theurer, F.D., K.A. Voos, and W.J. Miller. 1984. Instream Water Temperature Model. Instream Flow Information Paper No. 16. Washington, DC: US Fish and Wildlife Service (FWS/OBS-84/15). 200 pp.

Trihey, E.W., and D.L. Wegner. 1981. Field data collection procedures for use with the Physical Habitat Simulation System of the Instream Flow Group. Cooperative Instream Flow Service Group, Ft. Collins, CO. 131 pp.

Trinity County. 1992. Temperature modeling of Lewiston Lake with the BETTER two-dimensional reservoir flow mixing and heat exchange model. June 16, 1992. Weaverville, CA. Prepared for Trinity County Department of Transportation and Planning by Jones and Stokes Associates, Inc. (JSA 88-136), Sacramento, CA .

Trinity Journal. 1952. "Engle Says Dam Bill to be under Trinity County Thumb". Weaverville, Trinity County, CA, February 28, 1952.

Trinity Restoration Associates, Inc. 1993. Trinity River Maintenance Report, Evaluation of the 6000-cfs Release. February 1993. Prepared for the Hoopa Valley Tribe, Fisheries Department. 294 pp.

Trush, W.J., R. Franklin, and S. McBain, 1995. "Assessing downstream variability of fluvial processes for recommending maintenance flows in regulated rivers," in *Proceedings of the ASCE Waterpower 95 conference*, San Francisco, CA.

Twitty, V., D. Grant, and O. Anderson. 1964. Long distance homing in the newt *Taricha rivularis*. Proceedings of the National Academy of Sciences 51:51-58.

USBOR (U.S. Bureau of Reclamation). 1952. Trinity River Divison, Central Valley Project Ultimate Plan. Washington D.C. 184 pp+Appendixes.

USBOR (U.S. Bureau of Reclamation). 1991. Appendixes to Shasta Outflow Temperature Control: Planning Report/ Environmental Statement: Appendix A. USDI/BOR/Mid-Pacific Region. November 1990, Revised May 1991. v.p.

USFWS (U.S. Fish and Wildlife Service). 1980a. Trinity River Instream Flow Study, Lewiston Dam to the North Fork, June/July 1978. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 48 pp.

USFWS (U.S. Fish and Wildlife Service). 1980b. Environmental Impact Statement on the Management of River Flows to Mitigate the Loss of the Anadromous Fishery of the Trinity River, California. Volumes I and II. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA.

USFWS (U.S. Fish and Wildlife Service). 1983. Final environmental impact statement: Trinity River Basin fish and wildlife management program. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Division of Ecological Services, Sacramento, CA. INT/FES 83-53.

USFWS (U.S. Fish and Wildlife Service). 1985. Trinity River Flow Evaluation-Annual Report. U.S.Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 45 pp.

USFWS (U.S. Fish and Wildlife Service). 1986. Trinity River Flow Evaluation-Annual Report. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA.104 pp.

USFWS (U.S. Fish and Wildlife Service). 1987. Trinity River Flow Evaluation-Annual Report. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 157 pp.

USFWS (U.S. Fish and Wildlife Service). 1988. Trinity River Flow Evaluation-Annual Report. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 146 pp.

USFWS (U.S. Fish and Wildlife Service). 1989. Trinity River Flow Evaluation-Annual Report. U.S.Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 116 pp.

USFWS (U.S. Fish and Wildlife Service). 1990. Trinity River Flow Evaluation-Annual Report. U.S. Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 63 pp.

USFWS (U.S. Fish and Wildlife Service). 1991. Trinity River Flow Evaluation-Annual Report. U.S.Fish and Wildlife Service, Division of Ecological Services. Sacramento, CA. 57 pp.

USFWS (U.S. Fish and Wildlife Service). 1994. *Restoration of the mainstem Trinity River, background report*, Trinity River Fishery Resource Office, Weaverville, California. 14 pp.

USFWS (U.S. Fish and Wildlife Service). 1996. Trinity River Flow Evaluation hydraulic modeling procedures and calibration details: Feather edge studies, 1995. USFWS, Division of Ecological Services, Instream Flow Branch, Sacramento, California. 7 pp.

USFWS (U.S. Fish and Wildlife Service). 1997. Physical Habitat and Fish Use of Channel Rehabilitation Projects on the Trinity River. Coastal California Fish and Wildlife Office, Arcata, California. 19 pp.

USFWS (U.S. Fish and Wildlife Service). 1998. Juvenile salmonid monitoring on the mainstem Trinity River at Willow Creek and mainstem Klamath River at Big Bar, 1992-1995. Annual Report of the Klamath River Fisheries Assessment Program. U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, CA.

USFWS/CDFG (U.S. Fish and Wildlife Service and California Department of Fish and Game). 1956. A plan for the protection of fish and wildlife resources affected by the Trinity River Division, Central Valley Project. Prepared jointly by California Department of Fish and Game and U.S. Fish and Wildlife Service. 76 pp.

USHOR (U.S. House of Representatives). 1955. 84th Congress, 1st Session, Report No. 602. ct Authorizing the Secretary on the Interior to construct, operate, and maintain the Trinity River Division, Central Valley Project, California, under federal reclamation laws. Report

U.S. Senate. 1955. 84th Congress, 1st Session, Report No. 1154. Ct Authorizing the Secretary on the Interior to construct, operate, and maintain the Trinity River Division, Central Valley Project, California, under federal reclamation laws.

VTN Environmental Sciences. 1979. Fish and Wildlife Management Options, Trinity River Basin. Trinity River Basin Fish and Wildlife Task Force.

Waddle, T. , and J. Sandelin 1994. Managing reservoir storage for fish production, *IN* D.G. Fontane and H.N. Tuvel (eds.), Proceedings of the 21st Annual Conference, Water Resource Planning and Management Division, ASCE, 23-26 May 1994, Denver CO. pp 49-52.

Wallace, M., and B.W. Collins. 1997. Variation in use of the Klamath River estuary by juvenile chinook salmon. California Department of Fish and Game 83 (4): 132-143.

Walters, C. 1986. Adaptive management of renewable resources. Macmillian, New York.

Ward, J.V. 1998. Riverine Landscapes: biodiversity patterns, disturbance regimes, and aquatic conservation. Biological Conservation Vol. 83(3):269-278.

Wedemeyer, G. A., R. L. Saunders, and W. C. Clarke. 1980. Environmental factors affecting smoltification and early marine survival of anadromous salmonids. Mar. Fish. Rev. 42 (6): 1-14.

Wickett, W. P. 1954. The oxygen supply to salmon eggs in spawning beds. J. Fish. Res. Bd. Can. 11: 933-953.

Wilcock, P.R., G.M. Kondolf, A.F. Barta, W.V.G. Matthews, and C.C. Shea. 1995. Spawning gravel flushing during trial reservoir releases on the Trinity River: Field observations and recommendations for sediment maintenance flushing flows. Prepared for the U.S. Fish Wildlife Service, Sacramento, CA., Cooperative Agreements 14-16-0001-91514 and 14-16-0001-91515. 96 pp.

Williams, G.P. and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers. US Geological Survey Professional Paper Number 1286.

Williamson, S.C., J.M. Bartholow, and C.B. Stalnaker. 1993. Conceptual model for quantifying pre-smolt production from flow-dependent physical habitat and water temperature. *Regulated Rivers: Research & Management*. 8(1&2):15-28.

Wilson, R.A. 1993. *Trinity River riparian vegetation mapping - GIS*. U.S. Department of Agriculture, Forest Service, Pacific Southwest Experiment Station, Redwood Sciences Laboratory, Arcata, CA 62 pp.

Wilson, R.A., A.J. Lind, and H.H. Welsh, Jr. 1991. Trinity River Riparian Wildlife Survey -1990. Final report, submitted to the Wildlife Task Group, Trinity River Restoration Project, U.S. Fish and Wildlife Service and Bureau of Reclamation, Weaverville, California, 98 pp.

Wolman, M.G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union 35(6):951-956.

Zaugg, W. S. 1981. Advanced photoperiod and water temperature effects on Na^+-K^+ adenosine triphosphatase activity and migration of juvenile steelhead *(Salmo gairdneri)*. Canadian Journal of Fisheries and Aquatic Sciences 38:758-764.

Zaugg, W. S., and L. R. McLain. 1976. Influence of water temperature on gill sodium, potassium-stimulated ATPase activity in juvenile coho salmon *(Oncorhynchus kisutch)*. Comparative Biochemistry and Physiology 54A: 419-421.

Zaugg, W. S., and H. H. Wagner. 1973. Gill ATPase activity related to parr-smolt transformation and migration in steelhead trout *(Salmo gairdneri)*: Influence of photoperiod and temperature. Comparative Biochemistry and Physiology 45B:955-965.

Zaugg, W.S., B.L. Adams, and L.R. McLain. 1973. Steelhead migration: potential temperature effects as indicated by gill adensosine triphosphatase activities. Science 176:415-416.

Zedonis, P. 1997. A water temperature model of the Trinity River. Prepared for the U.S. Bureau of Reclamation. U.S. Fish and Wildlife Service, Coastal California Fish and Wildlife Office, Arcata, California. 97 pp.

Zedonis, P.A, and T. J. Newcomb. 1997. Flow and water temperatures for protection of spring salmon and steelhead smolts in the Trinity River, California. U.S. Fish and Wildlife Service, Arcata, CA. 20 pp.

PERSONAL COMMUNICATIONS

Aguilar, Bernard. 1997. California Department of Fish & Game. Weaverville, CA.

Foott, J. Scott. 1996. US Fish and Wildlife Service. California/Nevada Fish Health Center. 24411 Coleman Fish Hatchery Rd. Anderson, CA. 96007

Fujitani, Paul. 1997. US Bureau of Reclamation. Central Valley Operations Office. 3310 El Camino Way, Suite 300, Sacramento, CA. 95821

Gilroy, Ian. 1997. National Marine Fisheries Service. 1330 Bayshore Wy., Eureka, CA. 95501

Kamman, Greg. 1998. Kamman Hydrology, El Cerrito, CA. 94530

Lind, Amy. 1997. U.S. Forest Service, Pacific Southwest Research Station, Arcata, CA. 95521

McBain, Scott and Bill Trush. 1998. McBain and Trush Consulting. P.O. Box 663, Arcata, CA 95518

Wilcock, Peter. 1997. Department of Geography and Environmental Engineering, The John Hopkins University, Baltimore, MD, 21218

Zedonis, Paul. 1996. U.S. Fish and Wildlife Service. Arcata Fish and Wildlife Office. Arcata, CA. 95521