BATTLE CREEK FISHERIES STUDIES

TASK 4: SURVEYS OF BARRIERS TO THE UPSTREAM MIGRATION OF ANADROMOUS SALMONIDS

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INTRODUCTION

This report documents barrier surveys of the Battle Creek watershed, one in a series of aquatic resource studies conducted by Thomas R. Payne and Associates (TRPA) for the California Department of Fish and Game (CDFG). The objective of the Battle Creek studies is to "assess the impacts of the Battle Creek Hydroelectric Project on the stream's aquatic habitat and dependent fishery resources, and to develop recommendations for project operation which would restore and maintain Battle Creek's aquatic habitat and fishery resources". The major purpose of this task is to define limitations to upstream anadromous fish migration. Results, combined with other tasks in this series of studies (habitat versus discharge, hydrology, water temperature modeling, sediment and gravel recruitment, and hatchery interactions), will be used to ascertain the feasibility of re-establishing anadromous fish populations into upper Battle Creek.

The California Department of Fish and Game has established as a goal the restoration of anadromous fish runs into upper Battle Creek. The achievement of this goal will be influenced by the number and extent of existing migration barriers, as well as by the degree to which these barriers can be made passable. Fish access into upper Battle Creek is presently controlled by a weir operated and maintained by the Coleman National Fish Hatchery (CNFH), located downstream of the Pacific Gas and Electric Company's Coleman Powerhouse (Figure 1). Spring chinook and late run steelhead are allowed to pass the weir, but most fall chinook and winter steelhead are diverted into hatchery holding areas to meet spawner and egg-take requirements. Surplus fall chinook salmon are occasionally released above the weir and unknown numbers of fish also negotiate the weir during high flow periods (G. Forbes, Hatchery Manager, CNFH, pers. comm.). In some years, upstream releases of fall chinook have been in excess of 10,000 fish (McKevitt 1986).

Fish passage is currently provided at all of the PG&E diversion dams on the South Fork and on the North Fork below Keswick Diversion. However, fall-run chinook salmon are often intentionally prevented from getting above the Wildcat Diversion on the North Fork and the Coleman Diversion on the South Fork by closing the fish ladders. This closure, made by PG&E at the request of the U.S. Fish and Wildlife Service, is intended to prevent introduction of fish

pathogens into CNFH water supply intakes (McKevitt 1987). Fish are presumed to be able to pass upstream of diversions without the aid of installed passage structures when high flows over-top or inundate diversion structures (T. Healey, Fishery Biologist, CDFG, pers. comm.).

The natural limit of fish passage in the South Fork is considered to be a boulder falls near Panther Creek, approximately 30 miles upstream of CNFH (Tehama County 1983). Spring chinook salmon have been observed in the South Fork above the Inskip and South Diversions, and in the Inskip Canal (T. Healey, pers. comm.). Therefore, it is generally believed that there are no substantial natural barriers to passage of anadromous fish in South Fork Battle Creek up to Panther Creek (T. Healey, pers. comm.; P. Warner, Fish Habitat Supervisor, CDFG, pers. comm.).

The upper limit to anadromous fish passage under most conditions in the North Fork is not well defined. Salmon have been reported 20 miles above CNFH in the vicinity of the Manton Bridge (Undocumented Report; T. Healey, pers. comm.). A 1987 aerial survey of chinook spawning above CNFH found chinook redds and carcasses as far upstream as the Wildcat Diversion on the North Fork Battle Creek, but visibility into the Eagle Canyon reach limited the extent of the survey (Smith 1987). A survey of the North Fork between Digger and Mill Creeks identified a partial barrier which existed during low flow conditions (Elektra Power 1986).

The purpose of the current barrier survey was to determine and define present restrictions and limits to upstream anadromous fish passage in the mainstem and North and South Forks of Battle Creek. Results of the survey are to be used to evaluate possible alternatives for improving anadromous fish production in the watershed, including physically modifying barriers and increasing instream flows to facilitate fish passage.

METHODS

Barrier surveys of the entire length of the study area, from CNFH on the mainstem to the natural passage barriers on the North and South forks, were conducted under low flow conditions, at discharges ranging from 4 to 10 cfs, in August and September 1988. These surveys were conducted in conjunction with habitat mapping for the instream flow study and surveys of

spawning gravel quantity and location. Potential barriers were summarized for each of the following reaches: Mainstem Battle Creek from the Coleman Powerhouse upstream to the confluence of the North and South Forks, South Fork Battle Creek from the confluence upstream to the South Diversion, the Eagle Canyon Reach of the North Fork from the South Fork confluence upstream to Digger Creek, the Digger Reach of the North Fork from Digger Creek upstream to Bailey Creek, and the Bailey Reach of the North Fork from Bailey Creek upstream to Ponderosa Way Bridge.

Sites considered to fall within the partial and total barrier categories for chinook and/or steelhead were re-surveyed at higher flows to collect additional data on site geometry and hydraulics. One high-flow survey was conducted at a flow of about 90 cfs in April 1989. A second high-flow survey was conducted at about 35 cfs on the Eagle Canyon Reach in April 1990.

Potential migration barriers were described in a standardized field form (Appendix A). Each potential barrier was characterized based on classification components adapted from Powers and Orsborn (1986; Table 1) by site geometry (e.g. barrier height, pool depth, passage routes) and hydraulics (e.g. water velocity, direction, turbulence). Each site was also described by type (indicated as class in field forms, e.g. falls, chute), composition (e.g. bedrock, boulder) and photographed. Classification of barrier passability followed the terminology of Dane (1978):

1. Total: impassable to all fish at all flows.
2. Partial: impassable to some fish at all flows.
3. Temporary: impassable to all fish at some flows.

The above classification systems were only partially followed. For example, barrier passability (Dane 1978) was often characterized by descriptive language rather than total, partial or temporary. More importantly, many aspects of the Powers and Orsborn classification system were combined into general descriptions and drawings. This was found to be more suitable for field characterization of potential barriers, moreover Powers and Orsborn admit that much of their classification system is “subjective”. Actual passability for steelhead and chinook at different flow levels (observed and unobserved) was determined by general knowledge of swimming and leaping

abilities of these species and professional judgment. Passability of resident trout was also evaluated (noted on field forms) for most potential barriers but was not used in any barrier assessment.

Table 1 Characteristics of barrier classification components. (after Powers and Orsborn 1986).

Classification Component	Characteristics
Class	Site geometry and plan view Number of fish passage routes, flow patterns Characteristics of fish passage routes
Type	Site geometry in profile Bed slopes Pool Depths
Magnitude	Elevation drops Water velocities Slope lengths
Discharge	Flow rate at which class, type and magnitude were measured or estimated

The location of barriers, distance in miles upstream from the North and South Fork confluence, was determined by hip chain during habitat mapping. North Fork and South Fork barriers and landmarks are labeled by the prefixes NF and SF respectively, followed by their distance from the confluence of the North and South forks.

RESULTS

A total of 26 potential barriers to upstream migration of fish were identified within the study area (Figure 2; Table 2). The fish weir at the CNFH acted as a barrier to the upstream migration of fish during the time of these surveys. Completed barrier survey forms are contained in Appendix A and B. (Note: forms in Appendix A were transcribed from the original field forms because of poor copy quality and legibility of originals. In addition, some high flow barrier descriptions were completed in a field book and not on field forms. All original field notes and forms are included in Appendix B).

Mainstem Battle Creek

No natural barriers to upstream fish migration were found between CPH and the confluence of the North and South forks of Battle Creek at discharges of 15-20 cfs.

South Fork Battle Creek

Five potential barriers were identified in the South Fork during the low flow survey conducted between September 13 and 16, 1988 at discharges ranging from 4 to 10 cfs. Four were located within a 1-mile stretch beginning approximately 0.5 mile above Coleman Canal Diversion Dam (SF2.54) and one was 2.5 miles downstream of the South Diversion (SF14.35). Four of the five barriers were considered to be temporary barriers to most anadromous fish at the flows observed; the fifth may be a barrier at a slightly lower flow. None appeared likely to present an obstacle to passage at higher flows (estimated 30-50 cfs) due to the numerous routes available for fish to traverse problem areas.

Barrier Descriptions:

SF3.15 Bedrock/boulder falls (Figure 3). Water flowed over a shallow bedrock lip at the top of these falls and fell 3.5 feet onto boulders and cobble at the base. This was a barrier to all fish at 5 cfs due to a shallow landing area and an 8-foot horizontal jump distance. A moderate increase in flow would provide an alternate route passable by fish on the left bank.

Table 2. Summary of potential anadromous fish barriers located in Battle Creek, California. Class under barrier passability derived from field note descriptions when not actually indicated on field forms. (Q in cfs).

LOCATION RIVER MILE	TYPE	COMPOSITION	SURVEY DATE(S)	FLOW REGIME/Q	BARRIER PASSABILITY CLASS	FLOW	SPECIES	BARRIER CHARACTERISITICS	RECOMMENDATION
SOUTH FORK BATTLE CREEK									
SF3.15	Falls	Bedrock/Boulder	09/12/88	Low/ 4-5	Temporary Passable	Low <5 High	All All	Falls 3.5 feet high with 8 foot horozontal jump. High flow passage around main falls. Difficult passage at <5 cfs.	None
SF3.40	Falls/Cascade/ Chute	Bedrock/Boulder	09/12/88	Low/ 4-5	Passable	All	All	Series of cascades and plunge pools, 30 feet long. More routes available at high flow.	None
SF3.61	Falls/Cascade	Boulder	09/13/88	Low/ 5-8	Temporary Passable	Low High	chinook All	Numerous falls 3 to 4.5 feet high. No main channel - low flow distributed in four small channels. 6 to 10 foot horizontal jump.	None
SF3.81	Falls/Cascade/ Chute	Bedrock/Boulder	09/13/88	Low/ 6-7	Temporary Passable	Low <3-4 High	All All	Shallow chute (0.5 feet deep) over a 15 foot distance. Chute velocity 6-8 fps.	None
SF11.68	Cascade	Boulder	09/16/88	Low/ 6-8	Temporary Passable	Low High	All All	Majority of flow under boulder substrate	None
EAGLE CANYON REACH, NORTH FORK BATTLE CREEK									
NF2.16	Subterranean Flow	Boulder	9/7/88 4/9/90	Low/ ~7 Low/ ~5	Temporary Passable	Low High >20	All All	Shallow, most flow under boulder substrate. Passage problems not identifiable.	Estimated 20-30 cfs for chinook and steelhead passage
NF2.36	Falls	Boulder	9/7/88 4/9/90	Low/ ~7 Low/ ~5	Partial Passable	Low <5 High >20	All All	Shallow jump pool. Two-step, 4 foot falls. Horizontal jump distance of 9 feet.	Estimated 20-30 cfs for chinook and steelhead passage
NF4.50	Falls	Boulder	9/8/88 4/9/90	Low/ ~6 Low/ ~5	Temporary	Low	All	Falls 3-4 feet high. 10 foot horizontal jump out of 2.5 foot deep pool	Not a total barrier at low flow but more flow would help
NF4.84	Multiple Falls	Boulder	9/8/88 4/9/90	Low/ ~6 Low/ ~5	Passable	All	All	Multiple passage routes at various flow regimes.	None

Table 2. Summary of potential anadromous fish barriers located in Battle Creek, California. Class under barrier passability deriv descriptions when not actually indicated on field forms. (Q in cfs). cont.

LOCATION RIVER MILE	TYPE	COMPOSITION	SURVEY DATE(S)	FLOW REGIME/Q	BARRIER PASSABILITY CLASS	FLOW	SPECIES	BARRIER CHARACTERISITICS	RECOMMENDATION
EAGLE CANYON REACH, NORTH FORK BATTLE CREEK (cont.)									
NF5.12	Falls/Chute	Bedrock/Boulder	9/8/88 4/9/90	Low/ ~5 Low/ ~5	Passable	All	All	Character changed between surveys. Debris plug in main passage channel.	Debris plugs may be intermittent
NF5.14	Falls	Bedrock/Boulder/ Woody Debris	9/8/88 4/9/90 04/20/89	Low/ ~6 Low/ ~5 High/ ~88	Total Passable?	<75 cfs >75 cfs	All All	Falls 8-10 feet igh with 8 foot horizontal jump. Bedrock projection blocks jump	Blast steps ??
NF5.22	Chute/Debris	Boulder/ Woody Debris	9/8/88 4/9/90	Low/ ~5 Low/ ~5	Passable	All	All	Character changed between surveys. Debris jam removed	None
NF5.23	Falls/Cascade	Boulder	9/8/88 4/9/90	Low/ ~4-5 Low/ ~5	Passable	All	All	Character changed between surveys. Flow under rocks.	None
NF5.40	Falls/Cascade	Boulder	8/19/88 4/9/90	Low/ ~4-5 High/ ~35	Temporary Passable	Low High	All All	Boulders in pool may impede jumping ability. Mid-jump pool is very turbulant.	Remove boulders from pool.
DIGGER REACH, NORTH FORK BATTLE CREEK									
NF6.02	Falls	Boulder	8/19/88 4/20/89	Low/ ~10 High/ ~90	Partial Passable	Low High	chinook All	Jumps of 2-3.5 feet required into narrow openings between boulders.	Remove cork boulders
NF6.96	Falls	Boulder	08/19/88	Low/ ~10	Temporary Passable	Low High	All All	Shallow jump pool. Falls 4.5 feet high.	Remove boulder plug right side
BAILEY REACH, NORTH FORK BATTLE CREEK									
NF9.92	Falls	Bedrock/Boulder/ Woody Debris	9/15/88 4/20/89	Low/ ~7 High/ ~90	Total Passable?	All High	All steelhead	Falls 7 feet high with 5 foot horizontal jump. Jump pool 6 feet deep	Remove log left channel
NF10.72	Falls/Cascade	Bedrock/Boulder	9/23/88 4/20/89	Low/ ~7 High/ ~90	Partial Passable	All High	chinook steelhead	Initial jump height of 3.5 feet into shallow chute (0.75 ft deep) with 6 fps velocity.	Remove some boulders in right channel

Table 2. Summary of potential anadromous fish barriers located in Battle Creek, California. Class under barrier passability deriv descriptions when not actually indicated on field forms. (Q in cfs). cont.

LOCATION RIVER MILE	TYPE	COMPOSITION	SURVEY DATE(S)	FLOW REGIME/Q	BARRIER PASSABILITY CLASS	BARRIER PASSABILITY FLOW	BARRIER PASSABILITY SPECIES	BARRIER CHARACTERISITICS	RECOMMENDATION
BAILEY REACH, NORTH FORK BATTLE CREEK (cont.)									
NF10.78	Falls/Cascade	Boulder	9/23/88 4/20/89	Low/ ~7 High/ ~90	Temporary Passable	Low High	chinook All	Falls 4.5 feet high with 8 foot horizontal jump. Shallow landing area with 4 fps velocities	None
NF10.79	Falls/Cascade	Boulder	9/23/88 4/20/89	Low/ ~7 High/ ~90	Partial Passable	All All	chinook steelhead	Shallow cascasde. 8 foot horizontal jump distance. Left falls impassable at all flows	None
NF11.10	Falls	Boulder	9/23/88 4/20/89	Low/ ~7 High/ ~90	Partial Passable	All High	chinook steelhead	Falls 5-6 feet high. Shallow, narrow landing areas. Horizontal jump distances range from 4 to 9 feet.	None
NF11.31	Cascade/ Chute	Bedrock	9/23/88 4/20/89	Low/ ~8 High/ ~90	Partial Passable	All High	chinook steelhead	Chute: depth 0.3 feet, length 15 feetm velocity 10-12 fps.	None
NF11.45	Falls/Cascade	Boulder	9/23/88 4/20/89	Low/ ~8 High/ ~90	Total	All	All	No jump pool. 20 foot horizontal jump distance over 4.5 foot falls/cascade.	None
NF11.46	Falls	Boulder	9/23/88 4/20/89	Low/ ~8 High/ ~90	Partial Passable	All High	chinook steelhead	Two stage falls 9 foot total height. 8-10 foot horizontal jump out of shallow pool to clear 4.5 foot high second falls.	None
NF11.48	Falls/Cascade	Boulder	9/23/88 4/20/89	Low/ ~8 High/ ~90	Total	All	All	Falls 9.5 feet high. 7-10 foot horizontal jump distance . Cobble bottomed jump pool.	None
NF13.48	Falls	Bedrock	09/27/88	Low/ ~10	Total	All	All	Falls 24 feet high.	None

SF3.40 Bedrock/boulder cascade (Figure 4). This 30-foot series of cascades and plunge pools was not considered a barrier at 5 cfs but would be difficult for chinook and steelhead to negotiate at lower flows. Numerous routes existed for passage at higher flows.

SF3.61 Boulder falls and cascades (Figure 5). This barrier consisted of multiple falls and cascades in which the flow was distributed throughout five channels with no more than 25 percent of the total low flow passing through any one channel. The height of the various drops ranged from 3 to 4.5 feet. This barrier was impassable to chinook at approximately 6.5 cfs. Only one channel was considered passable to steelhead at this flow. Numerous routes would be available to all fish at an estimated flow of 30 to 40 cfs.

SF3.81 Bedrock/boulder cascades and chutes (Figure 6). This barrier consisted of a series of chutes and cascades approximately 45 feet in length. The chutes were between 0.5 and 0.75 feet deep with velocities ranging from five to eight feet per second (fps). This appeared to be a barrier to all fish at approximately 6.5 cfs. A secondary channel existed which would be passable at higher discharges.

SF11.68 Boulder jam (Figure 7). This barrier was formed where 70 percent of the stream discharge passed beneath boulder and cobble substrate for a distance of 20 feet. This site appeared impassable at a flow of about 7 cfs. The flow necessary for passage of steelhead and chinook was roughly estimated to be 40 to 50 cfs.

North Fork Battle Creek

Eagle Canyon Reach

Six of nine potential barriers in this reach were considered to be barriers to chinook migration at low flows of 4 to 7 cfs. Barrier NF5.14, just below Eagle Canyon Dam , was judged to be a complete barrier to all fish at all flows. All other locations were considered passable at higher flows though the exact level of flow at which each barrier became passable was not determined. Two sites, NF5.22 and NF5.23, originally classified as low flow barriers in the September 1988 survey, were re-classified during an April 1990 survey as being passable to all fish due to movement of some barrier components between surveys. Barrier NF5.12 was classified as a low flow barrier in the second survey, despite its passable classification in the first survey, because debris had plugged the main passage channel.

Barrier Descriptions:

NF2.16 Boulder jam (Figure 8). All water at 7 cfs passed under the substrate for approximately 27 feet. This barrier was impassable to large fish, particularly chinook, at 7 cfs. Numerous routes would become available for fish passage at an estimated 20 to 30 cfs.

NF2.36 Boulder falls (Figure 9). This barrier was a two-step falls approximately 9 feet long and 4 feet high. A shallow pool existed below the falls and an intermediate jump pool may also form in the main falls. This barrier was impassable at 5 and 7 cfs to all fish with the possible exception of steelhead. Other routes might become available for passage past this barrier at flows of 20 to 30 cfs.

NF4.50 Boulder falls (Figure 10). Water passing over this 3 to 4 foot falls landed on rocks before passing through a chute to a deep pool, covering a total horizontal distance of 10 feet. This distance was impassable to all fish at flows of 5 and 6 cfs. This barrier would become passable to all fish at undetermined higher flows.

NF4.84 Boulder falls. This group of multiple falls was not a barrier at low flow or high flow. This potential barrier was included since it shows many of the same characteristics of other barriers and maybe identified as a potential barrier in future surveys.

NF5.12 Boulder/bedrock falls and chute (Figure 11). In September 1988, all flow (5 cfs) passed over a 4 foot falls into a deep chute. At this time it appeared to be a barrier to chinook but not steelhead. In April 1990, the chute was blocked with debris and all water (5 cfs) flowed over an alternate route. It was not considered to be a barrier at this time. This barrier was presumed to be passable at an undetermined higher flow.

NF5.14 Boulder/bedrock falls (Figures 12 and 13). At low flows of 5 and 6 cfs, water corkscrewed down an 8 foot high vertical hole in the bedrock. This falls was about 9.5 feet long. At higher flows of approximately 88 cfs, water dropped swiftly from the top of the falls and fell against a bedrock wall. In order to pass this falls at high flows, a fish would have to leap a horizontal distance of 15 feet and a vertical distance of 6 feet at a 30 degree lateral angle. This barrier was considered nearly impassable by all fish at all flows. Steelhead and spring chinook in good condition might pass this falls at very high flows (i.e. greater than 88 cfs).

NF5.22 Boulder/woody debris chute (Figure 14). A chute at this site was plugged with debris in September 1988 and was classified as a low flow barrier at 5 cfs. However, the debris was not blocking the chute in April 1990. This site was reclassified as passable at all flows.

NF5.23 Boulder falls and cascade (Figure 15). In September 1988, a 2 foot falls at this site was determined to impede chinook passage at a flow of about 4.5 cfs. However, in April 1990, this falls was undercut and no longer posed a passage problem to any fish at any flow.

NF5.40 Boulder falls and cascade (Figure 16). This barrier consisted of a cascade below a 3.5 foot high falls at approximately 4.5 cfs. The horizontal distance from a pool below the cascade to the top of the falls was 8 feet. This configuration was considered to be impassable to chinook but passable to steelhead. At 35 cfs, the pool below the cascade was large enough to allow chinook and steelhead passage. Resident trout were observed unsuccessfully attempting to pass this barrier at 35 cfs.

Digger Reach

Two potential barriers were located during the low flow survey at 10 cfs.

Barrier Descriptions:

NF6.02 Boulder falls (Figures 17 and 18). This site required fish to accurately jump between 2 to 3.5 feet from a deep pool into narrow openings between boulders at a low flow of 10 cfs. This falls was considered marginal for steelhead and impassable to other fish at low flow. At 90 cfs, most of this barrier was submerged and was passable to all fish.

NF6.96 Boulder falls (Figures 19 and 20). This barrier consisted of a shallow jump pool below a 4.5 foot falls at a low flow of 10 cfs. It was considered impassable to all fish at low flow. Though not surveyed at higher flows, it was presumed that passage by all species would be possible when the jump pool was deeper.

Bailey Reach

Ten potential barriers found in this reach were classified as low flow barriers at 7 to 8 cfs. Nine of these were classified as high flow barriers to chinook. Three of the 10 barriers were considered impassable to steelhead at a high flow of 90 cfs. The apparent limit of fish passage on the North Fork was a series of high falls approximately 3 miles upstream of the Bailey Creek confluence.

Barrier Descriptions:

NF9.92 Bedrock/boulder falls with woody debris (Figure 21). This barrier was 7 feet high and 5 feet long at a low flow of 7 cfs and was considered impassable to all fish. At a high flow of 90 cfs, this barrier was 4.5 feet high and 5 feet long. This configuration was considered to be passable by steelhead and, perhaps, very strong chinook.

NF10.72 Bedrock/boulder falls and cascade (Figures 22 and 23). This barrier consisted of a 3.5 foot high falls and a 4 foot high cascade which covered a horizontal distance of 17 feet at a low flow of 7 cfs. This configuration was impassable to all fish at all flows. At a flow of 90 cfs, an alternate channel was present that was passable only to steelhead.

NF10.78 Boulder falls and cascade (Figures 24 and 25). At a low flow of 7 cfs, this barrier was 4.5 feet tall and 8 feet long, with shallow, high velocity water at the upstream end. It was impassable to all fish at this flow. However, this site would be passable to all fish at an estimated 20 cfs and was completely passable to all fish at the observed high flow of 90 cfs.

NF10.79 Boulder falls and cascade (Figures 26 and 27). This barrier was 6 feet high and 8 feel long at a low flow of 7 cfs. It was impassable to chinook at this low flow but was likely passable to strong steelhead. At a high flow of 90 cfs, this site was passable to steelhead but not chinook.

NF11.10 Boulder falls (Figures 28 and 29). The stream at this site was separated into three separate channels each with a falls ranging in height from 5 to 6 feet and length from 4 to 9 feet at a low flow of 7 cfs. These falls were slightly smaller at a high flow of 90 cfs. This site was considered impassable to chinook at all flows and passable to strong steelhead at all flows.

NF11.31 Bedrock cascade and chute (Figures 30 and 31). This barrier consisted of a 15 foot series of cascades and chutes with mean column water velocities estimated to range from 6 to 12 fps at a low flow of 8 cfs. It was considered impassable to all fish at this low flow. At a high flow of 90 cfs, water was deeper and faster at this site allowing passage of steelhead but not chinook.

NF11.45 Boulder falls and cascade (Figures 32 and 33). At a low flow of 8 cfs, this barrier was comprised of a 2 foot high falls above a 2 foot high cascade. No pool existed below the cascade from which fish could jump. This configuration was impassable to all fish at low flow. This site changed in character at a high flow of 90 cfs when it was comprised of a 4.5 foot high by 8 feet long cascade. At high flow this barrier was passable only to steelhead.

NF11.46 Boulder falls (Figures 34 and 35). A two-stage falls measuring 9 feet high by 8-10 feet long existed at this site at a low flow of 8 cfs. It was is impassable to all fish at low flow. At a high flow of 90 cfs, this barrier was passable to steelhead and possibly passable to chinook.

NF11.48 Boulder falls and cascade (Figures 36 and 37). This site was comprised of an 8 to 9 foot tall falls that spanned a 7 to 10 foot horizontal distance. This falls flowed into a shallow pool. It was considered impassable to all fish at all flows.

NF13.48 Bedrock falls. A 24 feet high falls at this site was considered impassable to all fish at all flows.

DISCUSSION

Most of the potential barriers located in Battle Creek are believed to impede fish migration at low flow. Only one potential barrier, below Bailey Creek on the North Fork (NF5.14), is believed to impede fish passage at higher flows.

Fish passage at low flow throughout the entire South Fork study area could be achieved by physical modification of the low flow barriers. Increasing fish passage throughout the North Fork would be less feasible due to the large number and inaccessibility of most barriers. Furthermore, only relatively short reaches would be made accessible by modification of individual barriers. The impassable barrier in the Eagle Canyon Reach (NF5.14) may be worth removal or modification since it appears to be the only probable high flow barrier between the mainstem and a group of barriers located upstream of Bailey Creek, a distance of more than 6 miles. Anadromous fish migration in the North Fork is feasibly limited to the upper portion of the Bailey Reach due to the large number and character of barriers in this reach.

Several barriers were observed to change between surveys (e.g., in the Eagle Canyon Reach), some becoming passable and others impassable at low flows. Battle Creek is typified by large boulders, mobile substrates and debris, and constricted channels, all of which contribute to the formation of debris blockages. These dynamic debris blockages are likely to form fish migration barriers, especially at low flow conditions. However, it is also likely that many of these dynamic barriers will change over time and become passable to migrating fish. Similarly, entirely new barriers can be expected to develop in the future, especially during significant flood events.

The level of discharge which would make low flow barriers passable can only be roughly estimated under the scope of this study. Intangible variables have a great effect on the ultimate success of upstream migration, including the physical complexity of the barriers and the size, physiology, and condition of migrating fish. Most of the barriers observed at low flows were estimated to become passable between 20 and 50 cfs. Those observed at both low flows and flows of approximately 30 cfs were judged to be passable at the higher flow. The best estimate of a flow that would achieve minimum passability at all low flow barriers is 30 cfs. This value could

be refined by additional surveys of the barriers at intermediate flow levels. For instance, fish passage potential at each barrier would be assessed at flow increments of, say, 5 cfs, until fish passage was considered to be possible. Ideally, fish passage potential would be confirmed by direct observation of migrating fish.

Fish passage within the Battle Creek watershed could be facilitated by the following courses of action:

1. Modify all current low flow barriers, monitor the streams each year, and modify or remove all new low-flow barriers prior to migration periods,

2. Provide flows of at least 30 cfs during migration periods and monitor the streams for new barriers only after significant flood events, or

3. Combine the two concepts by physically modifying all low flow barriers to the extent possible, increasing flows in increments until all impediments are judged passable, and monitoring for future changes.

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