Sound Watershed Consulting
Creating Functional Water Environments

Restoration Feasibility Assessment of Bear Creek, Tributary to the Mattole River in Humboldt County, California

Prepared for

The Mattole Salmonid Group

September 2008

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Hydrology
Geomorphology
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Restoration Design
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Integrated Watershed Management

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For

The Mattole Salmonid Group

Prepared by

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with

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September 2008

SWC Ref# 100607

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1 INTRODUCTION

This report describes the results of a preliminary restoration feasibility study conducted by Sound Watershed Consulting for Bear Creek, a tributary to the Mattole River. The Assessment focused on four restoration alternatives provided by the Mattole Salmonid Group.

A preliminary site review and survey was conducted on August 27th & 28th, 2007. During this site review, we:

- Reviewed the existing conditions of the site
- Considered each project alternative
- Performed preliminary topographic survey transects
- Performed a geomorphic survey of Bear Creek
- Explored the restoration footprint
- Collected initial hydrologic and geomorphic data

Based on information derived from our preliminary site review, Sound Watershed Consulting made a subsequent site visit in January 9th & 10th, 2008 to make wet season observations and to install 2 peizometers with datalogging pressure transducers (GlobalWater WL-15) to monitor winter and spring groundwater levels. The dataloggers were removed by Michael Evenson in late July, 2008.

This report documents the results of our assessment. It reviews the alternatives considered, describes the existing site conditions, evaluates opportunities and constraints associated with each alternative, and discusses next steps.

2 FEASIBILITY CONCLUSIONS FOR PROJECT ALTERNATIVES

This section describes each of the four project alternatives described by the Mattole Salmonid Group, and our conclusions as to the feasibility of each alternative.

2.1 Alternative 1) Stream Channel Habitat Enhancement South of Lighthouse Road

Existing slough channels, wetlands, and riparian habitat south of Lighthouse Road would be enhanced by directing Bear Creek into a new channel excavated in the vicinity of the historic channel that existed prior to diversion in the early 1970's to its present location (Figure 1). This alternative would involve:

- Constructing a diversion structure to direct all flow and sediment from Bear Creek into the enhanced reach. The diversion structure would be located upstream (south) of Lighthouse Road where Bear Creek exits its steep canyon and begins flowing unconfined across the outer Mattole River floodplain

- Excavating a new channel segments and/or modification of existing sloughs and swales to connect flow between the diversion structure and the Mattole River estuary

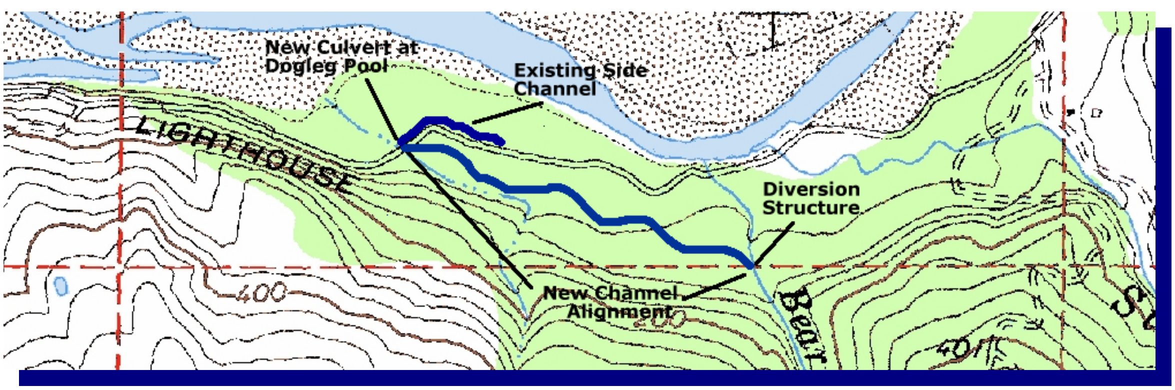


FIGURE 1) Conceptual depiction of Alternative 1. Actual channel sinuosity will depend on substrate conditions, channel dimensions, and other characteristics that will be developed during the next phase of design work.

- Installing round or arched half culverts at Bear Creek Road and Lighthouse Road at the "dogleg"

- Periodically removing sediment to maintain the diversion structure and associated channel

2.1.1 Feasibility of Alternative 1

We are very encouraged by the opportunity to restore fish habitat along the historically active floodplain area south of Lighthouse Road. Many of the core components necessary to support quality fish habitat exist here. These include:

- Good riparian cover
- Supply of naturally recruiting woody debris and organic litter
- Soils capable of supporting stable banks
- Potential groundwater support for perennial flow
- Good access for construction
- Appropriate gradient and valley width

The restored creek using this alternative can provide approximately 2600 feet of perennial, high-quality salmonid spawning and rearing habitat. Gravel supply from the upper Bear Creek could support creation and maintenance of spawning sites. Excellent existing riparian cover and groundwater sources will provide cool water temperatures in support of rearing habitat. The creek could also provide important off-channel refuge during peak runoff events in the mainstem Mattole River, and could provide important high-quality water supplies and food resources to the Mattole estuary during summer flows.

While there are many benefits to restoration at this project site, there remain several factors that need to be considered in greater detail before proceeding with site design. These are discussed in Sections 5 and 6.

2.2 Alternative 2) Stream Channel Habitat Enhancement North of Lighthouse Road

Existing slough channels, wetlands, and riparian habitat north of Lighthouse Road would be improved by routing Bear Creek flow into former channel features located directly north and parallel to Lighthouse Road (Figure 2). This alternative would involve:

- Improving the existing Lighthouse Road crossing of Bear Creek to provide fish passage, conveyance capacity, and sediment routing. Stream crossing improvement may include installing a new culvert, bridge, or causeway and may require raising the elevation of Lighthouse Road.

- Constructing a diversion structure capable of directing all flow and sediment from Bear Creek into the enhanced reach. The diversion structure would be located downstream (north) of Lighthouse Road where Bear Creek emerges from the Lighthouse Road crossing.

- Excavating a new channel segments and/or modification of existing sloughs and swales to connect flow between the diversion structure and the Mattole River estuary.

- Periodic sediment removal to maintain the diversion structure and associated channel.

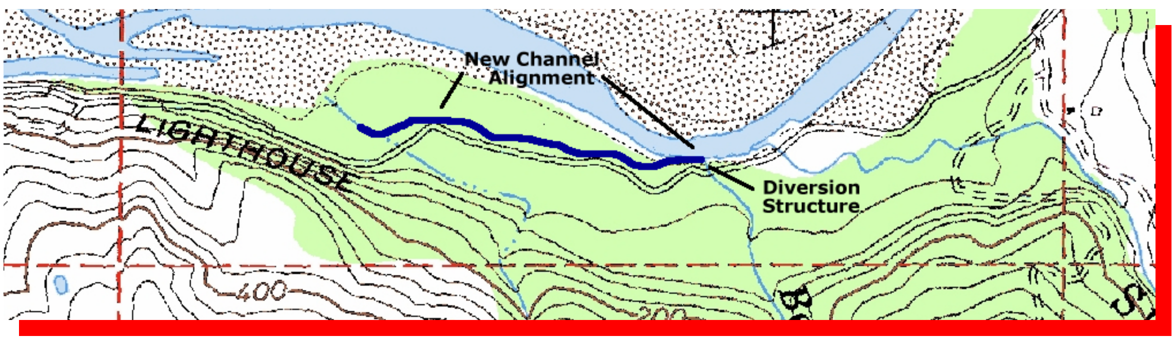


FIGURE 2) Conceptual depiction of Alternative 2.

2.2.1 FEASIBILITY OF ALTERNATIVE 2

We do not recommend this alternative.

The opportunities to restore a channel north of Lighthouse Road are limited. While there are some advantages that this location offers, there are a larger number of disadvantages and additional challenges. Some of the advantages include:

- A relatively blank slate - since no clear channel exists, we would be free to design just about any channel we would like.

- There is a large area, and the length of habitat created could be large (at least initially)

However, restoring a channel north of Lighthouse road is not promising with regard to fish habitat or a stable channel. There are several factors that limit restoration potential. These include:

- The lack of a clear channel pathway below Lighthouse road indicates that any new channel will be prone to sedimentation and channel avulsion
- The channel would remain an intermittent channel and would likely be dry much of the summer and early fall, since there is no bank or floodplain storage that can provide additional water through the dry season
- A floodplain environment that changes often in response to Mattole river floods – causing frequent changes in local slope and energy grade that are necessary to support a stable channel
- Insufficient floodplain storage adjacent to Reaches B and C to support perennial summer flow. Major modifications would be required, and the potential for flow improvement is low.
- Frequent inundation by the Mattole River would impose significant stresses on a restored channel
- The culvert at Lighthouse Road would continue to be a fish passage barrier, so peak flow refuge in upper Bear Creek (above Lighthouse Road) would remain blocked.
- Poor quality stream habitat in Reaches B and C might still require attention.

2.3 Alternative 3) Improved Lighthouse Road Crossing Of Bear Creek at Existing Site and Enhancement of the Existing Bear Creek Channel North of Lighthouse Road

The Lighthouse Road crossing of Bear Creek would be improved to provide fish passage, flow conveyance, and sediment routing; and the existing Bear Creek channel downstream of Lighthouse Road would be enhanced to improve habitat and provide a better a connection to the Mattole River Figure 3). This alternative would involve:

- Improving the existing Lighthouse Road crossing of Bear Creek to provide fish passage, conveyance capacity, and sediment routing. Stream crossing improvement may include installing a new culvert, bridge, or causeway and may require raising the elevation of Lighthouse Road.
- Excavating and/or modifying the existing channel to enhance habitat and better connect Bear Creek to the Mattole River during low flows.

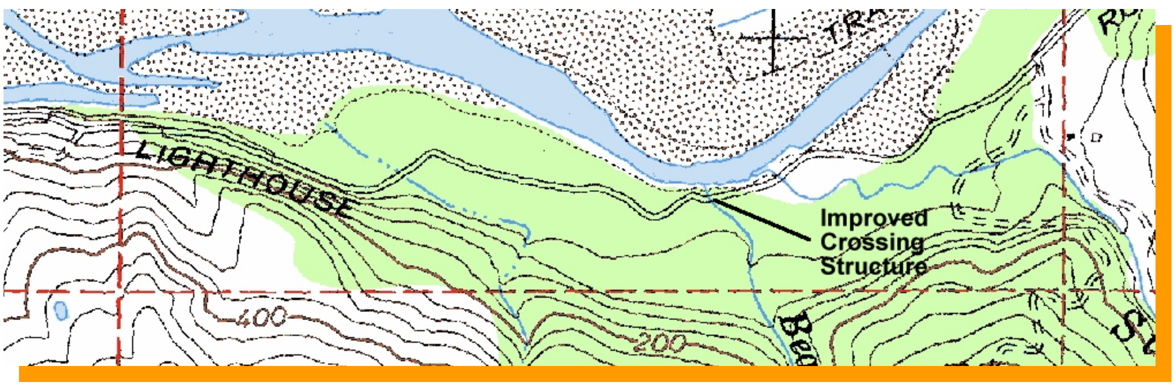


FIGURE 3) Conceptual depiction of Alternative 3. Note that the current location of the Mattole River is approximately 700 feet north of the location represented by this map image.

2.3.1 FEASIBILITY OF ALTERNATIVE 3

We do not recommend this alternative.

Similar to Alternative 2, this alternative offers too many constraints with too few opportunities. There remain a large number of obstacles to restoring a functional creek north of Lighthouse Road at its current location, and the potential value would remain low.

In addition, reconfiguring the Lighthouse Road passage would allow fish access during winter months, and would thus provide some peak flow refuge. However, a new crossing will do little to correct the lack of flows, and will ultimately provide limited benefit at a high cost.

2.4 Alternative 4) Maintain Existing Site Configuration

No change would be made to the existing Bear Creek channel upstream or downstream of Lighthouse Road, and no improvements would be made to the existing Lighthouse Road crossing of Bear Creek. This alternative would involve:

- Periodic sediment removal to maintain the diversion structure and associated channel.

2.4.1 Feasibility of Alternative 4

There are very few opportunities to improve fish habitat under the existing channel configuration.

3 Assessment Approach & Objectives

Our basic approach to evaluating the feasibility of these alternatives is to apply our scientific and restoration expertise to evaluate the existing conditions of the site, test alternatives against standard design feasibility metrics, and compare likely geomorphic and ecological responses. We understand that the primary creek enhancement objectives are to:

- Increase summer rearing capacity for salmonids through high quality instream habitat
- Increase estuarine habitat complexity through slough habitat and cold water connectivity
- Increase spawning and rearing habitat for coho and steelhead, especially in water year's with late onset of fall rain

Known conditions that this project is intended to address include:

- High coarse sediment transport rates due to natural and anthropogenic upslope sources
- Artificial diversion to current course under Lighthouse Road in mid 1970s
- Undersized, poorly functioning culverts placed at the Dogleg pool following 1993-94 winter flows

Our assessment is constructed around the desire to address these issues while evaluating the likely potential for success for each of the approaches.

4 EXISTING CONDITIONS

This section describes the site conditions relevant to considering the restoration alternatives. We begin with a somewhat detailed outline of the general site conditions, including the geology and hydrology factors that are relevant to the alternatives assessment. We proceed with a general characterization of Bear Creek (Section 4.2), the Mattole River (Section 4.3), and the floodplain surface south of Lighthouse Road (Section 4.4).

4.1 General Site Conditions

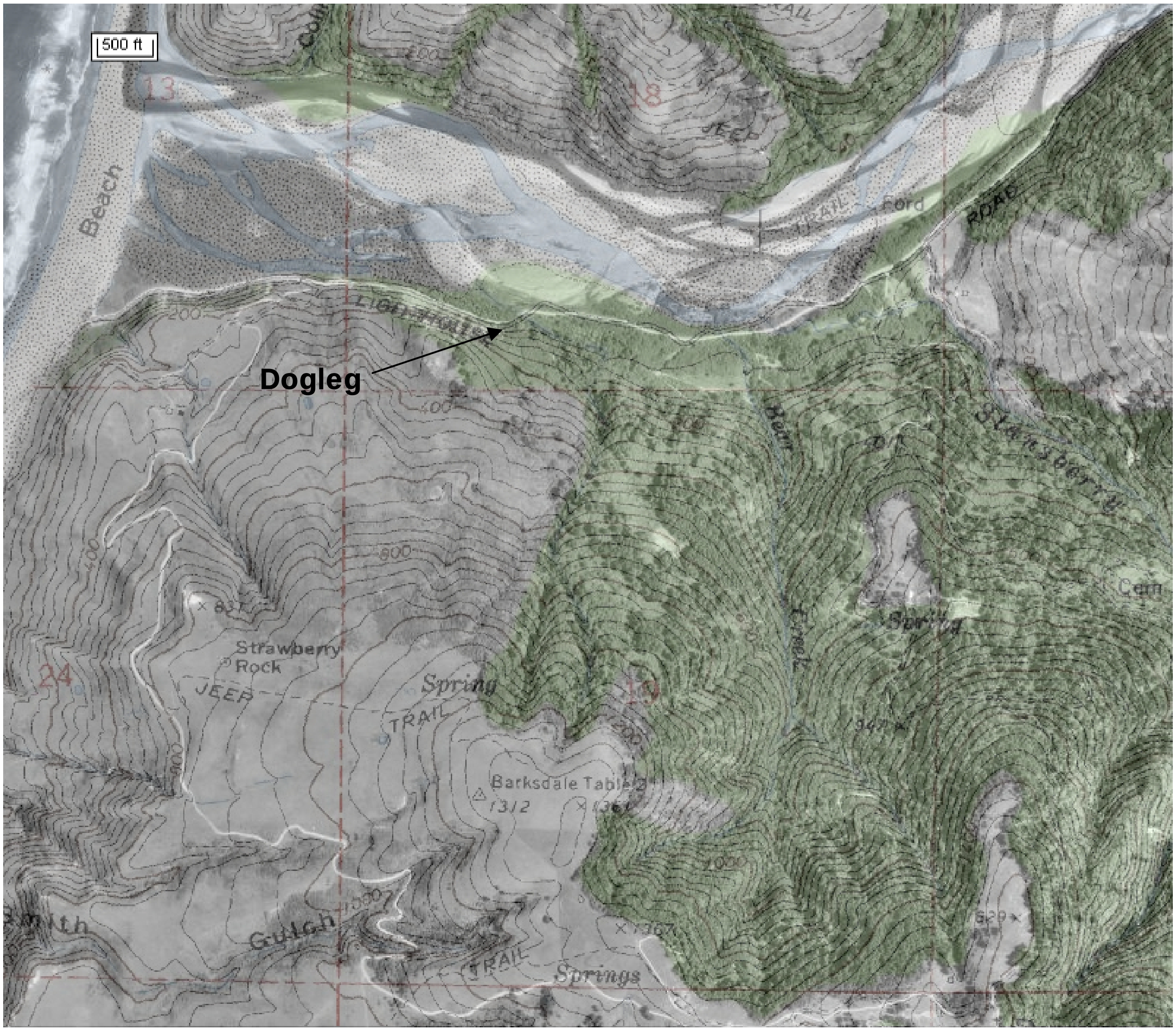
The current configuration of Bear Creek is the result of a project in the 1970s designed to improve fish passage into Bear Creek by dredging a straight channel from the Bear Creek alluvial fan at the base of the hillslope to the Mattole River. This historic project, while well intended, may not have recognized the important functional processes that support and maintain fish habitat in Bear Creek. Today, Bear Creek below the alluvial fan is dry during much of the year and provides little, if any, functional habitat value for fish.

Bear Creek is a north-trending tributary to the Mattole River about 6400 feet upstream from the Mattole River's confluence with the Pacific Ocean (Figure 4). Bear Creek drains a small 2^{nd}-order watershed of 363 acres. The watershed is a relatively undisturbed, and predominantly vegetated by a mixed Douglas fir/Grand fir forest. More detailed descriptions of Bear Creek and the Mattole River are provided in Sections 4.2 and 4.3.

4.1.1 GEOLOGY

The geologic terrain is very active in this landscape and poses a significant influence on geomorphic response of the Mattole River and Bear Creek. Landslides are prevalent in this landscape, and dominant substrates are only partially lithified. Fine sediment (silts and sands) are plentiful, as are coarse cobbles and boulders. Dominant geologic materials consist of Franciscan mélange of shattered sandstone and argillite (Davenport et al 2002).

Marshall et al (1993) report about 1.5 feet of uplift at the project site, and about 3 feet near the beach associated with the April 25, 1992 M7 Cape Mendocino earthquake. This uplift may be partly responsible for the migration of the Mattole River northward in response to subsequent



NOTES: Aerial Photo (June 1993) with USGS Topo map overlay (1989). Note the migration of the Mattole to the north in the 1993 image. Current location of the river is depicted in Figure 13

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Figure 4

Overview Map

Project: 1006	Date: August 2008

flooding in January 1993, which was not particularly large, although significant channel adjustment was observed. The uplift appears to have changed the local channel gradient and base level in a way that promoted sedimentation and channel migration.

4.1.2 HYDROLOGY

This study obtained and reviewed several hydrology sources of information. We present a summary of this information here. We recommend that more detailed analysis of available hydrologic data be conducted during subsequent phases of this project.

Local annual rainfall ranges from 27" to 110" based on rainfall records for Petrolia between 1966 and 1995. The average annual rainfall is 63", and the average maximum daily rainfall observed during this period is 3.94 ± 1.16 inches (Figure 5).

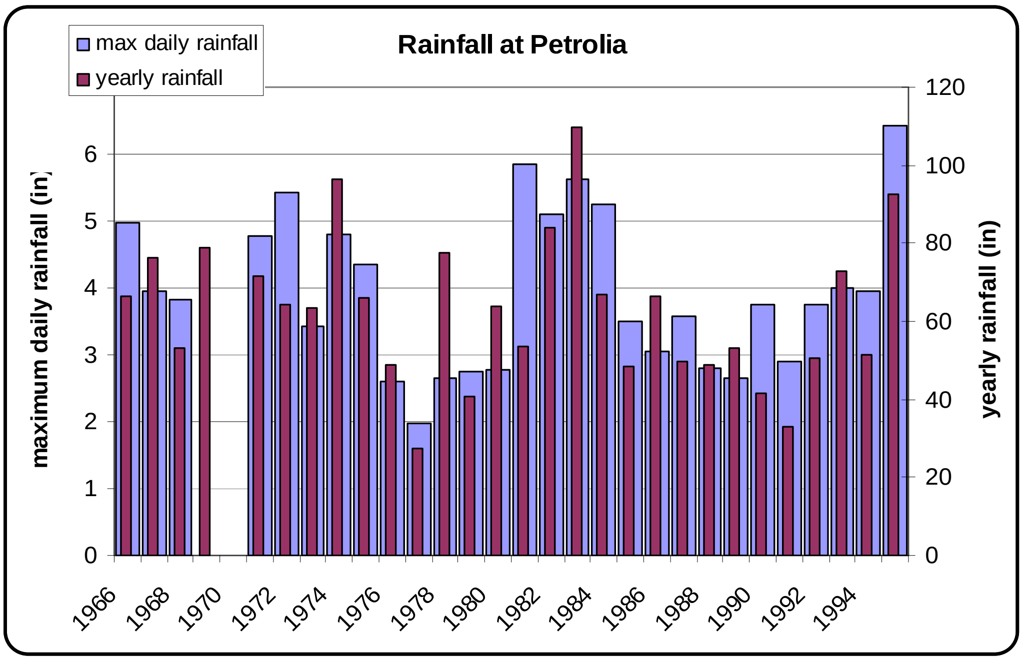


FIGURE 5) Rainfall summary for the Petrolia rainfall station.

The total catchment area for Bear Creek at Lighthouse Road is 363 acres. An additional small catchment to the west of Bear Creek also delivers runoff from about 246 additional acres to the floodplain surface south of Lighthouse Road. Using these data, we estimated peak flood flows for Bear Creek using regional regression relationships established by the US

Geological Survey (Waananen and Crippen 1977). These results are presented in Table 1. More detailed analysis will be required to support site design, however, these preliminary numbers are useful for our feasibility evaluation.

	Bear Ck	Western Catchment	Combined
Area (ac)	**336**	**246**	**582**
Frequency	**Q (cfs)**		
Q2	78	59	128
Q5	122	93	199
Q10	254	192	416
Q25	300	227	489
Q50	326	247	532
Q100	360	274	584

TABLE 1) Peak flow estimates for Bear Creek using regional regression equations (Waananen and Crippen 1977).

We also developed a peak flow flood frequency analysis for the Mattole River station near Petrolia (USGS station 11469000) from 1912 through 2005 (Figure 6) which suggests that floods as large as 20,000 cfs occur fairly frequently (every few years), and flood up to about 80,000 cfs have a 1% risk of occurrence in any given year.

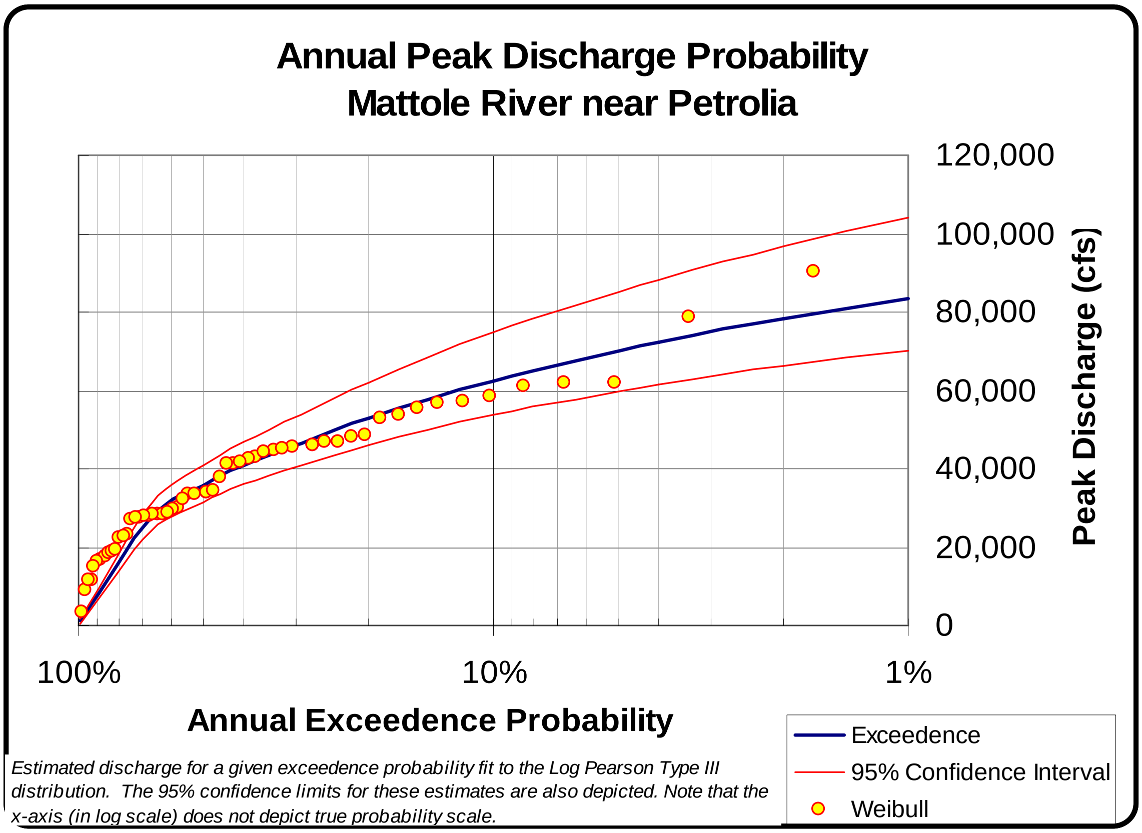
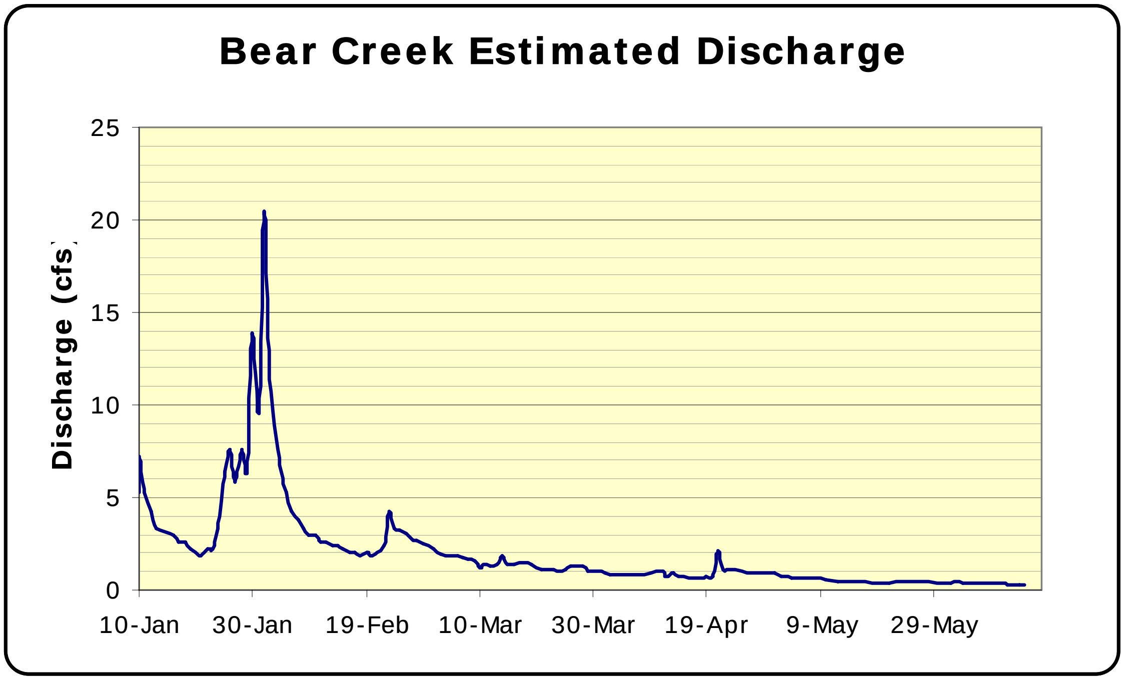


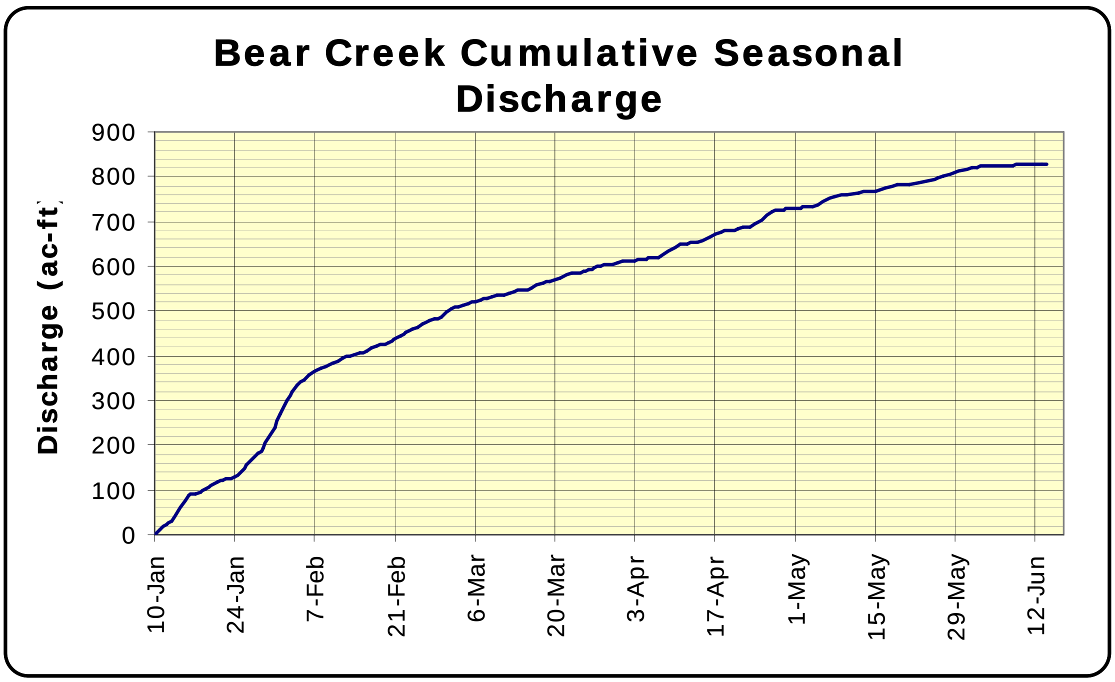
FIGURE 6) Peak flow estimates for the Mattole River using the Log Pearson III methodology (USGS Bulletin 17b) and Weibull methodology. Data was provided by the USGS gage for the Mattole River near Petrolia (station 11469000) from 1912 through 2005.

Stage data was measured in Bear Creek from January 10, 2008 through June 20, 2008, and this data was used to approximate daily and cumulative season flows (Figure 7). Individual discharge measurements were also made in August 28, 2007 and January 10, 2008 Table 2).

Date	Instantaneous Discharge (cfs)	Avg Daily Discharge (ac-ft)	Location
8/28/2007	0.042	0.083	Reach D
1/10/2008	7.26	14.4	Reach D
1/10/2008	9.44	18.7	at Lighthouse Road

TABLE 2) Measured discharge on Bear Creek. January 2008 flow measurements were made using a Globalwater Flowprobe velocity meter following standard discharge measurement methods. August flows were measured by diverting and capturing flows into a 5-gallon bucket. Three replicates of flow were captured and averaged.





NOTES: Estimated Daily and Seasonal discharge estimates for Bear Creek based on measured stage data. Note this data was collected during a period in which the Mattole River USGS gage at Petrolia recorded its lowest level on record.

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Figure 7

Preliminary Estimated Bear Ck Discharge

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This data is used in this assessment to estimate the forces applied to Bear Creek during large flows, and to estimate the amount of supporting summer baseflows that might support perennial flow conditions for each of the proposed alternatives. This assessment is discussed further in Section 6.

Data from the Mattole River provides a sense for how long the summer baseflow period extends. As shown in Figure 8 below, baseflows typically extend 4 months from mid June through early October. During this period, flows are very low.

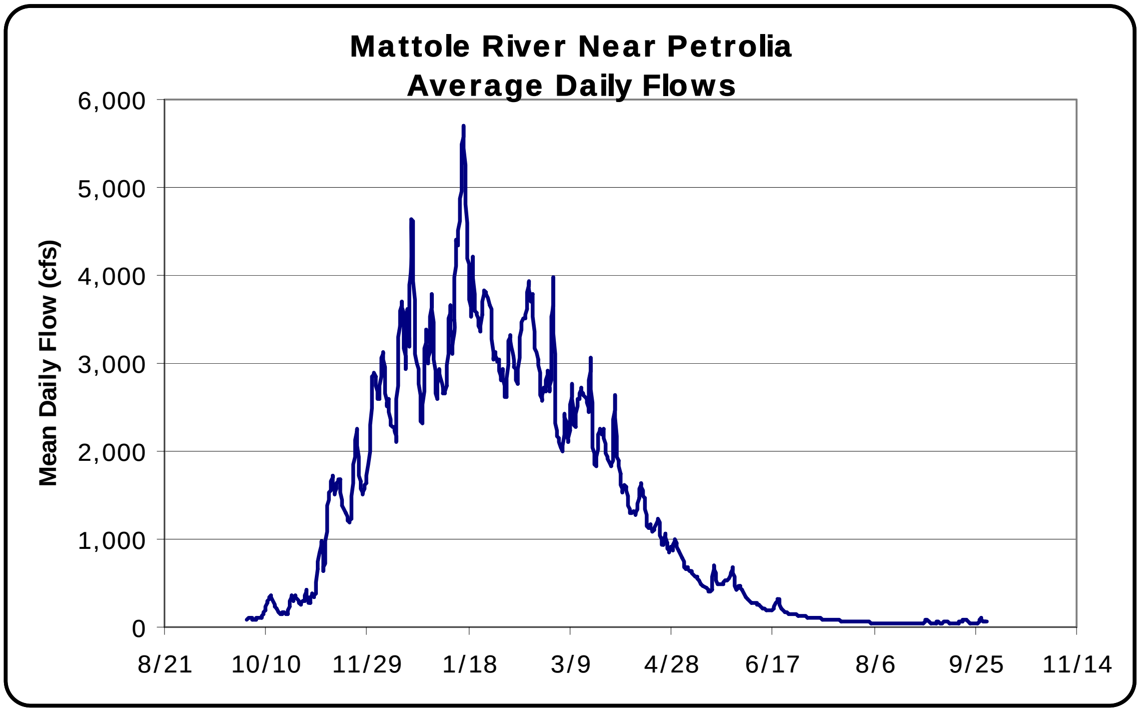


FIGURE 8) Average daily flows from 1911 through 2006.

The total annual discharge observed on the Mattole River since 1951 generally ranges from about 50,000 ac-ft to nearly 2,000,000 ac-ft (Figure 9). On only three occasions have flows been below 50,000 ac-ft for an entire water year.

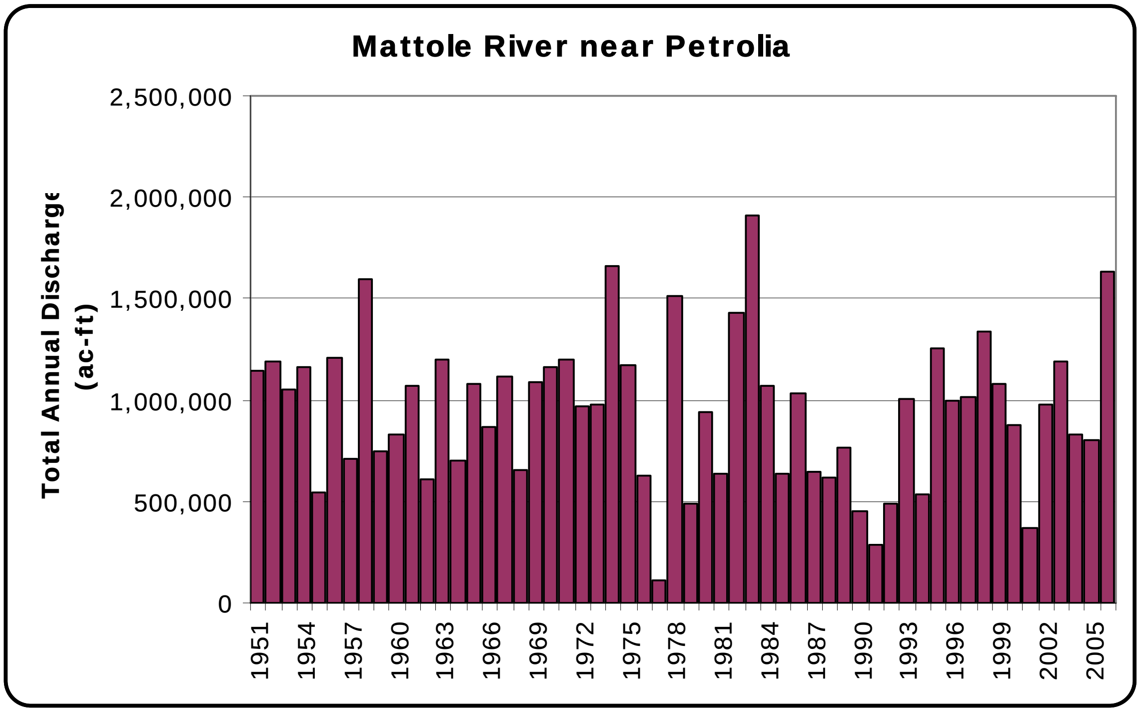


FIGURE 9) Annual runoff totals for the Mattole River near Petrolia.

4.2 Characterization of Bear Creek

Our characterization of Bear Creek is based on photo and map reviews, as well as detailed site surveys in August 2007 and January 2008. Four reaches of Bear Creek (Figure 10) were identified based on geomorphic criteria. Reach A extends north from the south culvert opening under Lighthouse Road towards the confluence with Mattole River. Reach B reflects a lower alluvial fan surface, Reach C is an upper alluvial fan section, and Reach D includes the lower section of Bear Creek that is confined by steep valley hillslopes.

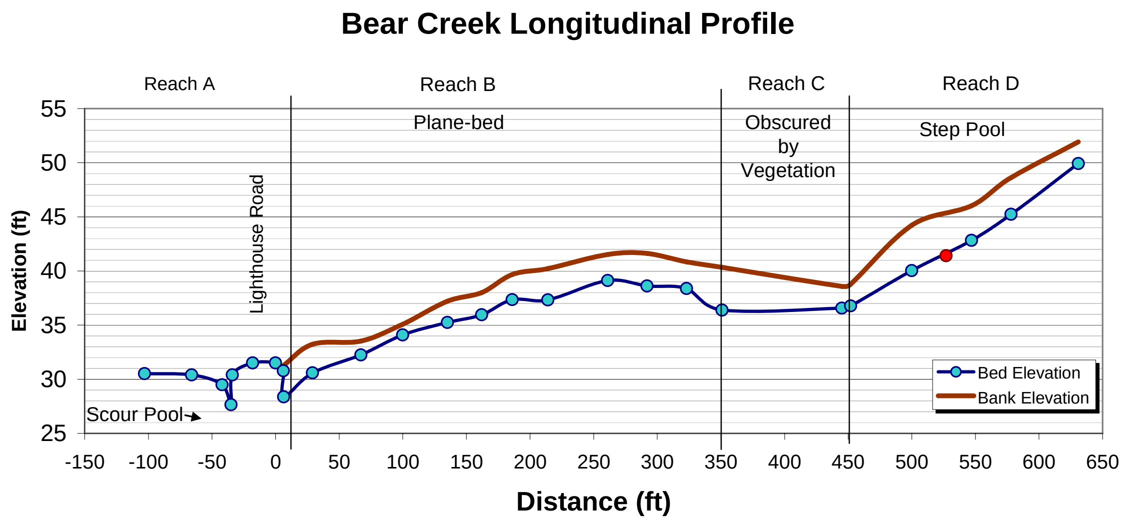
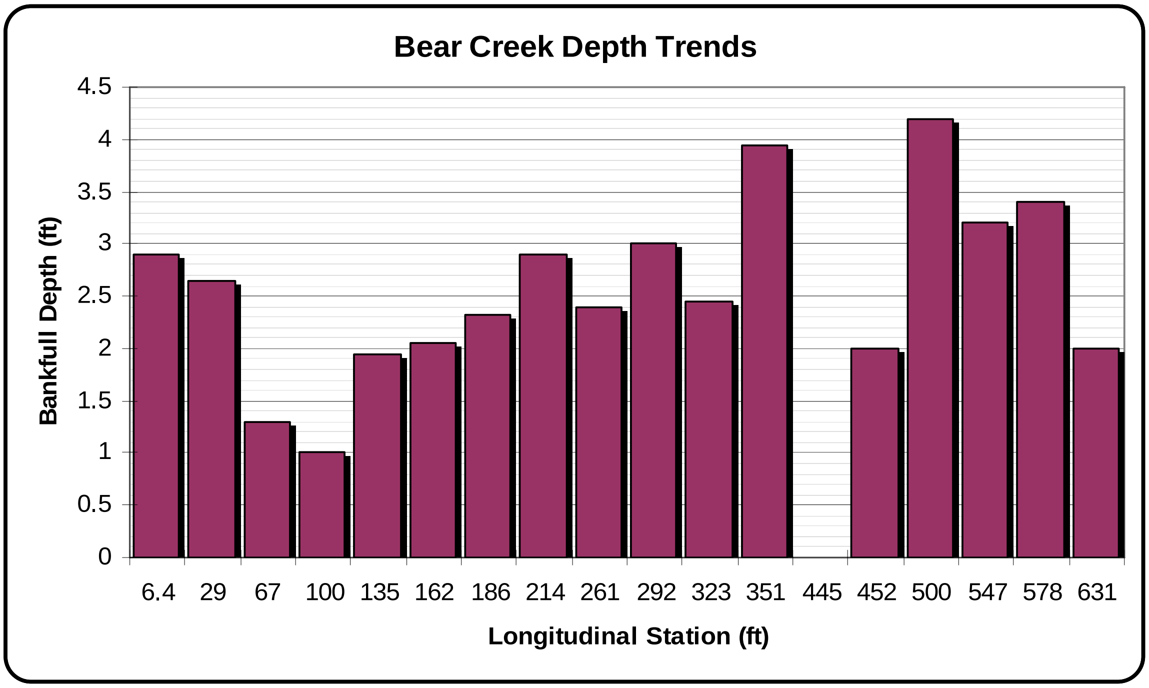


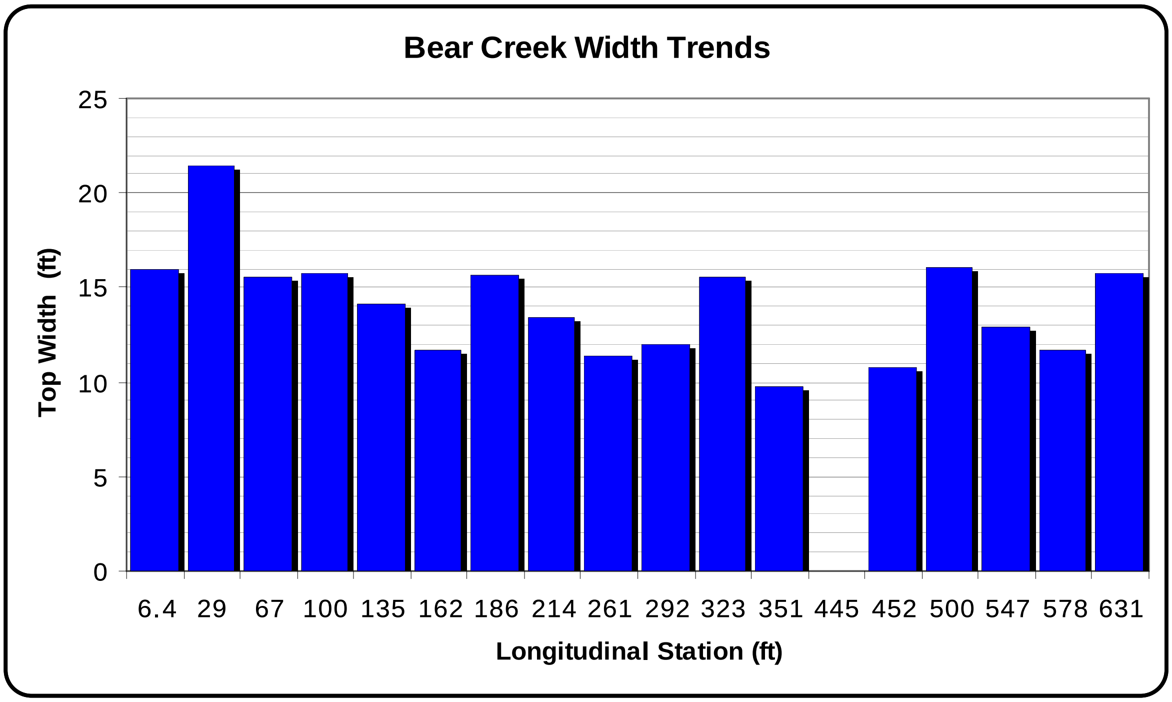
FIGURE 10) Longitudinal profile of Bear Creek, showing the variation in bed and bank elevations. Note that the slight decrease in bed height in Reach C. There may be survey errors associated with this depression, although a check point (red dot) surveyed from above suggests that elevations are correct in the profile. Thus the depression appears to be real, and may reflect a backwater zone formed by deposits of coarse sediment in the upper extent of Reach B.

Reaches A, B and C appear to have been significantly altered from their natural condition, while reach D appears largely intact. Table 3 summarizes the physical characteristics for each reach and Figure 11 shows the longitudinal trends in bankfull width and depth.

Physical Characteristics of Bear Creek Reaches						
	Length (ft)	Average Slope	Width (ft)	Bankfull Depth (ft)	Width to Depth Ratio	Sinuosity
Reach A	103	< 1.0%	multiple, poorly defined channels			1.0
Reach B	351	approx. 2-4%	9.8 to 21.4	1.0 to 4.2	6.9	~1.05
Reach C	94	approx. 2-6%	unmeasurable			~1.05
Reach D	186	>7%	10.8 to 21.4	2.0 to 4.2	4.9	1.2

TABLE 3) Selected physical characteristics of Bear Creek.





NOTES: Trends in bankfull channel dimensions. Longitudinal station zero is at Lighthouse Road; stations proceed upstream. Note capacity loss at station 67-100, indicating flood risks.

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Figure 11

Bear Creek Channel Trends

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4.2.1 Reach A – Downstream of Lighthouse Road

Reach A extends north from the culvert outlet at Lighthouse Road towards the Mattole River. This reach extends downstream for some distance below (north) of the road. Our survey extends about 200 feet due to dense vegetation and an unclear channel boundary. Several apparent flowpaths appear to have been recently active and sedimentation is extensive, filling part of the culvert and filling the channel immediately downstream of the culvert.

Figure 12) Photo of culvert

The culvert, a 4' wide circular CMP, is too small and too shallow relative to the road and creekbed. Immediately below the road, a short, deep scour pool has formed, and evidence of flow over the road is present. We suspect that the culvert is regularly drowned by flows from the Mattole River, and that the scour pool forms in association with pressure head discharge from the culvert. The upstream culvert is filled approximately 50% with sediment (Figure 12), indicating that backwater conditions may be common.

Sediment consists of poorly sorted, unconsolidated grains ranging from silt to coarse gravels. Fine deposition appears to be generated from Bear Creek flows backing up into Mattole River high water and losing competence. The northernmost portion of this reach is subject to erosion and deposition from the Mattole River. Banks are poorly defined and tend to consist of fluvial deposits similar to bed material.

The channel as observed was dry in August, but flowing well in January. Aquatic habitat quality is low. The dominant riparian vegetation consists of California blackberry (*Rubus ursinus*), alder (*Alnus sp.*) and willow (*Salix sp.*). Riparian cover ranged from approximately 90% near Lighthouse Road to 10% or less in the lowest sections near Mattole River.

4.2.2 Reach B – Lower Alluvial Fan

Reach B extends 350 feet south from Lighthouse Road upstream along a constructed bank. It appears significantly impacted by straightening, which apparently was conducted in the 1970's (*Michael Evenson, Personal Communication*), resulting in a trapezoidal constructed channel bound by levees along most of the reach. We understand the channel was last straightened in 2002. The simplified channel likely reflects the natural response to straightening, levee maintenance, backwater effects associated with the culvert, and channel maintenance activities.

This reach has a well-defined break in slope approximately 100 feet from the upper boundary of the reach. Below this break, the channel gradient is 5.0%, and above the break, the gradient is 0.7%. The break in slope appears to reflect instream deposition of coarse sediment exiting the confined upper reaches. The existing channel is mostly planebed, with three shallow pools. No appreciable pool-riffle or meander development was apparent. This reach is mostly dry except for the upper 28 feet, where a relatively deep pool appears to have intercepted the local groundwater elevation.

Bed material is similar to Reach A, with poorly sorted particles ranging from fines to coarse gravel. The bank along portions of the east side consists of dredge spoils. An open area to the east of the channel appeared susceptible to flooding.

This channel was also mostly dry in August except for the upper 28 feet, thus providing no functional summer aquatic habitat. Vegetation was dominated by California blackberry (*Rubus ursinus*) and cow parsnip (*Heracleum lanatum*). Riparian cover is estimated at 75%.

4.2.3 Reach C – Vegetated Reach

Reach C was not directly surveyed due to heavy vegetative cover, and the need for visual line of sight. Observations were made from each end of the reach.

Bed and bank materials appear similar to Reach B. Perennial streamflow of approximately 0.05 cfs entered this reach, but mostly dry, intermittent streamflow was observed at the lower end during summer months. Fish habitat quality was negligible as flows were too shallow and pools were absent. Peak season flows could support refuge, but offered no functional spawning habitat, as the substrate is generally too coarse. This reach was heavily vegetated, and included California blackberry (*Rubus ursinus*) and willow (*Salix sp.*). Riparian cover is nearly 100%

4.2.4 REACH D – CONFINED CHANNEL

Reach D appeared generally unmodified and consisted primarily of a step-pool to step-cascade system typical of confined, high-gradient mountain streams. Reach D was the only reach with appreciable sinuosity common in mountain streams.

The bed and banks in this reach contained a variety of particle sizes including fines, cobbles and small boulders consistent with mountain streams. The channel is generally too steep here for coho or Chinook habitat, but may support steelhead spawning and rearing.

Vegetation included California blackberry (*Rubus ursinus*) and willow (*Salix sp.*) and bigleaf maple (*Acer macrophyllum*). Riparian cover was estimated at approximately 90%, and primarily consisted of a high canopy relative to the low brush observed in reaches B and C.

4.3 Characterization of the Mattole River

The characterization of the Mattole River is based on photo (Figure 13) and map reviews, and field observations during site visits in August 2007 and January 2008.

The Mattole River near the Confluence of Bear Creek is highly dynamic and diverse, braided, gravel-bed river. Photographic and map evidence suggests that the Bear Creek confluence entered the Mattole River near the apex of a 110 degree bend, and the Mattole River was within a few feet of Lighthouse Road during the late 1980s. By 1993, the River had migrated about 700 feet north, leaving several remnant and distributary channels along the southern portion of the active channel migration zone (Figure 12).

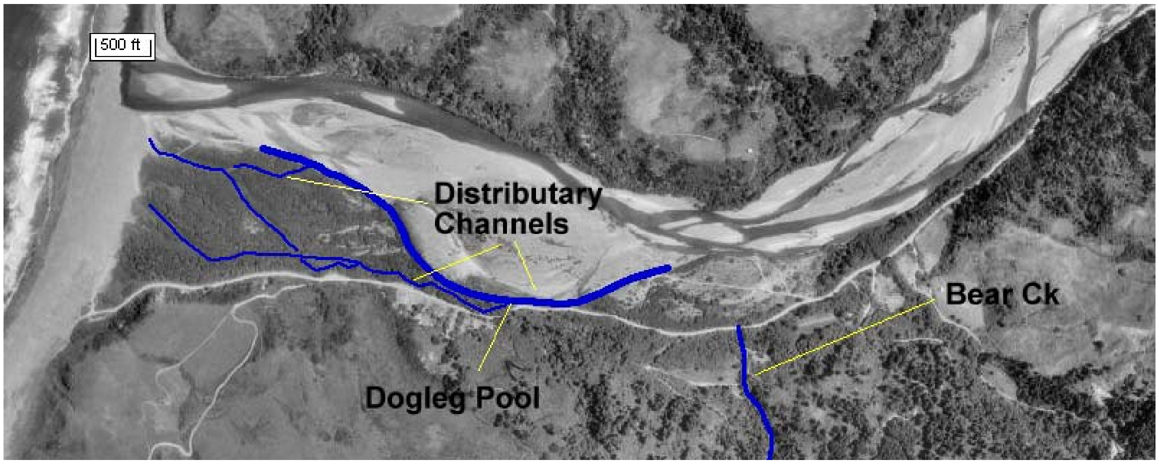


FIGURE 12) Selected traces of distributary channels within the Mattole active channel migration zone. The bold trace represents a large channel that has persisted annually since the channel migrated north (*Michael Evenson, personal communication*). Photo was taken in June 1993, a few months after the channel migrated to the north.

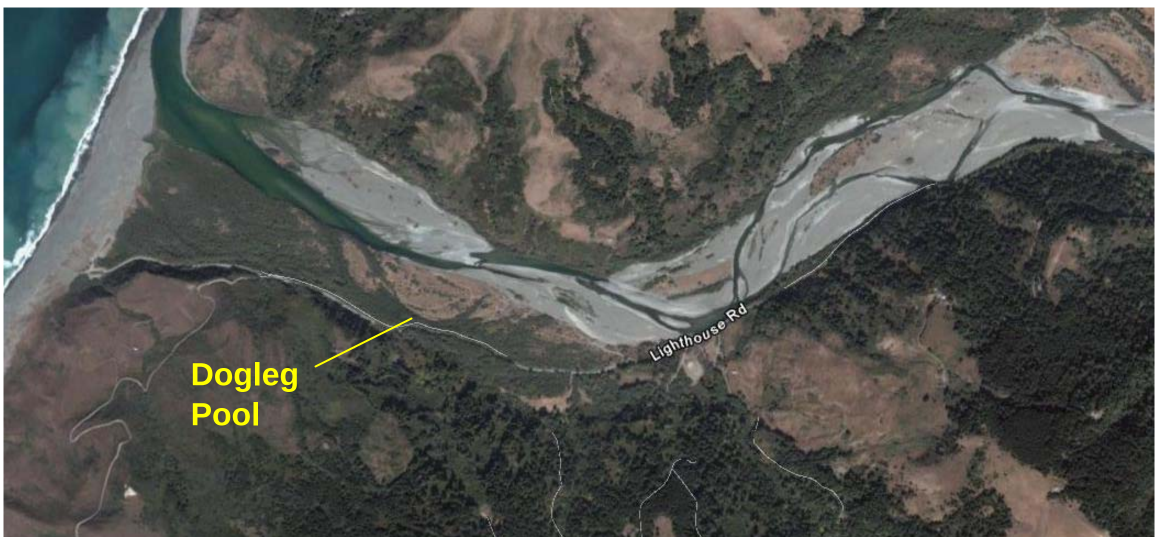


FIGURE 13) Aerial photo from July 2007. Note growth the vegetated floodplain near the Dogleg Pool. Vegetation outlines remnant channels well.

These channels appear to be active during peak flows, as indicated by relatively fresh sedimentary deposits and recent erosional features observed along some of these channels (based on reconnaissance observations). During low-flow periods, these channels may be disconnected from surface flows, but maintain a perennial condition from groundwater and hyporheic sources. The habitat quality along these channels can be quite good.

The area immediately north of Bear Creek represents a vegetated, quasi-stable floodplain feature formed by the Mattole River as it migrated north (Figure 14). The feature has a number of small ridges and valleys that were deposited as gravel bars as the channel migrated north. As such, the landform is dissected with a series of remnant channels, some of which have been adopted as informal roads. Topographically, this feature is within the flood zone of the Mattole River, and is therefore prone to erosion during large flood events. Based on photo records, this landform appears to have formed in response to flooding in 1993.

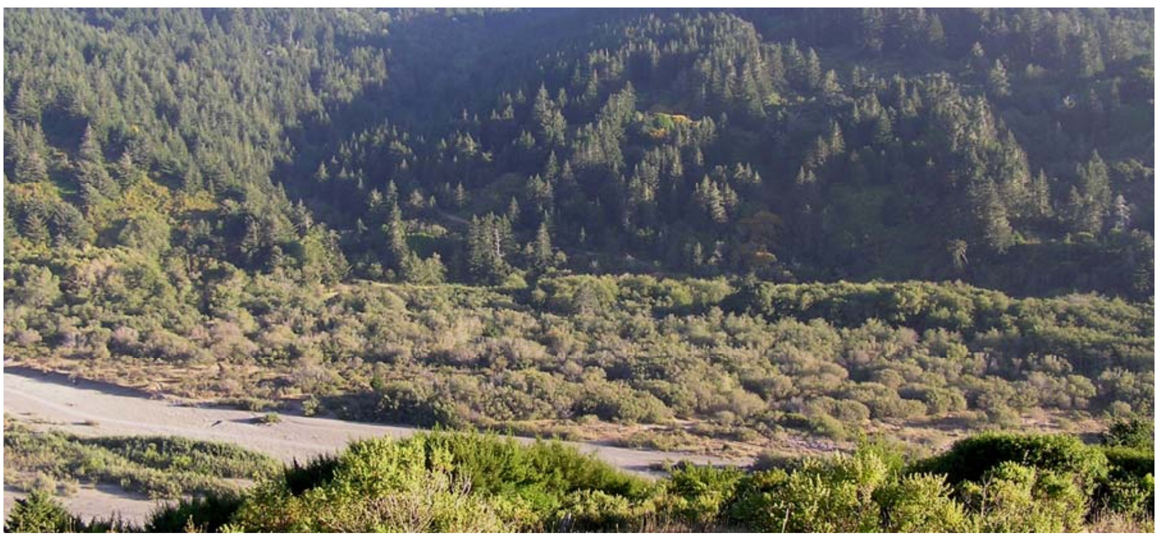


FIGURE 14) Quasi-stable floodplain feature downstream of Bear Creek within the active Mattole River channel migration zone.

Bear Creek splays into at least 3 major distributary channels immediately downstream of the Lighthouse Road culvert. These channels are poorly formed and completely dry during summer months. Headcuts in each of these distributary channels prevents fish passage by coho salmon. Habitat quality in these channels is poor, as there is limited cover, no instream pools, compacted and embedded gravel substrates, and flow is shallow and intermittent.

4.4 Floodplain Surface South of Lighthouse Road

The floodplain surface south of Lighthouse Road consists of a well-vegetated mosaic of meadows and wetlands intermixed with an alder

(*Alnus rubra*) riparian forest. Vegetation includes a complex of horsetail (*Equisetum arvense*), various sedges (Cyperaceae spp), rushes (Juncus spp.), stinging nettle (*Urtica dioica*), and others.

Lighthouse Road, and its adjacent rip-rap, provides a buffer that protects this floodplain surface from erosion by the Mattole River. A large, well-defined, perennial channel is adjacent to the road along the western extent (near the Dogleg Pool). The floodplain surface south of Lighthouse road is about 2 feet higher than the active floodplain north of the road (Figure 15).

A subtle swale extends along the length of this surface, and probably represents a former expression of Bear Creek before it was diverted into its present location. The soils are dominated by interbedded sands, clays and loams consistent with a active floodplain surface.

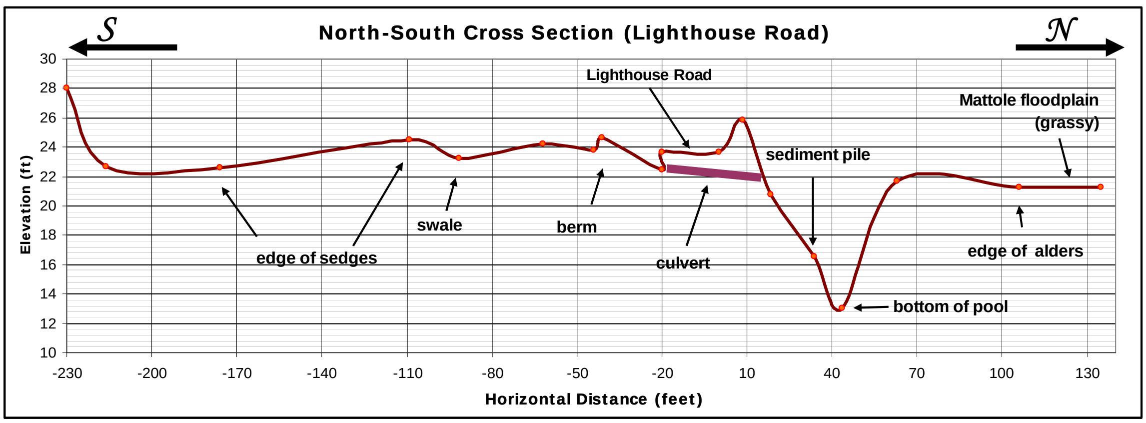


FIGURE 15) Cross-section profile of the floodplain south of Lighthouse Road.

This floodplain surface was probably formed by the Mattole River over a series of flood events and channel migration episodes. It's present expression is consistent with a low terrace or high floodplain surface that may only be inundated by the Mattole River under extremely large floods. We suspect that the recent uplift associated with the Cape Mendocino earthquake may influence the inundation frequency in future years.

The slope south of this floodplain contains several large deep-seated landslide deposits. Seeps and springs provide a low, yet chronic supply of runoff to this surface, sufficient to support a wide array of obligate and facultative wetland plant species.

5 SPECIFIC PROJECT OPPORTUNITIES & CONSTRAINTS

This section discusses the opportunities and constraints for Alternative 1 that we've evaluated in this assessment. Most of these assessments are preliminary, and would benefit by more detailed assessments to support project permitting and design.

5.1 Stable channel design

The most significant constraint for relocated Bear Creek onto this floodplain surface is the requirement for a positive downstream gradient. The 1992 M7 Cape Mendocino earthquake resulting in several feet of uplift at the project site. More importantly, this trend of uplift increases to the west (Figure 16). Therefore, we were concerned that flows may no longer trend to the west with sufficient gradient to draw flows along the floodplain surface.

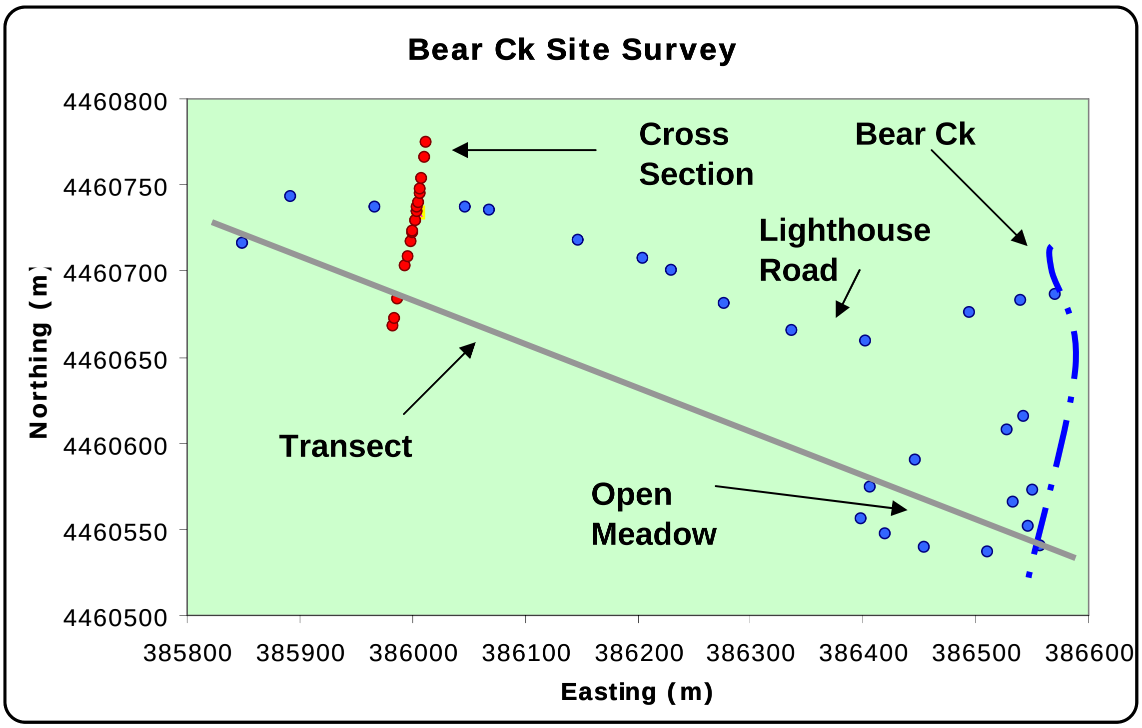


FIGURE 16) Surveyed points following the major features on the floodplain surface.

To address this issue, we surveyed the site using a rod and level to establish the approximate elevations. We established a temporary benchmark where Bear Creek meets Lighthouse Road, and we assigned this BM an elevation of 31.5 feet, based on values provided by the USGS 10-m Digital Elevation Model and Global Position System locators. We then surveyed an open-loop transect to determine the relative elevations of a downslope transect (Figure 16). The survey confirmed that we do have a positive downstream gradient along the length of the floodplain surface (Figure 18). The total gradient is low (0.4-0.5%) along the floodplain surface, which implies that a highly sinuous channel will be required for stability, or other design elements will need to be considered to support geomorphic stability. We're confident that this is achievable.

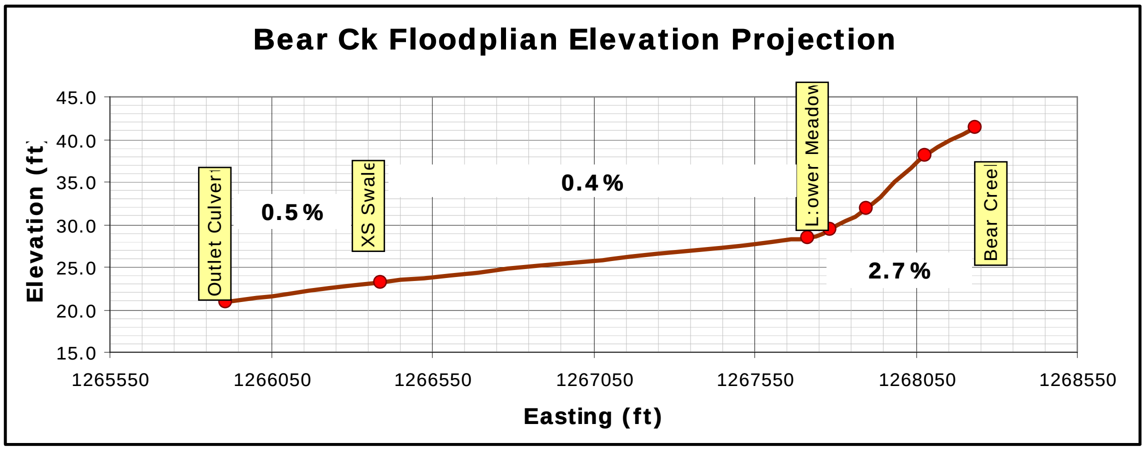


FIGURE 18) Projection surveyed points along transect between Bear Creek and the outlet culvert at the west end of the floodplain surface. Survey verifies that a downslope trend exists, satisfying the basic requirement for new channel design. Numbers between stations represent the average downslope gradient.

A restored channel will need to provide sufficient capacity to convey peak floods (greater than about 84 cfs for Bear Creek). Designing appropriate channel dimensions (width, depth, shape, sinuosity, slope, and roughness) will require an analysis of multiple factors. One concern is if the gradient can support a relatively stable channel with the given water supply and sediment load for Bear Creek. Another is the shape and configuration of the design channel with regard to groundwater influences. A third factor is the hydraulic conditions that will need to be met to provide a sustainable channel.

5.2 Sediment Supply & Management

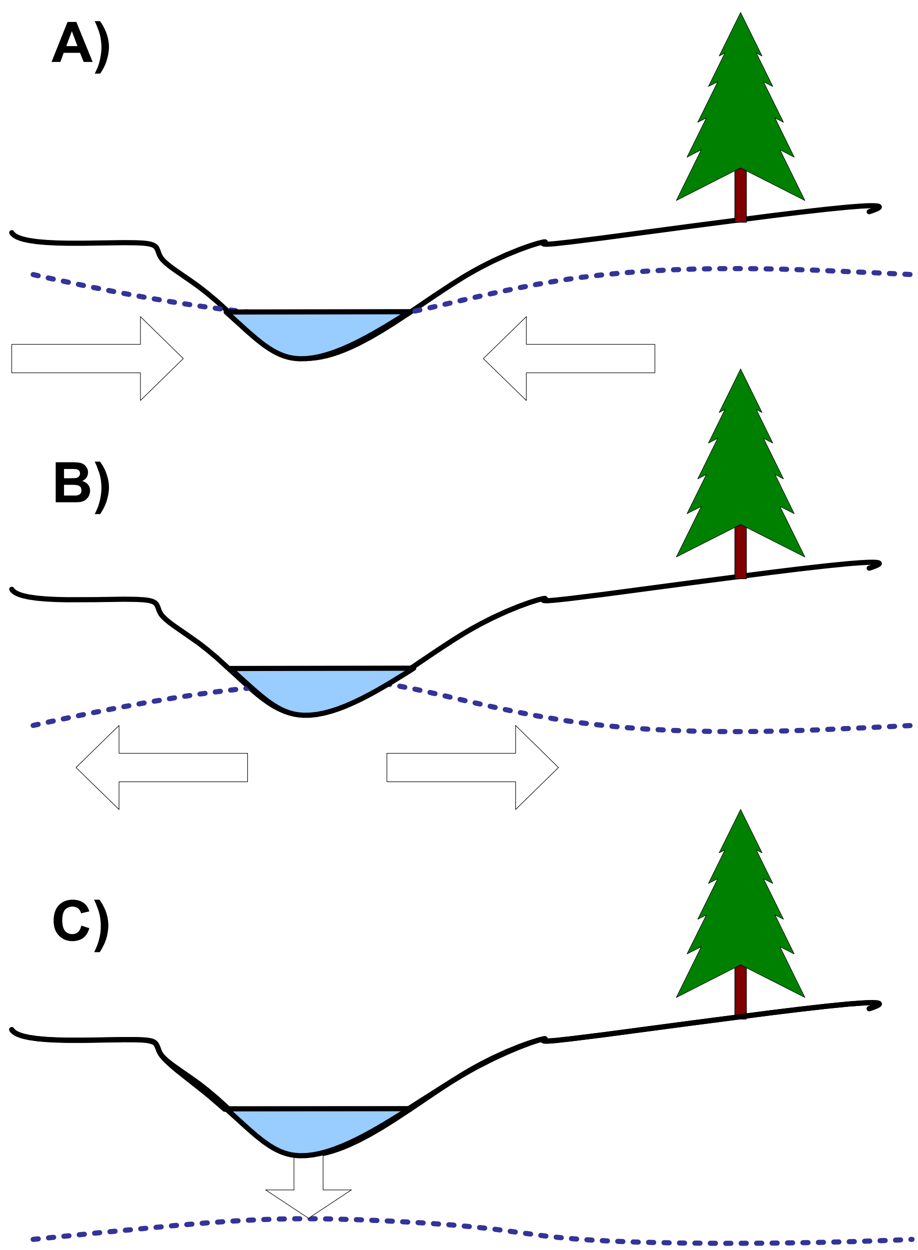
Our initial investigation suggests that sediment transport capacity during peak flow conditions decreases substantially downstream under both the existing conditions as well as those described by this alternative. This can have the advantage of providing spawning gravel supply to the restored channel. However, it also will require that sediment storage and transport considerations will be necessary to develop during the design of the restoration, to prevent the channel from filling and flooding the adjacent area.

The sediment supplied from Bear Creek appears to be substantial, based on the morphology downstream of Lighthouse Road and the character of sediment deposits in Reach B. Any design will need to accommodate some form of natural sediment transport through the channel so that the channel does not become unstable over time. Such a design might include maintenance, but it is preferable if the channel design can be self-sustaining. Evaluating the sediment supply and transport conditions will be necessary to support the design of the restored channel. Approaches might include an overflow channel, sedimentation structures, or distributed roughness features designed to scour and transport sediment.

5.3 Groundwater Support for Perennial Flows

One of the benefits in diverting Bear Creek onto the former floodplain is that the floodplain can act to store water for discharge during summer months. To maintain perennial flow in a diverted channel, there must be sufficient storage in the floodplain, sufficient supply of water onto the floodplain, and sufficient holding capacity within the floodplain (e.g. the stored water must not drain too quickly). We've begun to evaluate the site to assess the extent that each of these conditions is met.

Summer flow in the restored creek will depend upon the orientation of the groundwater table and the general rate of soil drainage (Figure 19). If the groundwater table remains high relative to the channel bottom, then water will flow from the floodplain into the stream, causing the stream to gain flow. If the groundwater table is lower than the stream, then water will infiltrate into the soils, causing the channel to become a losing (or potentially dry) stream. However if the groundwater table can remain relatively close the channel, then it is more likely that flows will remain sufficient to support fish habitat.



NOTES: Typical flow patterns for groundwater environments; A) gaining streams supported by higher groundwater table surfaces adjacent to the stream; B) losing streams where the stream supplies water laterally and C) losing streams where the stream supplies water vertically.	Sound Watershed Consulting *Creating Functional Water Environments* *Figure 19* **Typical Groundwater Profiles** Project: 1006 Date: August 2008

Using very preliminary estimation methods, we note that the floodplain area is approximately 12 acres, and the mean annual runoff volume from Bear Creek is approximately 380 ac-ft. This suggests that there is sufficient water supply to saturate the existing floodplain area to support flow during the wet seasons. However, flow from Bear Creek measured in August would only provide about 0.08 ac-ft of flow per day to the floodplain. Therefore, maintaining enough flow in the creek to support fish habitat would require either a) that the groundwater elevation remain elevated during the dry season, or b) that there is sufficient supplies from hillslope seeps and springs to offset groundwater losses.

The groundwater elevation depends in part on the geologic materials (e.g. sands, silts or loams) and the rate of drainage. We evaluated the groundwater conditions by installing one piezometer in the floodplain (i.e. small groundwater monitoring wells), and a recording stage datalogger in an existing well near the lateral margin of the alluvial fan constructed by Bear Creek. Both data sites were installed with limited resources (volunteer time & equipment from Sound Watershed Consulting). The well site took advantage of a deep and well constructed well that did not appear to be used as a water supply source during the period of monitoring. The floodplain site was installed using a hand auger, a screened 2" PVC tubing with a cap. Both sites used a Globalwater WL-15 pressure transducer with barometrically-correcting dataloggers.

The results were informative, if not entirely satisfactory. A dry winter condition limited the information that could be derived from the well data. However, we did establish and track estimated trends in the water table that helped to confirm that viability of this project (Figures 20 and 21).

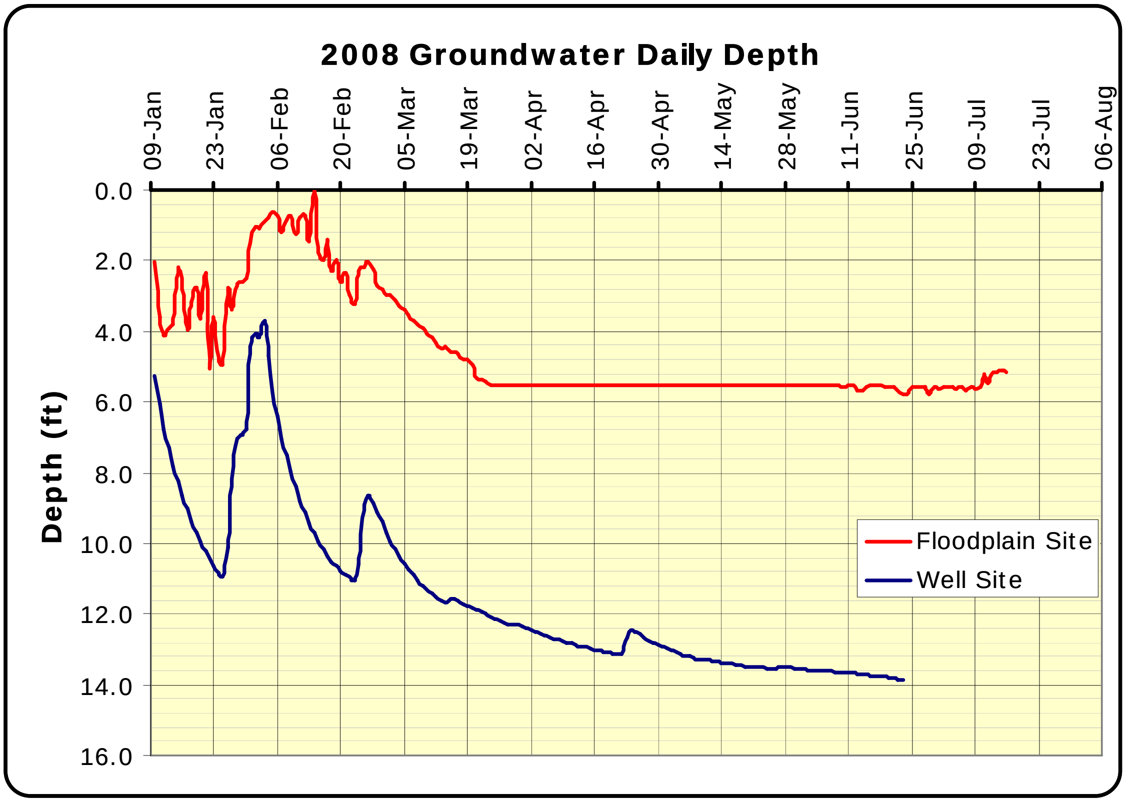
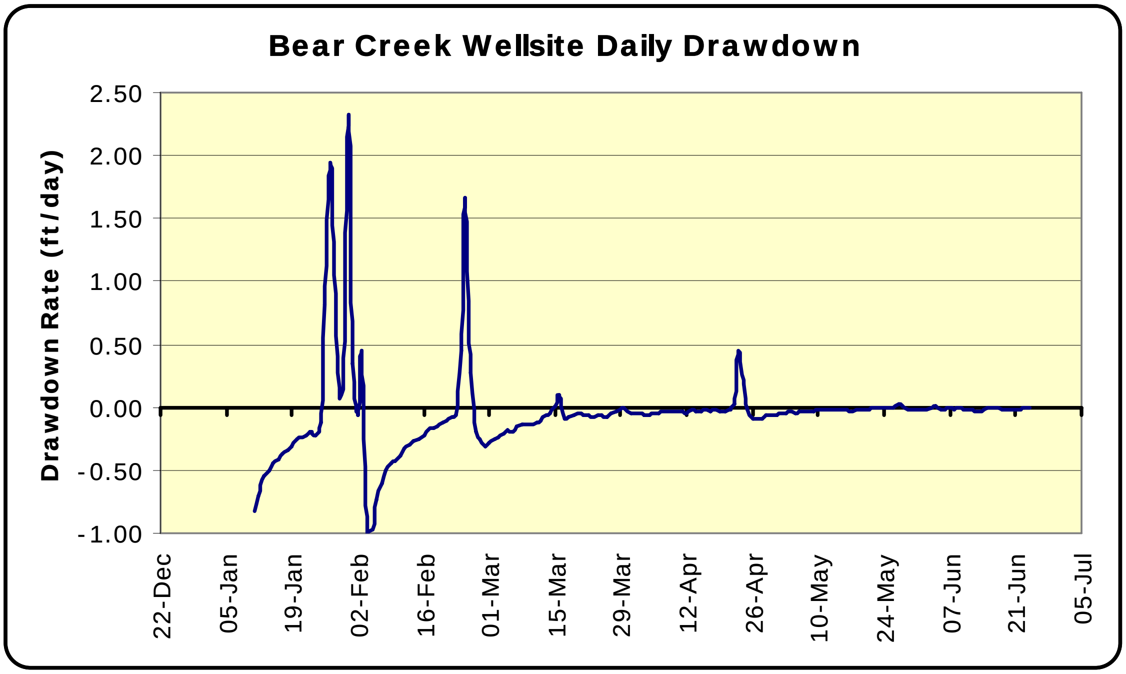
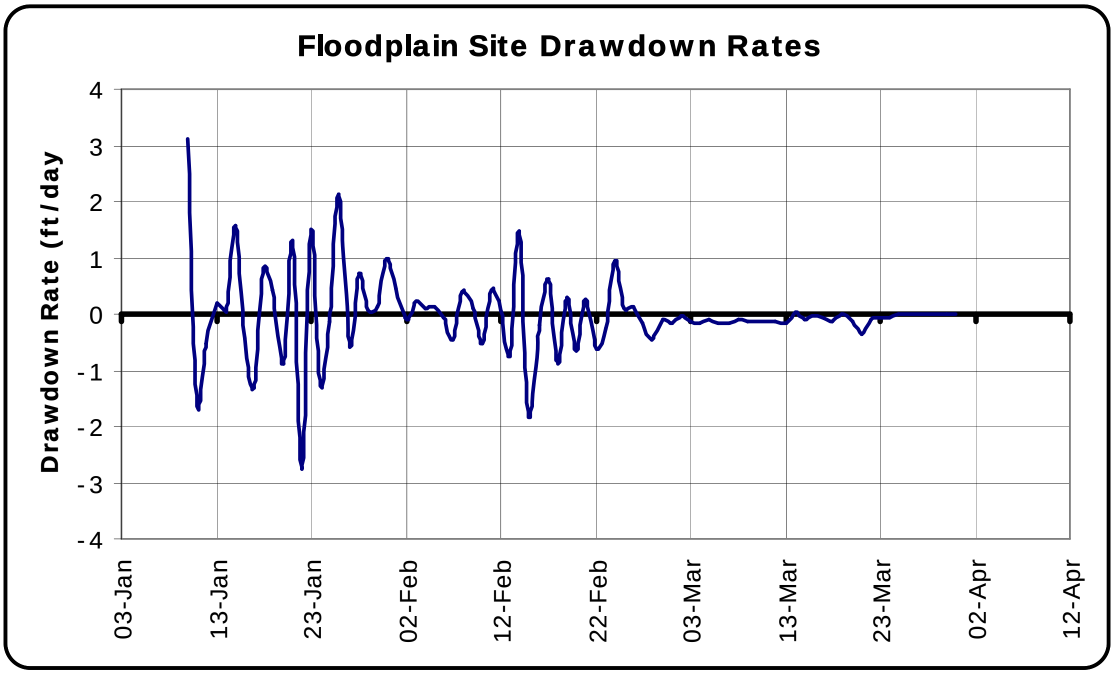


FIGURE 20) Cross-section profile of the floodplain south of Lighthouse Road.

The water table depth exceeded the depth of the instrument at the floodplain site, due in part to the relatively dry conditions combined with the limited depth of the piezometer installation. There also is considerable noise in the floodplain site that may be driven be excessive clay infiltration into the piezometer, that may have affected the instrument. The floodplain site was also influenced by spring and seepage flows from the hillslope that may supply water at the site.

The data suggests several interesting trends. Groundwater storage capacity in spring appears limited (only about 5-10 ac-ft) near the floodplain site, as evidenced by the relatively shallow depths to the watertable. However, groundwater storage along the alluvial fan (well site) might have an additional capacity of 40+ ac-ft during the spring. This implies some potential for supplemental storage that might offset the lack of summer flows. It also implies that only a small amount of water is necessary to fill the groundwater basin.





NOTES: positive values reflect aquifer filling. Negative values represent drawdown

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Figure 21

Groundwater Drawdown Rate

Project: 1006	Date: August 2008

However, the rates of drawdown from these sites is relative high (Figure 21). Drawdown rate suggest how fast groundwater can move, and the observed rates of vertical drawdown suggest rates of 1-2 feet/day, which is fairly rapid, and suggests groundwater conditions that are dominated by clean sandy deposits. This may be a problem for maintaining perennial flows, however, its not clear yet if this problem sufficiently challenges the feasibility of the project. Additional assessment is necessary to see how design may be able to compensate for this constraint.

These conclusions are preliminary and based on limited data and analysis. In addition to understanding the groundwater conditions, it will also be necessary to improve our estimates of flow from Bear Creek, as well as the un-named tributary to the west. These can be refined during the next phase of work on this project.

5.4 Fish Passage

The configuration of a restored Bear Creek as it enters the Mattole River will likely be somewhat complex. Rip rap along Lighthouse Road and improperly sized cross-drain culverts have resulted in a very large pool near the natural restored confluence site. A restored channel will likely require a new structure (bridge, arch culvert, etc). In addition, there is a substantial elevation change between the Mattole Floodplain/side channels and the floodplain bench that will need to be accommodated in a manner that will support migrating adults and juveniles. This will require some analysis, and a more detailed survey, but we are confident that a stable, well-functioning channel can be designed within these constraints.

6 NEXT STEPS

The next phase of the Bear Creek Restoration Project should conduct additional detailed site surveys and assessments to support project preliminary design and project permitting. We recommend addressing several specific design tasks as described in the sections below. This analysis is necessary to establish that the restored channel can sustain perennial flow in support of summer rearing habitat, mobilize sediment in support of spawning habitat, and maintain a self-organizing channel environment.

The next phase should seek to develop a preliminary restoration design that will identify geomorphic, hydraulic and hydrologic characteristics for the restored channel. The design will likely require more detailed hydrologic, hydraulic and geomorphic analysis to support the design and permitting elements of the project. We've listed a comprehensive outline of recommended tasks based on our experience in stream restoration projects. We strongly recommend that all these tasks be completed prior to construction. However, the depth and detail necessary for any individual assessment can vary according to the risk tolerance and resources available to the project.

While we are optimistic about the conceptual alternative 1, we recommend that the next phase of this project include the following feasibility tasks, which are summarized in Table 4, along with some recommended approaches for accomplishing these tasks:

6.1 Project Planning Tasks

Most of the key project planning tasks have been completed. Clear project objectives have been established. A generalized watershed characterization is available (Section 4), and site constraints have been identified (Section 5). A strategic approach is outlined in the proposed Alternative 1 that we believe is feasible and could be highly effective in meeting the project goals.

What remains to be accomplished includes:

Detailed Technical Objectives and Design Criteria – that would guide specific project design. Such technical objectives should be developed in a collaborative dialog with a small design team consisting of

Table 1) Bear Creek Alternative Feasibility Review
Status and Recommendations for Bear Creek Stream Enhancement

Status	Typical Project Requirement	Description	Example Techniques & Tools Appropriate for this Project
Project Planning			
✓	Project Objectives	A clear statement of project objectives in sufficient detail as to guide analysis	• Table or List • Conceptual Diagram
✓	Watershed Characterization	Generalized characterization of the watershed conditions sufficient to understand the key ecosystem processes that will affect restoration	• Maps of Key Characteristics • Historical Photos & Maps • General Historical Review • Land-Use Distribution
✓	ID Site Constraints	A clear list of known project constraints that may affect specific design alternatives	• Table or List
✓	Strategic Approach	A general sense of the specific approach that will meet the project objectives	• Concept Diagrams • Flow Charts • Plots of Supporting Data
Priority	Technical Objectives / Design Criteria	More detailed design objectives that apply to specific design components	• Design Tables • Flowcharts
Hydrology			
✓	Hydrologic Characterization	Characterizes the general hydrologic regime associated with Bear Creek and the Mattole River	• Flood Frequency Analysis • Flow Duration Analysis • Hydrograph Analysis • Hydrologic Modeling
Partial?	Creek-Groundwater Interactions	Evaluates the movement of water between the creek and groundwater for different seasonal conditions to determine contraints on perennial flow design	• Describe Floodplain Stratigraphy • Compare to Known Water Table Elevations • Estimated Hydraulic Conductivity
Design	Creek-Estuary Interactions	Addresses issues with the confluence of the restored Bear Creek with the Mattole River	• Describe Floodplain Stratigraphy • Compare to Known Water Table Elevations • Estimated Hydraulic Conductivity
Design	Design Hydrology Assumptions (e.g. stormwater, climate change, etc.)	Establish the specifications and constraints for a functional channel design	• Sensitivity Analysis in Hydraulic Modeling • Integrated Stormwater Evaluation

Table 1) Bear Creek Alternative Feasibility Review
Status and Recommendations for Bear Creek Stream Enhancement

Status	Typical Project Requirement	Description	Example Techniques & Tools Appropriate for this Project
Hydraulics			
Design	Hydraulic Parameters (e.g. width, depth, slope, roughness, shear stress, velocity, sinuosity, stream power, etc.)	Establish the specifications and constraints for a functional channel design	• Analysis of XSs (existing and design) • Regime Equations • Empirical Relationships
Design	Design Discharge Analysis	An evaluation of the expected design discharge necessary to support a stable channel.	• Flood Frequency Analysis?? • Duration Analysis?? • Expected Hydrologic Regime Analysis • Field Calibration • Flow Calculations
Design	Sediment Transport Analysis	An evaluation of the expected sediment transport capacity necessary to support a stable channel.	• Basic Transport Equations • Entrainment Thresholds Analysis • Hydraulic Modeling (limited)
Geomorphology			
✓	Channel Characterization & Reach Delineations	Evaluates existing conditions sufficient to understand the functional processes that influence channel stability and evolution	• Bank Condition Mapping • Montgomery & Buffington Classification • Geomorphic Forms • Sedimentation Characteristics mapping • Create reach breaks via Channel Type
✓	Historical Evaluation	Reviews historical conditions to support geomorphic interpretations	• Maps of Key Characteristics • Historical Photos & Maps • General Historical Review • Land-Use Distribution
✓	Diagnose Existing Instabilities	Uses available information to identify and diagnose "what's broken"	• Systematic Geomorphic Interpretation • Analytical Queries of Existing Data • Tests of Multiple Working Hypotheses
Design	Sediment Characterization	Identify the estimated volume and characteristics of sediment sufficient to design structures for storing and/or transporting sediment loads	• Existing Sediment Characterization • Estimates of Supply • Spatial Distribution Variation • Erosion & Deposition Patterns • Compare to Hydrodynamic Forces

Table 1) Bear Creek Alternative Feasibility Review
Status and Recommendations for Bear Creek Stream Enhancement

Status	Typical Project Requirement	Description	Example Techniques & Tools Appropriate for this Project
Design	Design Basemap	Develop a topographic and/or photographic map from which the engineering design can be completed.	• Aerial Photos • Topographic Map • Ground Staking • GIS/CADD Maps
Design	Channel and Planform Stability Analysis	Does the integration of geomorphic, hydrologic and hydraulic analysis support a stable channel design?	• Geomorphic Interpretation • Entrainment Estimates • Shear Stress & Stream Power Profiles • Bank Stability Assessment • Excess Shear Stress Plots • Specific depositional & erosion mapping • Historic channel migration trends • Longitudinal Shear Stress • Longitudinal Channel Dimension Changes
Ecology			
Design	Fish Passage	Can fish passage be achieved by the design?	• Fish passage modeling • Simple passage criteria • Hydraulic modeling
Design	Aquatic Habitat Structure	What is the habitat structures that will support aquatic communities	• Interpretation of Geomorphic Maps • Habitat Typing Map • Bed Facies Map
Optional	Vegetative Habitat Structure	what is the role of vegetation toward influencing hydrologic, geomorphic or biological processes. How will these change in response to the design?	• Vegetation Succession Mapping • Ecotone Interpretation Mapping • Soil Type Mapping • Wetland Delineation
Optional	Wildlife Habitat Structure	What is the habitat structures that will support terrestrial communities	• Succession Profiles • Integrated Landscape Habitat Models • Habitat Typing Map • Extended Habitat Qualities Matrix

experts in stream restoration design engineering, geomorphology, hydrology, and fish biology.

6.2 Hydrology & Hydraulics Design Tasks

This study has provided a preliminary hydrologic assessment of Bear Creek and the Mattole River (Section 4.1.2).

What remains to be accomplished includes:

Detailed Hydrologic Characterization - We recommend a more complete hydrologic investigation be developed to identify the flood frequency, flow duration, annual total discharges, and flood hydrograph conditions for Bear Creek. These evaluations will directly support channel design by establishing design hydrology conditions for the restored channel.

Creek-Groundwater Interactions – additional investigation of groundwater conditions may be beneficial. Such investigations may opt to collect additional data or evaluate the existing data in more detail. The specific requirements will depend in part on the more detailed technical objectives and design criteria.

Creek-Estuary Interactions – what has not been established by this study is the extent that a diverted Bear Creek would provide access to fish through the Mattole estuary. At the least, this can be evaluated by simply walking the downstream extent and characterizing potential access, keeping in mind that the lower estuary is highly dynamic and can change year to year.

Design Hydrology Assumptions – the design will benefit by a more specific set of design hydrology assumption that establish the design characteristics (e.g. how big a flood must the channel sustain, etc). Typically this assessment evaluates effects from stormwater, climate change, etc.

Design Hydraulic Parameters – hydraulics refers to the forces applied by flowing water, and the design will benefit by a more specific set of design hydraulic calculations that will establish the design width, depth, slope, roughness, shear stress, velocity, sinuosity, and stream power at each station of the design. These variables are the critical factors that affect the stability and function of the design, and they must be carefully established.

Design Hydraulic Parameters – the design will benefit by a more specific set of design hydraulic calculations that will establish the design width, depth, slope, roughness, shear stress, velocity, sinuosity, and stream power at each station of the design. These variables are the critical factors that affect the stability and function of the design, and they must be carefully established.

Sediment Transport Analysis – the stability of the channel depends on its ability to transport and deposit sediment at appropriate locations. A functional sediment transport analysis can be accomplished in collaboration with hydraulic and geomorphic assessments to evaluate the potential for design failure or adjustment.

6.3 Geomorphic Design Tasks

This study has provided a preliminary geomorphic assessment of Bear Creek (Section 4.2), the Mattole River (Section 4.3), and the floodplain surface (Section 4.4). We've also performed a preliminary historical review of the site, and have informally diagnosed existing conditions and opportunities (Section 2.1).

What remains to be accomplished includes:

Sediment Characterization – a more detailed analysis of the sediment supply from Bear Creek will be necessary to determine the extent of sediment transport capacity that will be necessary in the supporting design.

Design Basemap – there are several cost-effective approaches to developing a design basemap that may include more detailed ground survey, aerial photos, ground staking, and/or GIS mapping. The objective of the basemap is to provide a tool for making ground calculations as well as communicating the design elements.

Channel and Planform Stability Analysis – this assessment should evaluate the forces that will be applied to the design channel to ensure that they can remain stable over time. It will consider channel sinuosity, gradient, and bankfull flow dimensions, and will compare these to the detailed design hydrologic characterization.

6.4 Ecologic Design Tasks

This study has not provided much specific detail on ecological factors.

What remains to be accomplished includes:

Fish Passage – an evaluation of the fish passage requirements at a newly constructed culvert.

Aquatic Habitat Structure – opportunities to include various aquatic habitat structures into the design channel. Features like pools, boulder clusters, large woody debris, gravel bars, scour objects, etc. can be designed into the new channel.

Vegetative Habitat Structure (optional) – It may be desirable to include an assessment of vegetative changes that may occur in association with the new hydrologic and geomorphic conditions.

Wildlife Habitat Structure (optional) - It may be desirable to include an assessment of wildlife habitat changes that may occur in association with the new hydrologic and geomorphic conditions.

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