4.3 Hydrology

Affected Environment

Battle Creek drains a watershed of approximately 357 square miles in the southern Cascade Range of the northern Central Valley and flows into the Sacramento River at RM 272, approximately 5 miles east of the town of Cottonwood, California. Battle Creek and its tributaries drain the western volcanic slopes of Mount Lassen, which is located at the eastern edge of the watershed. The large snowfields on this 10,000-foot peak maintain streamflow until late in the summer. The volcanic formations and alluvial stream channels buried by lava flows store most of the wet season rainfall and convey it to the streams and numerous springs as base flow.

Average annual rainfall is approximately 36 inches. The highest amounts of rainfall occur from December through March. There is very little rain from June to September. However, because streamflow is supplied by snowmelt and a large contribution from spring flow, Battle Creek has a relatively high base flow throughout the summer and fall. Representative wet, normal, and dry water years are indicated on Figure 4.3-1. The average flow in Battle Creek is approximately 500 cfs. Battle Creek flow remained above 200 cfs even in the dry year of 1994.

Battle Creek is composed of two main branches: North Fork Battle Creek and South Fork Battle Creek. North Fork Battle Creek, which is approximately 29.5 miles long from its headwaters to the confluence, drains a basin of approximately 213 square miles. South Fork Battle Creek, which is approximately 28 miles long from its headwaters to the confluence, drains a basin of approximately 124 square miles (Reclamation 2001a). The upper portion of North Fork Battle Creek and the upper portion of South Fork Battle Creek are inaccessible to anadromous salmon and steelhead because natural barriers impede fish migration (Figure 4.3-2).

The North Fork Battle Creek natural fish barrier is a waterfall located at North Fork Battle Creek RM 13.5, above the confluence of Rock Creek and Bailey Creek, and about 4 miles above North Fork Battle Creek Feeder Diversion Dam at NFBC RM 9.4. The watershed upstream of the natural fish barrier provides about 20% of the Battle Creek flow, but the majority is diverted at the Al Smith and Keswick Diversion Dams. Rock Creek and Bailey Creek provide a substantial flow at the North Battle Creek Feeder Diversion Dam, which is about 15% of the total Battle Creek flow.

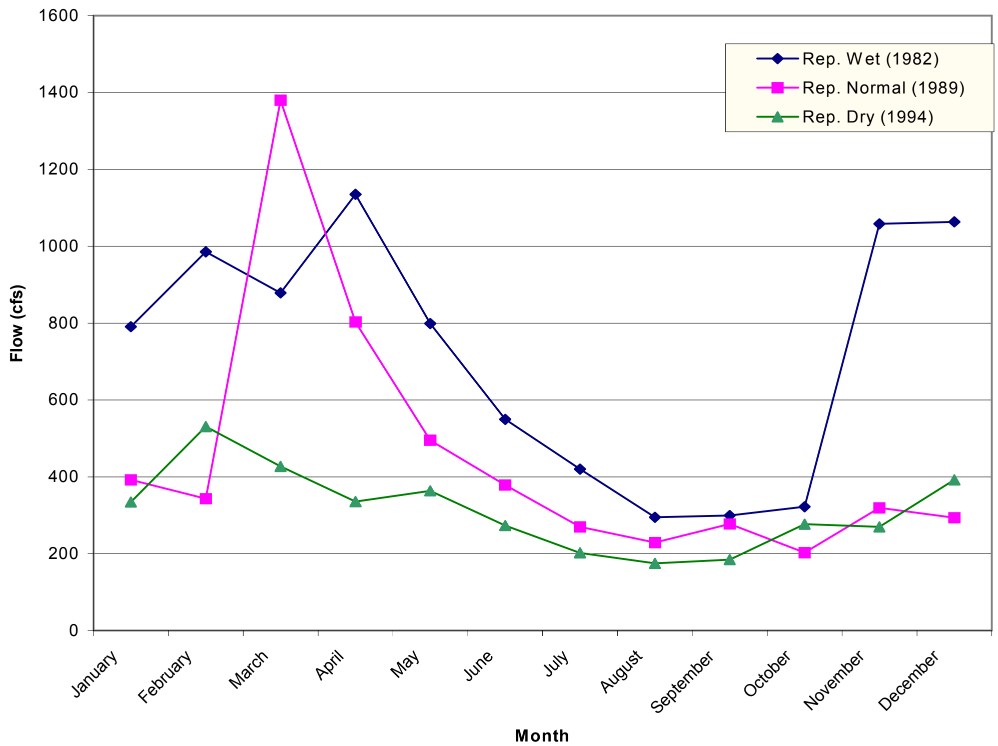


Figure 4.3-1
Representative Wet, Normal, and Dry Water Years

The South Fork Battle Creek absolute fish barrier is Angel Falls, located at South Fork Battle Creek RM 18.9, about 4.5 miles above the South Diversion Dam. The watershed upstream of Angel Falls provides about 15% of Battle Creek flow.

The mainstem valley reach of Battle Creek flows approximately 17 miles from the confluence of its forks to the Sacramento River. The Coleman National Fish Hatchery is located at Battle Creek RM 7.5. The U.S. Geological Survey Battle Creek flow gage is located just downstream of the hatchery.

Within the Eagle Canyon reach, North Fork Battle Creek receives significant spring flow from basalt formations. Figures 4.3-3 and 4.3-4 illustrate the spring flow entering North Fork Battle Creek at the Eagle Canyon Diversion Dam. The spring flow at Eagle Canyon Diversion Dam enters the Eagle Canyon Canal that runs along the southern canyon wall and contributes to the Inskip Powerhouse flow.

Figure 4.3-3
Spring Flow at Eagle Canyon Diversion Dam Flowing out of a Basalt Formation on the Southern Canyon Wall

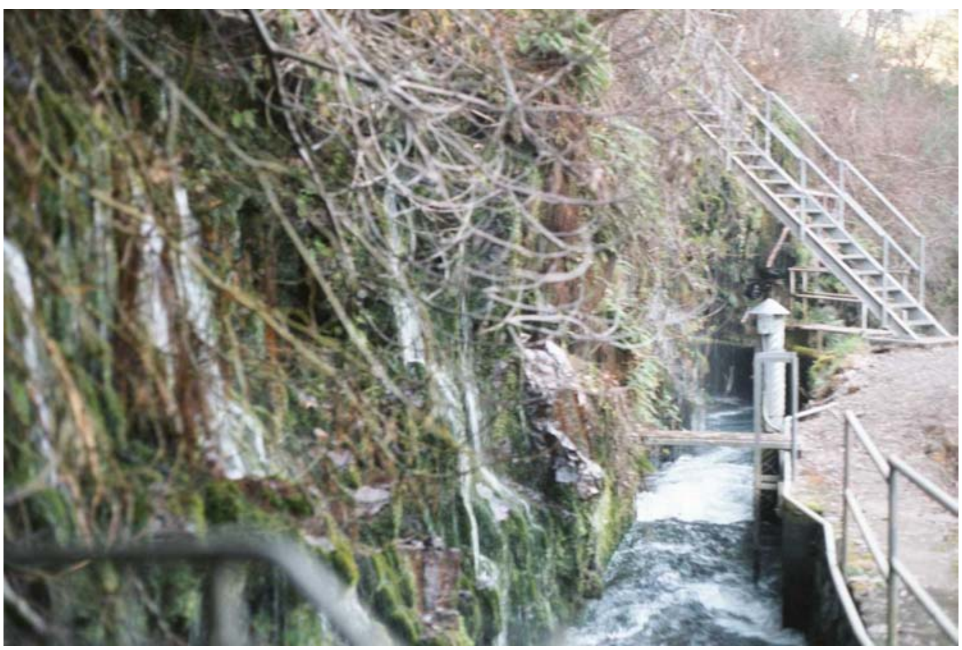


Figure 4.3-4
Spring Flow Entering Eagle Canyon Canal at Eagle Canyon Diversion Dam, Looking Downstream

Soap Creek, which is entirely diverted by Soap Creek Feeder to South Canal, enters South Fork Battle Creek between South Diversion Dam and Inskip Diversion Dam. Ripley Creek, which is entirely diverted by Lower Ripley Creek Feeder to Inskip and South Canals, enters South Fork Battle Creek between Inskip Diversion Dam and Coleman Diversion Dam. Baldwin Creek, which is partially diverted by Asbury Diversion Dam to Coleman Canal, enters Battle Creek downstream of the confluence of North Fork and South Fork Battle Creek.

Battle Creek has the largest base flow or dry-season flow of any of the tributaries to the Sacramento River between the Feather River and Keswick Dam. The spring-fed nature of Battle Creek results in an average September flow of 255 cfs reaching the Sacramento River from the Battle Creek drainage area (USGS 1995).

Flow measurements have been performed at the Coleman National Fish Hatchery since 1940. The relative contributions of North Fork and South Fork Battle Creek were taken from DWR, PG&E, and Resource Management Inc. estimates published previously. Reclamation has approximated the flow in the upper reaches of the North and South Forks Battle Creek by using the square root of the ratio of the contributing watershed area to the entire watershed area of the corresponding creek (Reclamation 2001a). During heavy rainfall, local runoff may be higher than expected from the watershed fraction. However, during the base flow periods, the watershed fraction provides a good estimate of flow.

Based on recent stream gage records from two gages installed by DWR near the confluence of North Fork and South Fork Battle Creek, the South Fork Battle Creek drainage basin (124 square miles) is more likely to experience runoff from intense rainfall. Therefore, of the two forks, South Fork Battle Creek can experience larger peak flows. The North Fork Battle Creek drainage basin is larger (213 square miles) and includes more area at high elevations. North Fork Battle Creek receives a greater portion of its water from snowmelt and spring-fed streams and, therefore, exhibits less variability. Generally, during peak flows, South Fork Battle Creek may contribute more flow than North Fork Battle Creek, but during most of the remainder of the year, North Fork Battle Creek contributes a larger portion of the flow.

Hydraulic Gradients and Sediment Movement

The overall hydraulic gradient of North Fork Battle Creek is high (3%); the creek falls more than 5,000 feet in less than 40 miles. South Fork Battle Creek has a slightly lower gradient (2%) (Figure 4.3-5). Gradients upstream of Eagle Canyon Diversion Dam in North Fork Battle Creek and upstream of Inskip Diversion Dam in South Fork Battle Creek are similar to portions of Deer and Mill Creeks between 2,000 and 4,300 feet in elevation.

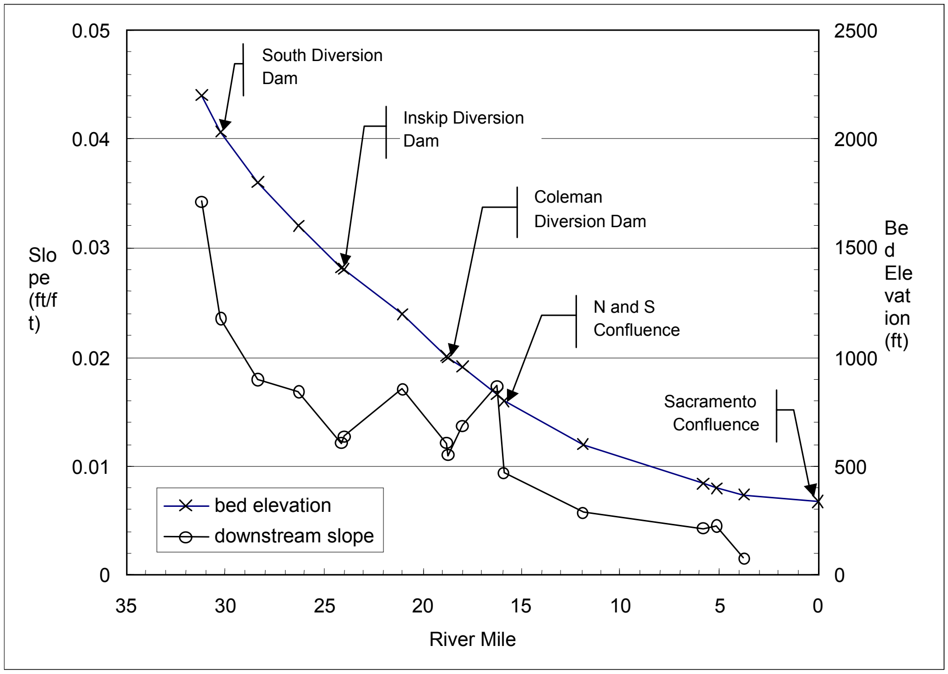
Throughout most of its length, Battle Creek is characterized by alternating pools and riffles with rocky cascades. The pools are deep, slow-moving stretches of river with fine bed material. The riffles are shallow, swiftly moving stretches of river with relatively coarse bed material. Only large cobbles are retained in the cascades.

Battle Creek has a large range of sediment sizes available for transport. These sediment sizes range from fine sand to large boulders, with the greatest portion in the gravel and cobble size ranges. Very little silt or clay is present in the bed of Battle Creek until near its confluence with the Sacramento River. Throughout the system, the many gravel bars hold a significant amount of sediment. These bars provide a reservoir of stored sediment that may be mobilized by high flows, resulting in downstream movement to another pool or riffle.

There are several different flow gradients along South Fork Battle Creek. These flow gradients are important because they may control the amount of sediment movement in the stream. A background study of sediment in Battle Creek was conducted by Reclamation (Reclamation 2001b). Because the gradient upstream of South Diversion Dam is steep (3%), South Fork Battle Creek can transport large material and has a large average bed material.

Between South and Inskip Diversion Dams, South Fork Battle Creek's slope gradually decreases, and the average bed material size decreases slightly. Near Inskip Diversion Dam, the average bed material size is approximately half the size of material upstream of South Diversion Dam. Downstream of Inskip Diversion Dam, the slope (averages 1.5%) continues to decrease. The stream then enters a relatively steep canyon where the slope is high. Near Coleman Diversion Dam, the canyon opens up and the slope flattens somewhat, such that the slope near the dam is similar to the slope at Inskip Diversion Dam (1%). Because of their similar slopes, the average bed material size near Coleman Diversion Dam is similar to that at Inskip Diversion Dam (Figure 4.3-6).

Downstream of the County Road Bridge to its confluence with North Fork Battle Creek, South Fork Battle Creek enters a canyon, and the slope increases again. After the confluence, the slope flattens substantially to about 0.5%. However, because of the contribution of flow from North Fork Battle Creek, the sediment-carrying capacity of mainstem Battle Creek probably does not decrease below the confluence. The stream travels through several miles of canyon, until the terrain opens up just upstream of Coleman Powerhouse. Downstream of the Coleman National Fish Hatchery, the slope is significantly flatter (0.2%), and the bed material becomes substantially finer.



Source: Bureau of Reclamation 2001b

Figure 4.3-6
Bed Profile of South Fork and Mainstem Battle Creek

Based on estimates developed by Reclamation, the sediment transported past Coleman Diversion Dam on South Fork Battle Creek is approximately 100,000 cubic yards per year. Of this load, approximately 8,000 cubic yards is gravel-sized or larger (Reclamation 2001b). The volume and maximum depth of trapped sediment behind Eagle Canyon, Wildcat, South, and Coleman Diversion Dams, assuming a trapezoidal channel with an average width equal to the present channel width, are presented in Table 4.3-1. Bed load material mobilized during high storm events is allowed to pass over the dams.

Table 4.3-1. Estimated Sediment Volume and Depth Behind Potentially Removed Dams

	Eagle Canyon Diversion Dam	Wildcat Diversion Dam	South Diversion Dam	Coleman Diversion Dam
Sediment volume behind dams (cubic yards)	3,200	5,000	30,000	28,000
Maximum depth of sediment (feet)	10	10	23	13

Hydroelectric Developments in Battle Creek

Battle Creek has been extensively developed for PG&E's Hydroelectric Project. The Hydroelectric Project consists of five powerhouses (Volta, Volta 2, South, Inskip, and Coleman), two small upstream storage reservoirs (North Battle Creek and Macumber), three forebays (Grace, Nora, and Coleman), five diversions on North Fork Battle Creek , including the North Battle Creek Feeder, Eagle Canyon, and Wildcat, three diversions on South Fork Battle Creek (South, Inskip, and Coleman), numerous tributary and spring diversions, and a network of some 20 canals, ditches, flumes, tunnels and pipelines (Figure 4.3-7).

Each of the eight diversion dams diverts a portion of the streamflow from North Fork and South Fork Battle Creek into canals leading to Hydroelectric Project facilities. These facilities use the diverted water for generating hydropower and then release it to Battle Creek. Some of the water is rediverted below South Powerhouse at Inskip Diversion Dam and below Inskip Powerhouse at Coleman Diversion Dam. In addition, a few tributaries to South Fork Battle Creek (Soap Creek and Ripley Creek) have small dams to divert flow into the canals leading to the South and Inskip Powerhouses, respectively. A full description of the Project hydroelectric facilities is provided in Chapter 2, "Purpose and Need, Project Description, and Project Background."

The range of streamflows at each Battle Creek diversion dam, the diversions for hydroelectric power, and remaining habitat flows below each diversion dam are evaluated with the monthly flow and power generation model (Appendix L) for the No Action Alternative and each restoration alternative.

Regulatory Setting

The following federal regulations apply to the Restoration Project.

Federal Flood Insurance Program

Congress, alarmed by increasing costs of disaster relief, passed the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. The intent of these acts is to reduce the need for large publicly funded flood control structures and disaster relief by restricting development on the floodplain.

The Federal Emergency Management Agency (FEMA) administers the National Flood Insurance Program (NFIP) to provide subsidized flood insurance to communities that comply with FEMA regulations that limit development in floodplain. FEMA issues Flood Insurance Rate Maps (FIRMs) for communities participating in the NFIP. These maps delineate flood hazard zones in the community.

Executive Order 11988

Executive Order 11988 (Floodplain Management) addresses floodplain issues related to public safety, conservation, and economics. It generally requires federal agencies constructing, permitting, or funding projects within floodplains to:

1. avoid incompatible floodplain development,
2. be consistent with the standards and criteria of NFIP, and
3. restore and preserve the natural and beneficial floodplain values.

Environmental Consequences

Summary

All of the action alternatives include activities that could impact the Battle Creek streamflow by changing the pattern of diversions and providing higher streamflow below the diversion dams. Dam removals would have the greatest potential to impact streamflow because the diversions at these removed dams would cease. These changes in streamflow are considered to be potential impacts only in the context of fish habitat and are indirectly evaluated in the fish impact assessment (Section 4.1, "Fish"). Because the minimum required flows established by FERC as part of the Hydroelectric Project regulations would increase under each alternative, the actual changes in streamflow are considered less than significant because they may approach more natural flow conditions but would not increase the risk, duration, or frequency of flooding.

Dam removal may also impact the downstream movement of sediment now trapped behind the dams. However, the bulk of the sediment behind the dams would be gradually redistributed downstream during high flow events from winter storms. Within 2–3 years after dam removal, high winter flows are expected to provide sufficient energy to redistribute most of these sediments to downstream reaches. During this time, this redistribution of trapped sediment could lead to temporary increases in the amount of fine sediments deposited in downstream pools. These temporary sediment impacts are expected to be minor and less than significant, with little long-term effect on streambed elevations, gradation, or composition. Reclamation would mitigate for some of these potential impacts by constructing pilot channels to facilitate the downstream redistribution of sediment now trapped behind dams. Monitoring of postremoval sediment would be conducted, and sediment reworking would be used, if necessary, to assist in the restoration of an equilibrium sediment transport condition that would be achieved largely through the natural redistribution of these materials during high-flow events.

Impact Significance Criteria

For this analysis, the impact significance criteria were taken from section 15065 and Appendix G of the CEQA guidelines. Hydrology or sediment impacts for the Restoration Project would be significant if implementation would:

- substantially alter the existing drainage pattern of the site or area, including alteration of the bed elevation or the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner that would result in on-site or off-site flooding, or
- expose people or structures to a significant risk of loss, injury, or death involving flooding, including flooding as a result of the failure of a levee or dam.

Impact Assessment

As applicable, the General Environmental Protection Measures listed in the introduction to this chapter will be used for this resource. In addition, specific mitigation measures for this resource are identified below.

No Action Alternative

The No Action Alternative would not affect hydrology. Under the No Action Alternative, the Hydroelectric Project would continue to operate consistent with its current FERC license. The instream flow releases would be the license-required minimum flows below dams (i.e., 3 cfs in North Fork Battle Creek and 5 cfs in South Fork Battle Creek). The actual release flows are often set at 2 cfs above the FERC requirements to ensure compliance with the minimum flows. No hydrology impacts would occur under this alternative.

Five Dam Removal Alternative (Proposed Action)

Impact 4.3-1 Less than Significant—In-water construction could result in short-term disruption of streambed and flows.

Implementation of the Five Dam Removal Alternative would result in short-term, localized disruption to the hydraulics near the sites where in-water construction affects the bed and banks of Battle Creek. However, these localized impacts would be mitigated by Reclamation during construction as described in the General Environmental Protection Measures, and all natural hydrologic processes would return to their normal dynamic equilibrium within 1 year. This impact is considered less than significant.

Impact 4.3-2 Beneficial—Coleman Diversion Dam removal could reduce the 10-, 25-, and 50-year floodwater surface profiles at Inskip Powerhouse.
Hydraulic analyses conducted by Reclamation (Reclamation 2001a) for the removal of Coleman Diversion Dam indicate that the dam removal would reduce floodwater surface profiles at Inskip Powerhouse by approximately 6.2, 5.4, and 4.9 feet for the 10-, 25-, and 100-year floods, respectively. This impact is beneficial because it would reduce the exposure of Inskip Powerhouse structures to a significant risk of damage from flooding.

No Dam Removal Alternative

Impact 4.3-3 Less than Significant—In-water construction could result in short-term disruption of streambed and flows.
Implementation of the No Dam Removal Alternative would result in short-term, localized disruption to the hydraulics near the sites where in-water construction affects the bed and banks of Battle Creek. However, these localized impacts would be mitigated by Reclamation during construction as described in the General Environmental Protection Measures, and all natural hydrologic processes would return to their normal dynamic equilibrium within one year. This impact is considered less than significant.

Six Dam Removal Alternative

Implementation of the Six Dam Removal Alternative would result in similar impacts on hydrology as those identified for the Five Dam Removal Alternative. An additional impact associated with the removal of Eagle Canyon Dam is addressed below.

Impact 4.3-4 Less than Significant—Removal of Eagle Canyon Diversion Dam could result in minor increases to downstream bed elevations.
The amount of sediment stored behind Eagle Canyon Diversion Dam is estimated to be 3,200 cubic yards. Because this amount is relatively small, releasing sediment from behind the dam would result in only minor impacts. To limit the effect of the high concentrations of fine material, the removals of Eagle Canyon and Coleman Diversion Dams should be separated by at least 2 months. If the removals were scheduled for the same time, high concentrations of fine material may exist in both North Fork Battle Creek and South Fork Battle Creek simultaneously. If the removals were separated, clean water from one fork would dilute the high concentrations of fine material coming from the fork on which the dam was removed.

As part of the Six Dam Removal Alternative, Reclamation will construct a pilot channel through the sediments behind the dam. The pilot channel would facilitate the distribution of sediments by natural high-flow events and ensure that the mass of sediment does not impede fish passage, should low flows predominate after dam removal. Under low-flow conditions, the pilot channel geometry would provide a sufficient depth of water and keep flow velocities low enough to support fish passage. Under typical winter flow conditions, sediments would quickly begin to erode and distribute downstream. This impact is considered less than significant.

Impact 4.3-5 Less than Significant—In-water construction could result in short-term disruption of streambed and flows.
This impact is the same as Impact 4.3-1 described above for the Five Dam Removal Alternative and is considered less than significant.

Impact 4.3-6 Beneficial—Coleman Diversion Dam removal could reduce the 10-, 25-, and 50-year floodwater surface profiles at Inskip Powerhouse.
This beneficial impact is the same as Impact 4.3-2 described above for the Five Dam Removal Alternative.

Three Dam Removal Alternative

Implementation of the Three Dam Removal Alternative would result in similar impacts on hydrology as those identified for the Five Dam Removal Alternative.

Impact 4.3-7 Less than Significant—In-water construction could result in short-term disruption of streambed and flows.
This impact is the same as Impact 4.3-1 described above for the Five Dam Removal Alternative and is considered less than significant.

Impact 4.3-8 Beneficial—Coleman Diversion Dam removal could reduce the 10-, 25-, and 50-year floodwater surface profiles at Inskip Powerhouse.
This beneficial impact is similar to Impact 4.3-2 described above for the Five Dam Removal Alternative.

Cumulative Impacts

Cumulative impacts resulting from changes in flow or sediment movements in Battle Creek are not anticipated by implementing the Restoration Project and other related projects (including those mentioned in Chapter 6) in the vicinity of the project area. No other projects that could modify Battle Creek hydrology are proposed.

Downstream of the Restoration Project area, several modifications are proposed for the Coleman National Fish Hatchery, including the screening of the hatchery's water intakes and modifying the hatchery's barrier weir and upstream fish ladder. These projects would not result in a change to hydraulic conditions in Battle Creek.

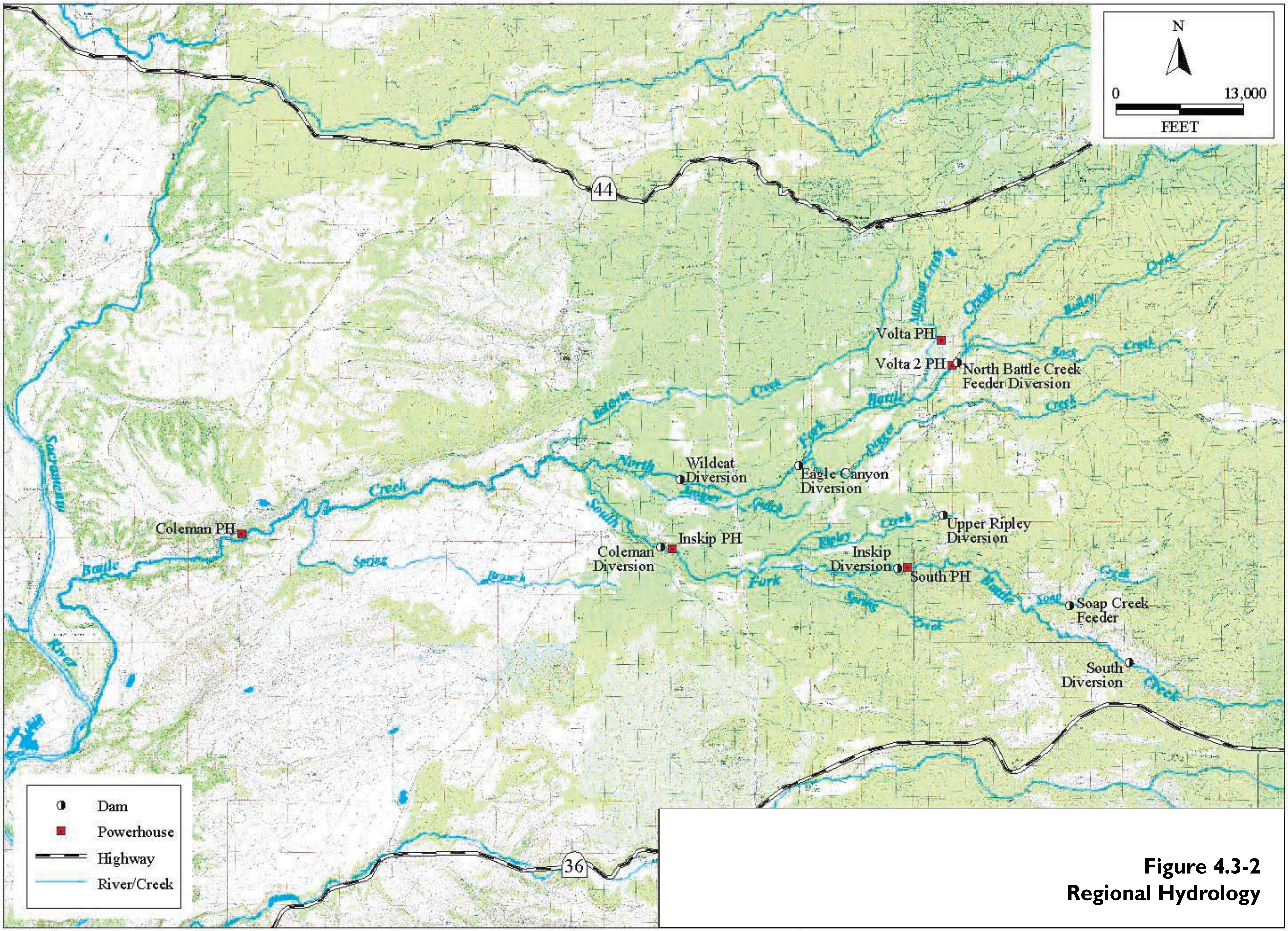
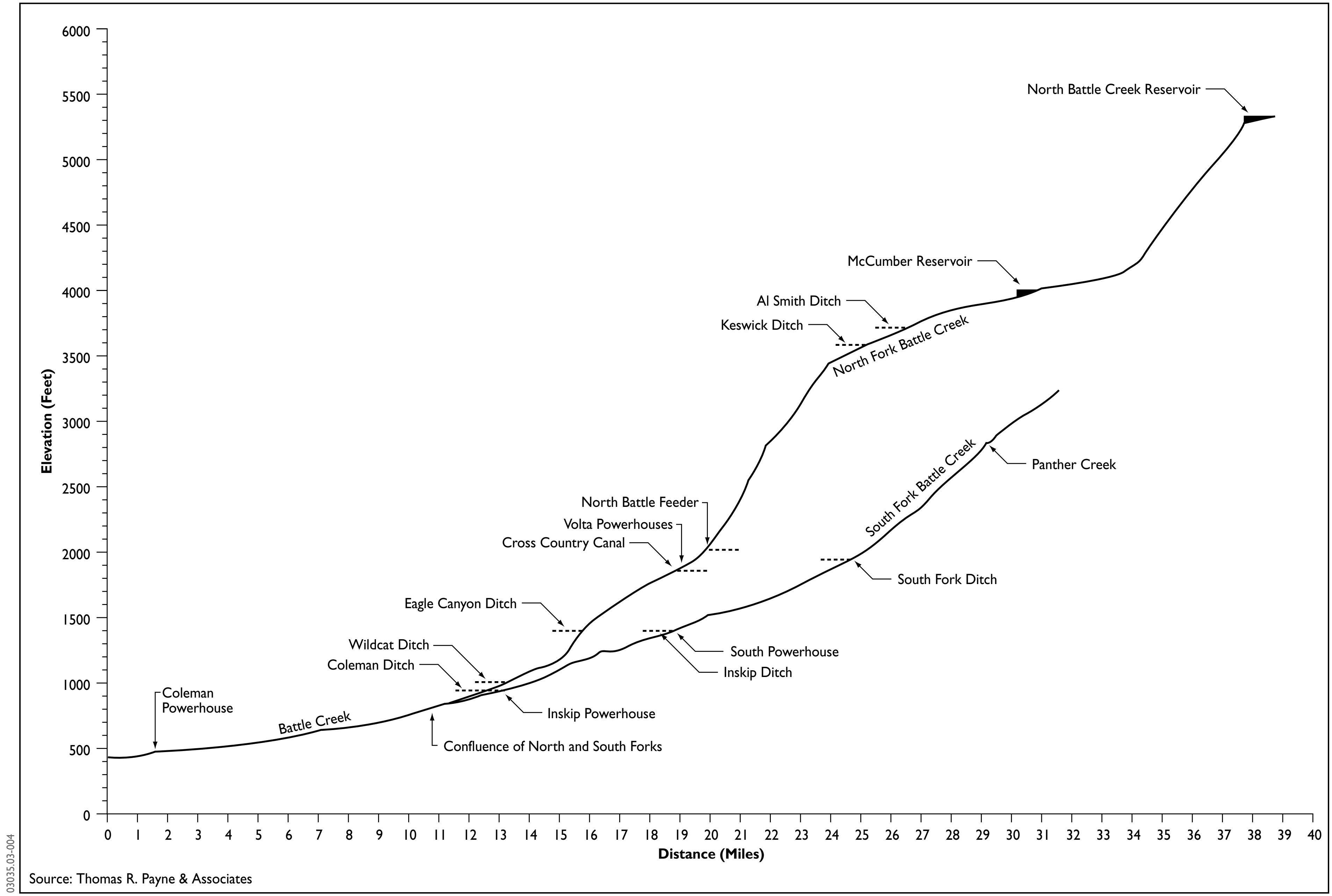
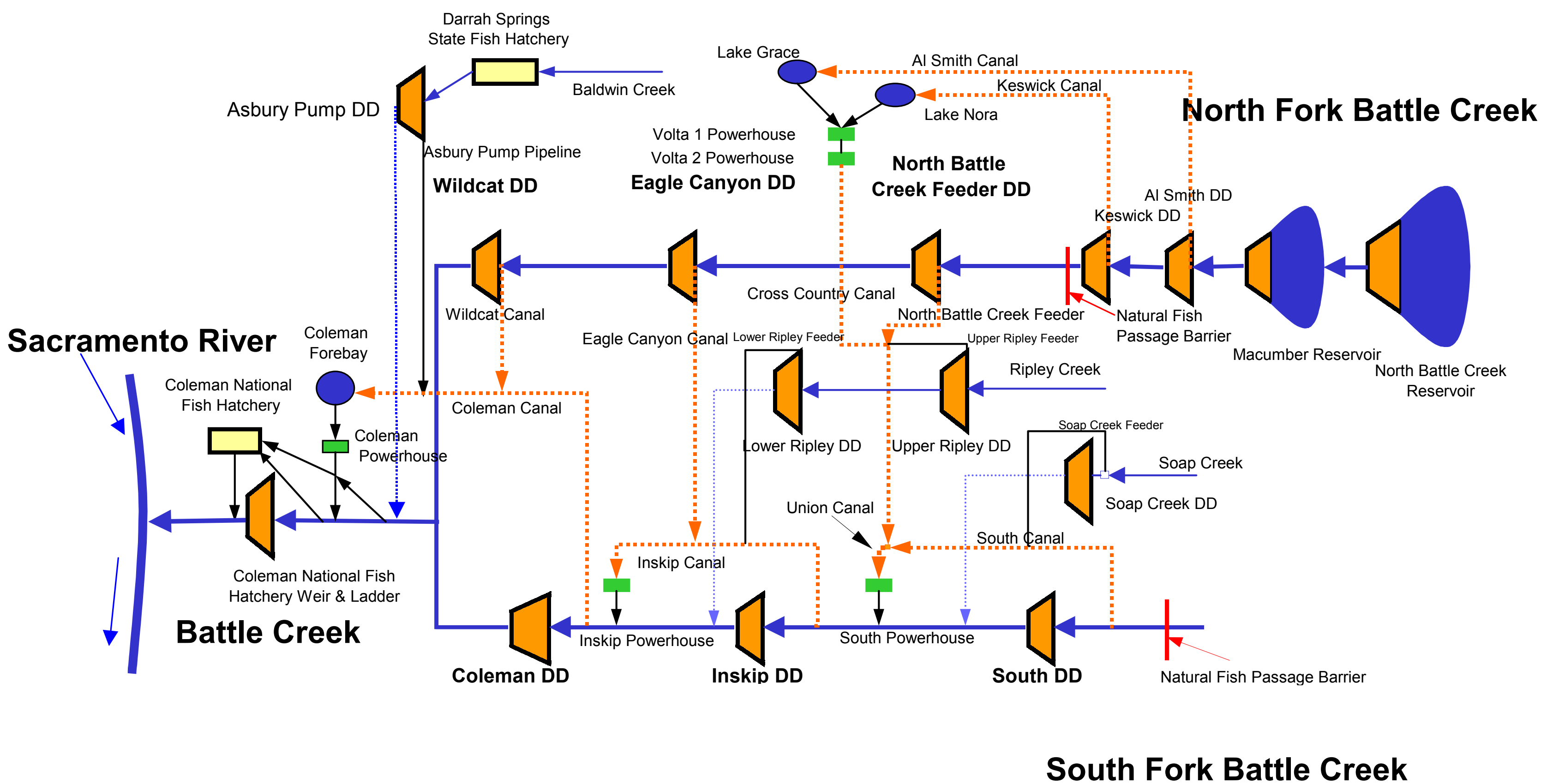


Figure 4.3-2
Regional Hydrology



Source: Thomas R. Payne & Associates

Figure 4.3-5
Longitudinal and Elevation View of the Battle Creek System



DD = diversion dam

Figure 4.3-7
Battle Creek Hydroelectric Project Flow Routing