Lower Strawberry Creek Restoration Planning Report

Prepared for:

Pacific Coast Fish, Wildlife and Wetlands Restoration Association

Redwood National and State Parks

US Fish and Wildlife Service

Prepared by:

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Project Funded by:

U.S. Fish and Wildlife Service Coastal Program

Resources Legacy Fund Foundation Preserving Wild California

March 2008

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March 2008

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1 Project Background

1.1 Overview

Fish production within Strawberry Creek, part of the Redwood Creek/South Slough estuary, is severely limited by degraded habitat and blocked access. Historic land use activities within the Strawberry Creek watershed have resulted in the spread of invasive reed canary grass which chokes the channel, degrades water quality, and prevents native riparian growth. Additionally, numerous culverts impede flow and create partial barriers to anadromous fish migration.

This project involves developing detailed recommendations for improving fish passage, estuarine and freshwater habitat to guide restoration efforts on Strawberry Creek.

1.2 Project Location

Strawberry Creek is located within the northwestern portion of Humboldt County, California and is a tributary to lower Redwood Creek. Strawberry Creek flows towards the northwest, draining hillslopes located along the southern and western edges of the Orick Valley. Strawberry Creek flows across the historic Redwood Creek floodplain before entering the South Slough of the Redwood Creek estuary near the town of Orick (Figure 1.1).

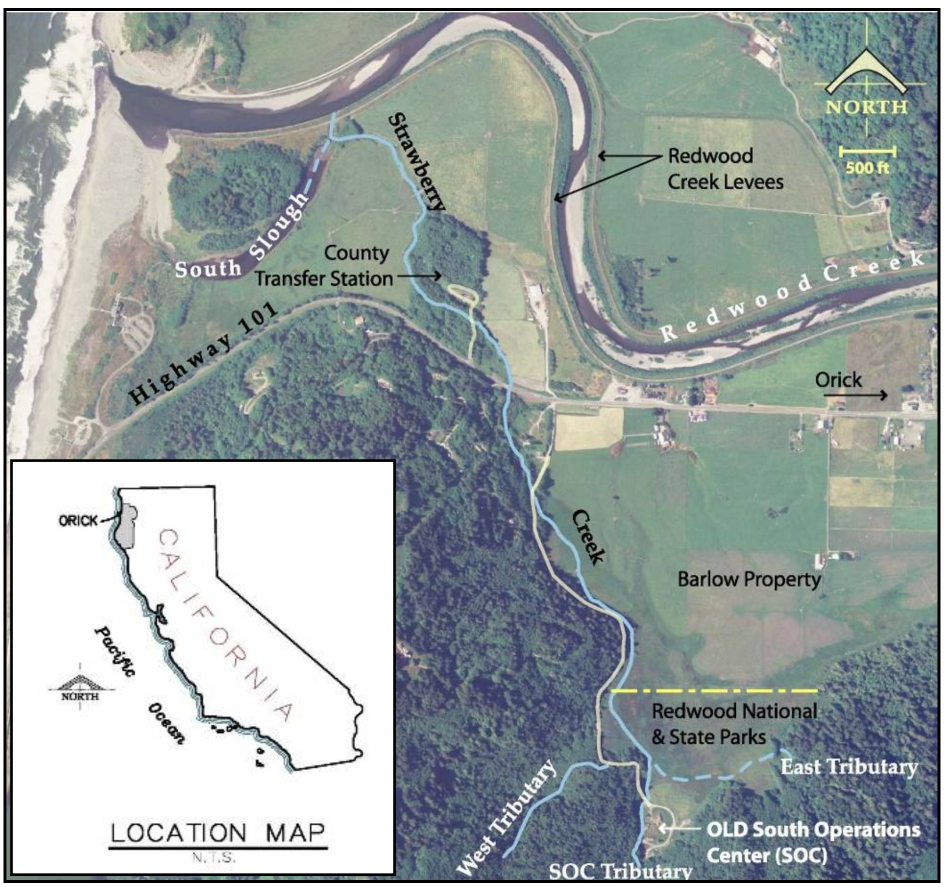

Figure 1.1 - Location of Strawberry Creek as it flows from south to north along the western edge of the Orick Valley and into the South Slough of Redwood Creek.

The Strawberry Creek restoration project encompasses approximately 9,000 feet of lower Strawberry Creek, from its confluence with the South Slough to just upstream of the now vacant Old South Operations Center (SOC) on lands managed by Redwood National and State Parks (RNSP).

1.3 Project Impetus

Historically, Strawberry Creek drained expansive freshwater wetlands within the southern portion of Orick Valley. This, combined with the stream's proximity and direct connection to the Redwood Creek estuary made it a productive tributary for supporting healthy salmonid populations within the basin. Recent studies have found that these types of low-gradient wetland habitats provide abundant foraging habitat for juvenile coho salmon and coastal cut-throat trout (Pollock et al., 2004). These habitats are often sought out by coho as they move down from their natal tributaries towards the estuary. The foraging opportunities provided by wetlands within or adjacent to the estuary commonly produce large coho smolts, which substantially increases their chances of surviving and returning as adults to spawn (Holtby et al., 1990). However, wetland and estuarine habitat has largely been lost from the lower Redwood Creek basin due to changes in land-use.

The Army Corps of Engineers (ACOE) Lower Redwood Creek Flood Control Project, constructed after the 1964 flood, has substantially reduced the size and altered the morphology of the Redwood Creek estuary and lower portions of its freshwater tributaries and wetlands, including Strawberry Creek. Current and past land-use within the Strawberry Creek Watershed has lead to a decline in riparian and aquatic habitat, water quality, in-channel flood capacity, and fish passage. Stream channel function and salmonid habitat have been compromised throughout Strawberry Creek for a variety of reasons:

1. Draining and grading of a once complex system of marshes combined with removal of native riparian and wetland vegetation
2. Ditching and straightening portions of Strawberry Creek to create pasture
3. Introduction of Reed Canary Grass *(Phalaris arundinacea)* (RCG) for fodder, which spread into the channel and adjacent wetlands, preventing native vegetation from establishing, and impeding transport of sediment and fish movement
4. Adjacent land uses causing streambank erosion and nutrient loading
5. Installation of five culverts that may impede fish movement during low and high flows
6. Excessive sediment contributions from historic timber harvest activities within the upland areas of the watershed increasing in-channel sedimentation
7. Partial disconnection of the South Slough from the mainstem of Redwood Creek and confinement of Redwood Creek between flood control levees minimizing connectivity between freshwater and tidal flow

The Redwood Creek Basin, including Strawberry Creek, is currently identified as a specific hydrologic unit in the California Department of Fish and Game (CDFG) Recovery Strategy for Coho Salmon (CDFG, 2004) because it constitutes a unique and important component for coho in the Southern Oregon-Northern California Coast Evolutionarily Significant Unit of coho salmon.

Redwood Creek and its estuary are currently listed under CWA Section 303(d) as impaired for sediment and temperature (CDFG, 2004). Excessive sediment, elevated summer water temperatures, and loss of critical diverse habitat in the Redwood Creek estuary, mainstem and tributaries are critical factors that create unfavorable salmonid rearing conditions in the watershed (CDFG, 2004, RCWG, 2006b). Populations estimates of summer-rearing juvenile Chinook and steelhead in the Redwood Creek estuary indicate that only 7-15% of the arriving populations survive the summer rearing season (RCWG, 2006b). Fish arriving in the estuary from the watershed were undersized, with less than 70 mm fork lengths. The high juvenile mortality rate through the summer rearing season was attributed to low watershed growth rate, elevated temperatures, and low dissolved oxygen in the closed estuary. Coho salmon and coastal cutthroat trout were also found rearing in the estuary during summer, but mortality rates were not available.

Lower growth rates and poor estuarine rearing habitat emphasize the need for creating access and improved rearing habitat in estuarine tributaries, including Strawberry Creek. With the loss of estuarine and freshwater wetland habitat and its associated biological productivity, the potential to restore Strawberry Creek is a unique and valuable opportunity that will contribute to rebuilding salmonid populations in Strawberry Creek and the Redwood Creek Basin.

The impetus for restoration of Strawberry Creek also results from a desire on the part of private landowners and Redwood National and State Parks (RNSP) to restore the stream to once again support a sustainable run of coastal cutthroat and steelhead trout, and coho salmon. In particular, the Barlow family, who owns a substantial segment of the stream flowing through their property (Figure 1.1), wish to take an active role in bringing back the fisheries. They have also led the way for other streamside landowners to consider participating in more comprehensive restoration projects on Strawberry Creek.

1.4 Project Goals and Objectives

The *Watershed-wide Aquatic and Riparian Habitat Restoration Strategy* report prepared by the Redwood Creek Watershed Group (RCWG, 2006a) and the *Redwood Creek Integrated Watershed Strategy* (RCWG, 2006b) assessed existing conditions within lower Strawberry Creek and receiving South Slough and provided recommendations for improving habitat conditions. These recommendations complement the larger scale restoration recommendations for the Redwood Creek Hydrologic Unit recommended in CDFG, 2004. Both RCWG reports emphasized the need to improve riparian vegetation function along the banks of Strawberry Creek and the South Slough with a goal of reestablishing a self maintaining ecosystem that supports and maintains high-quality aquatic and riparian habitat. This may be accomplished by implementing the following measures:

1) Remove reed canary grass from portions of the stream channel and floodplain

2) Revegetate the riparian corridor with native vegetation

3) Fence riparian corridors to prevent riparian area grazing and streambank impacts

4) Replace culverts that currently impede fish passage and natural geomorphic processes, and

5) Eliminate critical erosion and sediment delivery to the stream within the upland portions of the watershed.

Following the recommendations of the Reports, RNSP will pursue implementing road decommissioning and road drainage improvements within the upslope portions of the watershed in an effort to reduce delivery of fine sediments to Strawberry Creek. RNSP has also requested funding for other improvements, including those recommended in this report.

Utilizing recommendations provided in the RCWG (2006a) report, this report further defines the existing hydraulic, hydrologic, topographic, geomorphic, and biological characteristics of the project area and develops conceptual restoration designs for lower Strawberry Creek.

1.5 Project Team and Funding

This report has been prepared by Michael Love &Associates. Gedik BioLogical prepared the Enhancement Planting Plans (Appendix A) for the project. Graham Matthews & Associates assisted with conducting the project topographic survey and developing the project basemap. The report was produced for, and in cooperation with, Pacific Coast Fish, Wildlife and Wetlands Association (PCFWWRA) and Redwood National and State Parks (RNSP). PCFWWRA is a non-profit organization based in Humboldt County dedicated to the restoration of fish and wildlife habitats.

Project funding was provided by the U.S. Fish and Wildlife Service (USFWS), Coastal Program and the Resources Legacy Fund Foundation, Preserving Wild California.

In December of 2006, the project team met at Strawberry Creek with landowner, Ron Barlow, and staff from RNSP, USFWS, and PCFWWRA to gain historical background and further define project objectives. The project geomorphologist also met with RNSP staff at the Old SOC in November 2007 to discuss the scale of the project and assess the physical characteristics of the SOC Tributary and culvert, which had been cleared of brush.

In December 2007 the project team and staff from RNSP, PCFWWRA, and USFWS met to discuss project findings, initial recommendations and funding opportunities. During this time RNSP staff provided the project team with background information, hydrologic and topographic data, historical documents and aerial photographs.

2 Project Setting

The Strawberry Creek project area consists of approximately 9,000 linear feet of stream channel and adjacent floodplain. At its confluence with the South Slough, Strawberry Creek has a contributing drainage area of approximately 2.1 square miles. The steeper headwater streams of Strawberry Creek originate on the mostly second growth forested RNSP property. The East, West, and SOC tributaries form the three main forks of the headwaters of Strawberry Creek (Figure 1.1).

The three main forks of Strawberry Creek join together on RNSP property at the southwestern edge of the Orick Valley, which is part of the historic Redwood Creek floodplain. From here, lower Strawberry Creek flows northwesterly through cattle pastures and two rural residences before crossing under Highway 101. Downstream of the highway, the stream flows through the Humboldt County (County) owned waste transfer facility and two cattle pastures before entering the South Slough of Redwood Creek.

2.1 Historic Conditions

The historic land use, vegetation and biologic resources of the Redwood Creek Estuary and surrounding areas, including Strawberry Creek, are well documented (RCWG, 2006a; RCWG, 2006b; RNP, 1986). European settlement of the Strawberry Creek area began in the 1800's. Spruce forest, which formerly covered the project area, was logged during the 1920's to the 1950's. Later, the Antonioli, Barlow and Zuber families established dairy and beef ranches on the site. Historic accounts by residents Savina Barlow (RNSP, 1981) and Earl Roberts (RNP, 1986) indicate that during the 1930's the project area was comprised of floodplain vegetation and large Sitka spruce which was logged for firewood and construction materials. The remaining snags were burned to clear the land for agriculture.

RCWG (2006a) indicates that Redwood Creek once meandered back and forth across the Orick Valley, leaving obvious backchannels and meander scar depressions throughout the valley. During large floods, such as the 1964 flood, Redwood Creek inundated most of the Orick Valley, including all of lower Strawberry Creek. Lower Strawberry Creek on the RNSP property likely follows a valley floor depression that may have been formed by Redwood Creek in historic times.

Downstream of Highway 101, Strawberry Creek flowed across the floodplain created by a large meander in Redwood Creek before entering a backwater channel connected to the estuary. Flood control levees completed in 1968 eliminated overflow channels preventing Redwood Creek from migrating across the valley floor and flooding Strawberry Creek and the South Slough, thus limiting the historic physical, hydrologic, and biological linkages between Strawberry Creek, South Slough, and the Redwood Creek estuary.

2.1.1 Interpretation of Aerial Photos

A collection of aerial photographs of Lower Strawberry Creek and the Redwood Creek estuary were provided by RNSP. An understanding of the historic physical and biological conditions of Lower Strawberry was gained through interpretation of these photographs, combined with historical accounts provided by the Barlow family. Vertical aerial photographs from RNSP included coverage from 1936, 1948, 1962, 1966, 1968, and 2005. Additionally, several oblique aerial photographs from the late 1940's and early 1950's of the Redwood Creek estuary and the mouth of Strawberry Creek were provided by RNSP and found in the Shuster Collection at Humboldt State University.

Historic accounts indicate that Orick Valley was once vegetated with redwood, Sitka spruce, and red alder forests mixed with sedges (RCWG, 2006a). Ranch roads located along the valley floor were elevated above the surrounding ground and composed of imported fill. Culverts and drainage ditches associated with these roads have altered the hydrology and geomorphology of the creek from its natural condition.

Upstream of Highway 101

The 1936 and 1948 photographs show that much of the once forested valley bottom had been cleared for agriculture. However the area adjacent to Lower Strawberry Creek upstream of Highway 101 had not yet been cleared. From the photographs this area appears to contain a mixed species composition, with both lower height deciduous and taller conifer tree species.

Based on the aerial photographs, existing topography and hydrology, discussions with the Barlow family and other residents of the valley confirm that the area of Lower Strawberry Creek currently within RNSP and portions of the Barlow's property contained a complex wetland comprised of spruce, willow and alder (RNSP, 1986). Large trees, which were likely mature Sitka Spruce within this wetland complex, are evident in the 1936 (Figure 2.1) and 1948 photographs (RNSP, 1981). Historic accounts indicate that the project area was dominated by large salmonberry and Sitka Spruce "Big enough to hold a dance on" (RNP, 1986). Spruce forests were described as extending from the hillslopes to downstream of Highway 101. Residents indicate that when land was cleared for agriculture, at least 160 large spruce trees were cleared from the floodplain on what is currently the RNSP property (RNP, 1986). In fact, small patches of higher ground within the existing wetlands still contain Sitka Spruce snags, stumps, and saplings (Figure 2.2).

By the time of the 1962 aerial photograph, nearly all of the historic wetland area had been cleared and drained for cattle pasture and the forested upland areas behind the old SOC had been recently logged. The flow path of the East Tributary and the ditched and levied Lower Strawberry Creek are clearly visible in the 1968 aerial photograph (Figure 2.3). The shading and patterns within the pasture clearly demarcates the location of the historic wetland, which continues to be frequently inundated following winter rains.

Following acquisition of the southern portion of the project area by RNSP with the park expansion in the early 1980's, cattle were removed from the RNSP property allowing reed canary grass (RCG) to grow unchecked in this area. The result is a thick floating mat of RCG that covers vast areas of the historic wetland complex, obscuring the current location of Lower Strawberry Creek and the East Tributary that lie within RNSP property.

The topographic survey, field reconnaissance, and aerial photograph interpretation suggest these channels are in the same location as seen in the 1968 aerial photograph. RCG is found throughout the pastures north of the RNSP property, but grazing and topography have limited the growth of floating RCG mats.

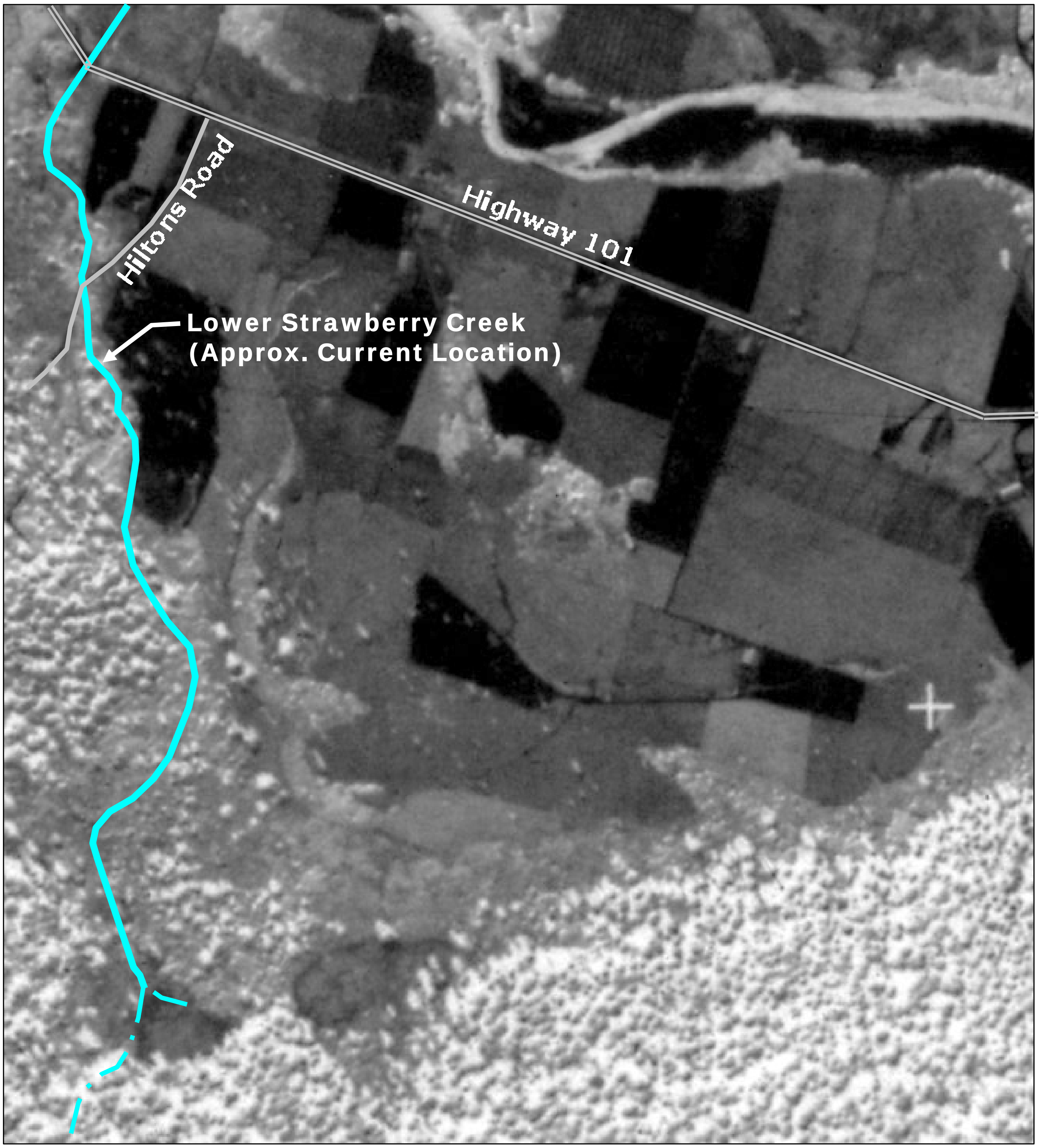

Figure 2.1 – The current location of Strawberry Creek overlaid on the 1936 aerial photograph, which shows that the lands adjacent to the stream were vegetated with a mixed height canopy.

Figure 2.2 – Present conditions on RNSP property, looking northward across the lower Strawberry Creek wetland complex towards an island of higher ground that supports a large snag and a living Sitka spruce tree. In the foreground several new spruce saplings grow next to a stump on another island within the wetland.

Downstream of Highway 101

Historical aerial photos taken prior to the construction of the Redwood Creek Flood Control Project show Strawberry Creek downstream of Highway 101 flowing across a floodplain formed by a bend in Redwood Creek. From there, Strawberry Creek flowed into an overflow channel of Redwood Creek, the last meander of Redwood Creek, now called the South Slough (Figure 2.4).

The flood control project, completed in 1968, was built to contain the waters of Redwood Creek between the constructed levees. This effectively ended the processes that formed and maintained the overflow channel. Subsequently, the overflow channel became the sole conveyance channel for draining Strawberry Creek into the South Slough. Disconnection of the overflow channel from Redwood Creek dramatically changed the channel characteristics and processes that originally formed it (RCWG, 2006 and Ricks, 1995).

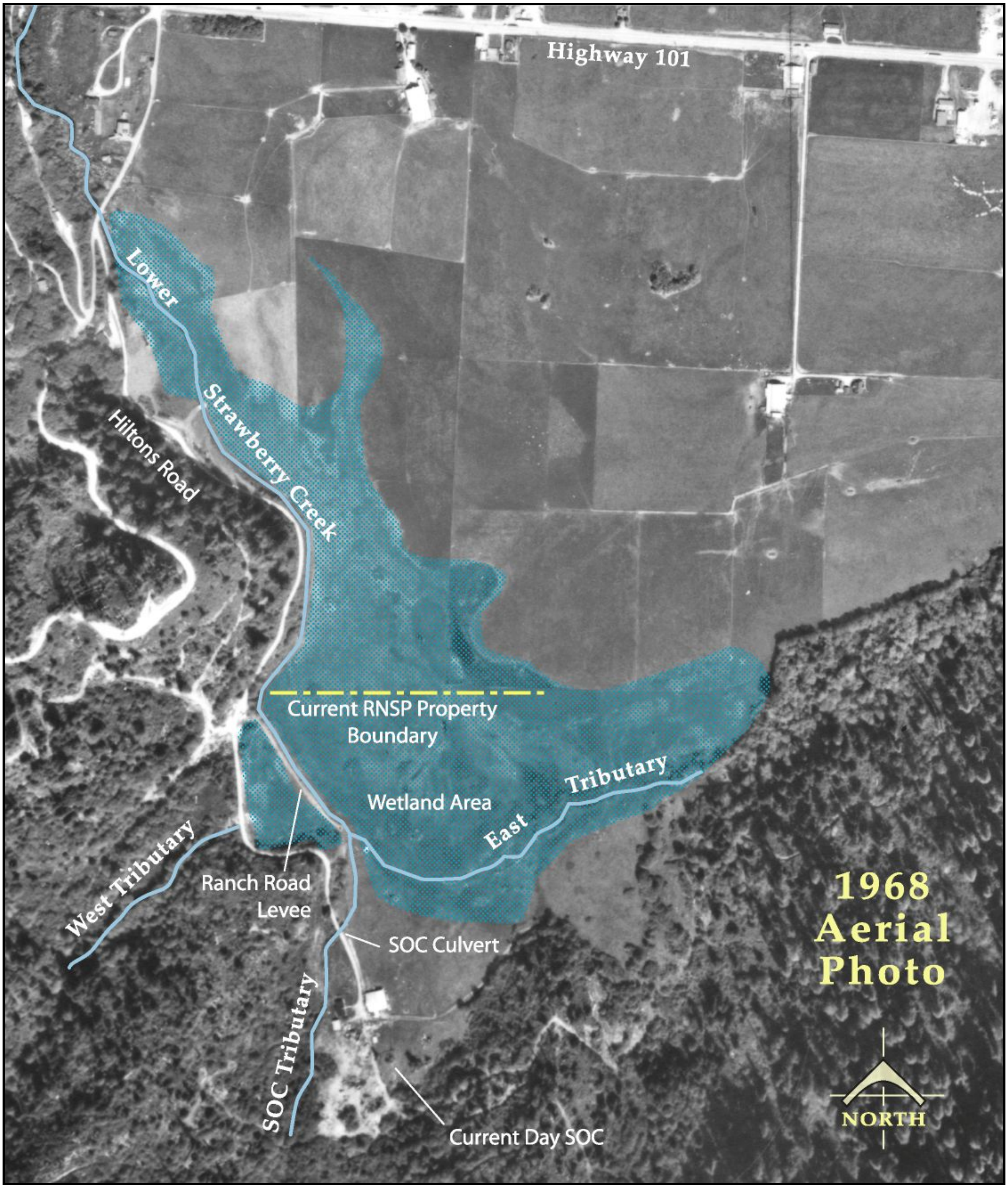

Figure 2.3 - 1968 Aerial photograph of Lower Strawberry Creek showing the recently cleared Old SOC area, East tributary and levied areas. Shading indicates limits of historic wetland.

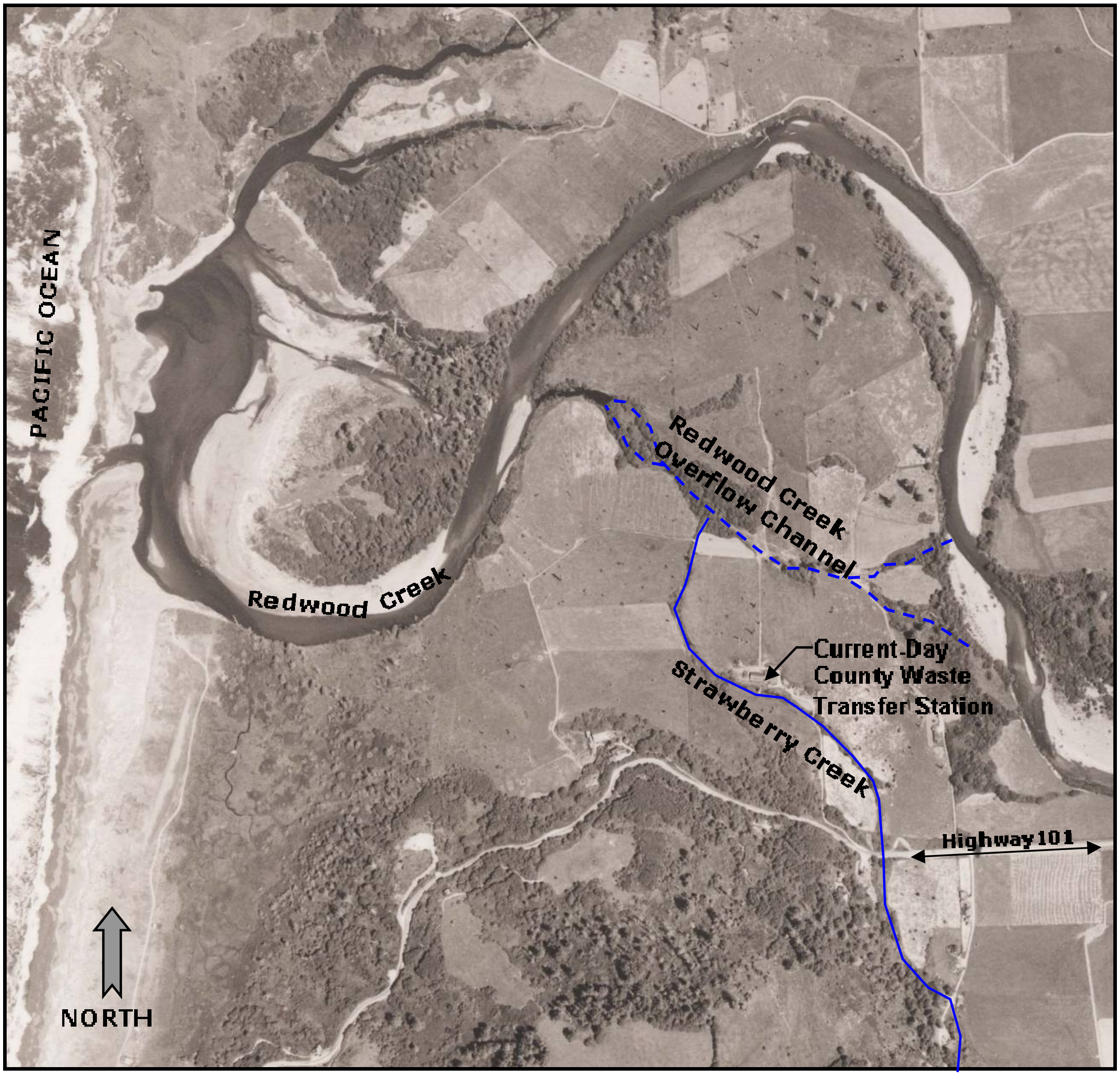

Figure 2.4 – Lower Strawberry Creek flowed into an overflow channel formed by Redwood Creek, as seen in this 1948 aerial photograph. The overflow channel was disconnected from Redwood Creek following construction of the flood control levees in 1968.

2.1.2 Historic Fisheries and Habitat

Historically, Strawberry Creek was an important cutthroat trout stream. Anecdotal reports of sport fishing for coastal cutthroat on Strawberry Creek confirm their historical presence and abundance. A detailed discussion of historic and current fishery resources in the Redwood Creek estuary is presented in the *Redwood Creek Integrated Watershed Strategy* (RCWG, 2006b).

Savina Barlow, formerly Savina Antonioli, grew up and lived her adult life in the Orick Valley on what is currently the Barlow Property (RNSP, 1981). She provided anecdotal evidence of fisheries in the Redwood Creek Estuary, including Strawberry Creek. As a child, she fished for cutthroat and steelhead in Strawberry Creek and noted that when Strawberry Creek was "cleaned out" the fishing improved. She also noted that small steelhead were present in the Redwood Creek Slough (South Slough), and there were large runs of coho and king salmon in nearby Hufford (North) Slough.

2.2 Present Site Conditions

2.2.1 Topography

Between late November 2006 and early March 2007 the project team surveyed approximately 9,000 linear feet of Strawberry Creek, starting at the South Slough and continuing up the main channel and into the SOC Tributary. The survey was conducted using real time kinematic (RTK) GPS combined with a total station in areas where GPS coverage was insufficient. The survey coordinate system is California State Plane Zone 1. Survey elevations are in the 1988 North American Vertical Datum (NAVD 88). Within the project area NAVD 88 is 3.39 feet lower than the National Geodetic Vertical Datum 1929 (often referred to as Mean Sea Level), which was used in earlier reports.

A detailed field-run topographic survey of the channel and adjacent floodplain was conducted upstream of the Humboldt County Waste Transfer Station. A longitudinal profile was surveyed throughout the project limits, including a detailed thalweg profile, water surface elevations, and major features of the project. Prior to the survey, an approximate 1,400 foot reach of the channel, from Hiltons Road culvert upstream to the RNSP boundary, was cleared of RCG. This allowed for clear identification of channel features within this reach for the survey.

In addition to a longitudinal profile survey, detailed cross sections of the overbank wetland area were surveyed. In wetland areas where the RCG mat entirely covered the channel, the top of the mat was surveyed and the ground elevation was determined based on select measurements of depth to ground beneath the floating mat. In portions of the RNSP property, cross sections were surveyed within the floating mat area that included points both on top of the RCG mat and on the ground surface.

The topographic survey downstream of Highway 101 was supplemented with a recent LIDAR survey of the area collected as part of an earlier project funded by the California Coastal Conservancy, and provided by RNSP. Field survey and LIDAR data were used to create a combined digital terrain model used for analysis.

Figure 2.5 shows the topographic base map created for the project. It consists of the surveyed topography represented by contours spaced at one foot intervals overlaid onto the 2005 aerial photograph. Figure 2.6 presents the longitudinal channel profile of the project area showing major features and distinct channel reaches.

2.2.2 Description of Existing Conditions by Reach

The Watershed-wide Aquatic and Riparian Habitat Restoration Strategy for Strawberry Creek report prepared by RCWG (2006a) divided Lower Strawberry Creek and the lower portion of the SOC Tributary into nine reaches and provided recommendations for restoration of each reach. Reach limits are shown in Figure 2.6 and Figure 2.7. Reach lengths were slightly modified for this report based on physical and biological characteristics of the reach, property ownership and proposed restoration approach.

PREPARED BY	KB	DATE 2/07	REV. DATE	PREPARED FOR MICHAEL LOVE	OWNED BY	STRAWBERRY CREEK TOPOGRAPHY FEBRUARY, 2007 Humboldt County, California
REVIEWED BY						

STRAWBERRY CREEK TOPOGRAPHY
FEBRUARY, 2007
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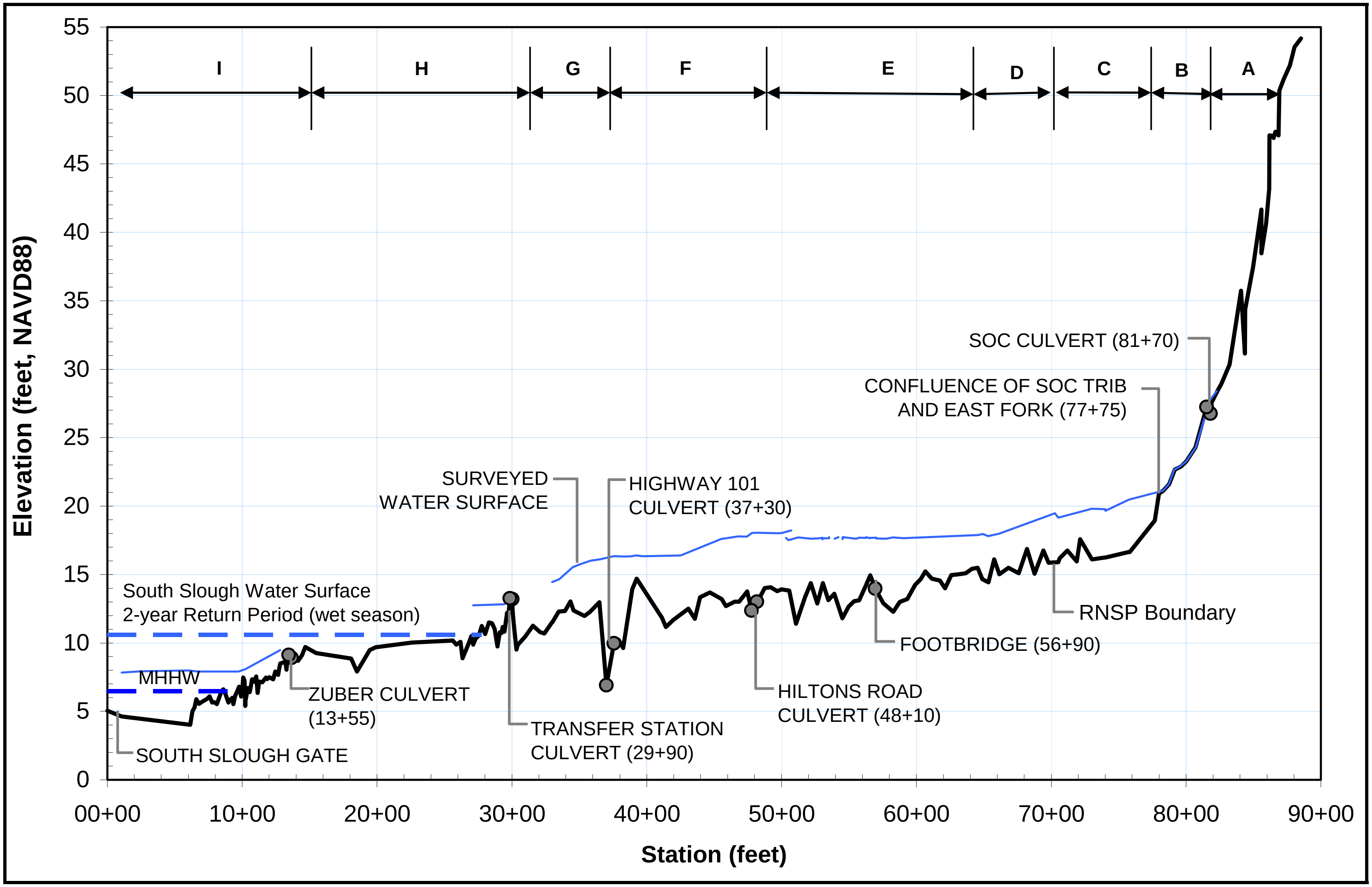


Figure 2.6 – Longitudinal profile of Lower Strawberry Creek and the lower 1,100 feet of the SOC Tributary. Project reach boundaries are denoted at the top of the figure. Plotted water surface represents winter baseflow conditions during time of survey (December 2006 through March 2007). Mean Higher High Water (MHHW) and approximate two-year water surface elevation at the mouth of Redwood Creek are shown as dashed blue lines.

Redwood National and State Park Property (Reaches A-C)

Reach A and SOC Culvert (Stations 88+50 to 81+70)

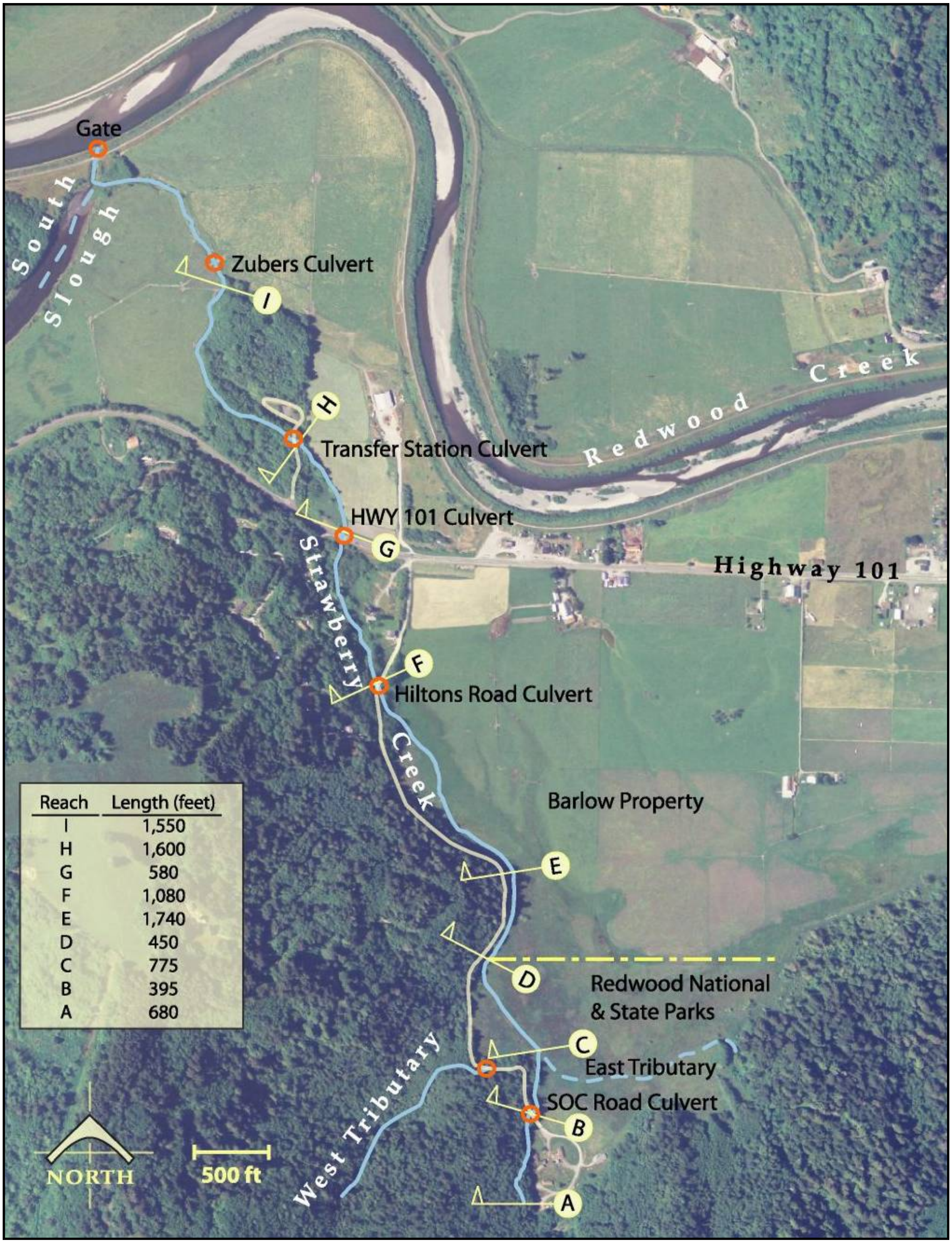
Reach A is 680 feet long and located on the RNSP property. It extends from the gravel turnaround at the Old South Operations Center (SOC) to the culvert on the RNSP Access Road. With the completion of the new South Operations Center in Orick in 2003, the Old SOC has been mostly vacated, except for a residence occupied by a park ranger on the eastern portion the site. RSNP may use the Old SOC site as a future park facility, and wishes to maintain the existing useable building area and existing road access.

The 680-foot reach has an overall channel slope of 4.0% and an average bankfull width of about 12 feet. This reach is located on the upper half of an alluvial fan that forms the transition from the steep mountain stream channel to the low gradient channel along the Orick Valley bottom. The upper 300 feet of the channel contains a forested riparian area along both banks and numerous wood-forced steps in the channel profile (Figure 2.8a). Further downstream, several buildings are adjacent to the creek and a small levee separates the channel from the adjacent lowlands. Along the levied side of the channel there is a lack of riparian vegetation. This levee has deteriorated in the absence of routine maintenance activities. RNSP personnel note that during larger storm events, the stream flows out of bank upstream of the Old SOC facility, flooding some of the buildings. Downstream of the buildings the stream channel is presently incising into a clay layer. There is little cobble and gravel substrate within the channel, and no wood features controlling the channel profile. This portion of the reach is covered with a dense thicket of Himalaya berries (*Rubus discolor*). At the end of the reach the channel is aggraded with sediment as the channel slope decreases and flow is backwatered by an undersized culvert. The SOC culvert on the RNSP Access Road is a two foot diameter corrugated metal pipe more than three-quarters full of sediment (Figure 2.8b).

Reach B Alluvial Fan (Stations 81+70 to 77+75)

Reach B is a 395-foot long channel reach located on the alluvial fan of the SOC Tributary on RNSP property. The reach extends from downstream of the SOC culvert to the confluence with the East Tributary, which is located on the edge of a large wetland. The average channel slope within this reach is currently 2.0% and the channel is about 12 feet wide. The morphology of this reach is defined as the lower portion of an alluvial fan where larger substrate is deposited as the channel slope decreases.

After flowing out of the SOC culvert, the channel runs along the toe of the hillslope to the west. A small levee along the east bank is intended to contain the flow. However, this channel reach is aggrading and streamflow frequently overtops the levee and flows across the alluvial fan. The entire length of this reach is choked with a dense thicket of invasive Himalaya berries (*Rubus discolor*). The area east of the channel is mowed by RNSP, though frequent overflows from the distributary stream channel keep it wet.



Reach	Length (feet)
I	1,550
H	1,600
G	580
F	1,080
E	1,740
D	450
C	775
B	395
A	680

Figure 2.7 – Location of Reaches A through I and road-stream crossings within lower Strawberry Creek and the SOC Tributary.

Figure 2.8 – Upstream of the old SOC (a) the tributary is characterized as wood-forced step-pool channel. The channel grade decreases as it flows across the alluvial fan, causing aggradation at the Access Road culvert inlet (b) and outlet.

Reach C Floating Mat (Stations 77+75 to 70+00)

Reach C is a 775-foot long channel reach on RNSP property with a channel gradient that lessens abruptly from 2% to nearly flat as it transitions from alluvial fan to bottomland. Reach C starts at the historic confluence of the East Tributary with the SOC Tributary, forming the Strawberry Creek main channel. The reach ends at the RNSP boundary with the privately owned Barlow property.

The area surrounding this reach is a perennial wetland with standing water covered by floating mats of RCG. The stream channel, levees and overbanks of Reach C and the East Tributary are poorly defined as a result of being entirely covered with the floating RCG mats. Figure 2.9 shows four cross sections surveyed in Reach C, along with the elevation of the floating RCG during 2006/2007 winter baseflow conditions (see Figure 2.5 for plan view location). The figures clearly indicate that the Strawberry Creek channel is still located in its historic realigned location, as seen in the 1968 aerial photograph (Figure 2.3). The average channel width within the cross sections is about 30 feet. The Ranch Road levee is also still present and covered with RCG along the west side of the channel.

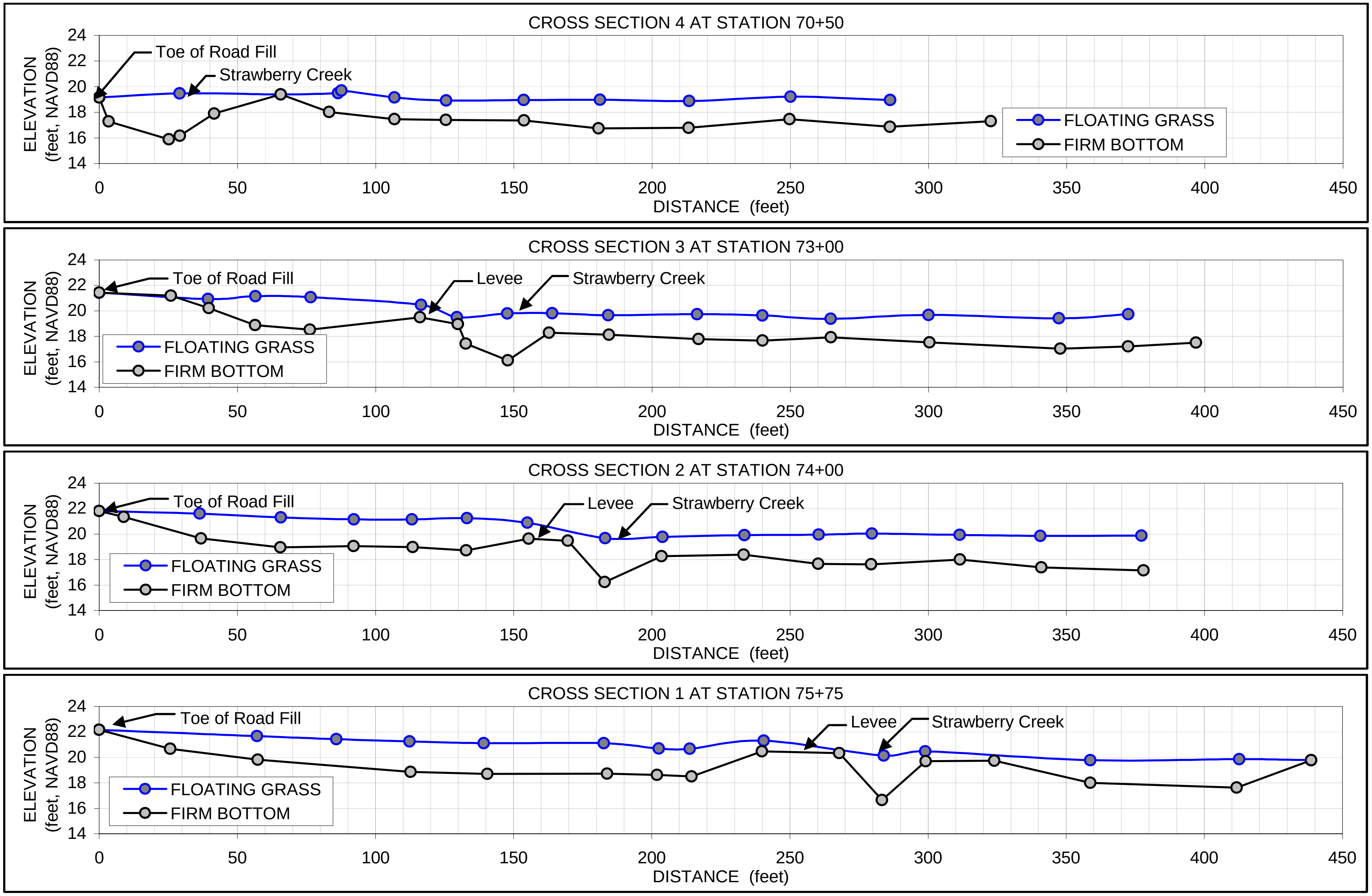


Figure 2.9 - Channel cross sections 1 through 4 surveyed in the winter of 2006/2007. Located in Reach C, these cross sections show the surface of the reed canary grass mat floating over the ground surface. This section of channel was historically ditched, with the drivable Ranch Road Levee along the left bank.

Upstream Highway 101 (Reaches D–F)

Reach D Barlow Property—Upstream (Stations 70+00 to 65+50)

Reach D is a 450-foot long reach located on the Barlow Property. Strawberry Creek flows from the floating mat area in Reach C into a large cattail pond and wetland area (Figure 2.10). RCG floating mat and wetland area are present around the perimeter of the pond. The pond holds water through the summer months and is used by migratory waterfowl. Short reaches of fully inundated stream channel are present to the west of the cattail pond. Water from the ponded area on the RNSP property flows into the main channel of Strawberry Creek via a slight depression in the channel bank at the downstream limit of the reach. The overall water surface slope across this reach is approximately 0.25%.

Reach E Barlow Property—Downstream (Stations 65+50 to 48+10)

Reach E is 1,740-feet long, located exclusively on the Barlow Property, and ending at the culvert under County maintained Hiltons Road. The reach has an overall slope of 0.1% and maintains a bankfull width of about 30 feet. Land along the eastern streambank is actively used for cattle grazing and the stream channel is accessible to cattle for watering during summer months, when the field dries out. The floodplain remains wet late into the spring and a historic meander scar forms a temporary pond from winter and spring surface runoff. The pond is used by migratory waterfowl.

RCG persists in the stream channel as a floating mat. Grazing on the overbanks has limited grass height, but it is the dominant vegetation species in the area. In an effort to improve drainage in this area, RCG was removed from this reach in the summer of 2006, and again in 2007 (Figure 2.11).

The Hiltons Road culvert is an 8-foot diameter circular metal culvert replaced in the late 1990's. The culvert was placed at a steep slope, with the soffit of the outlet approximately 1-foot above the channel bed. The culvert invert is currently filled with fine substrate. Until the RCG was removed upstream of the culvert in 2006, the channel and culvert were entirely choked with RCG. A buried water line that goes to the Old SOC is present in the vicinity of the Hiltons Road culvert crossing.

Reach F Cook Property (Stations 48+10 to 37+30)

Reach F is a 1,080-foot long reach that begins downstream of the Hiltons Road Culvert and extends to the Highway 101 culvert crossing. This reach is more confined than upstream and contains a well defined channel with a discontinuous earthen levee on the east bank. The overall slope of the reach is about 0.23% and the average channel width varies between 30 and 45 feet. Residential buildings are located east of the earthen levee. The levee and overbanks are covered with RCG. The RCG also covered the active channel until it was cleared between Hiltons Road Culvert and the County Transfer Station property line in summer and fall of 2007 (Figure 2.12). The upslope area along the west bank is forested and well drained.

The Highway 101 culvert is a triple-bay concrete box culvert with a riprap lined bottom, owned by California Department of Transportation (CalTrans). An Orick Community Services District municipal water line is buried in the streambed just upstream of the culvert. CalTrans right-of-way extends approximately 50 feet upstream and downstream of this culvert.

Figure 2.10 – Reach D consists of a wetland adjacent to the stream channel (below dashed line) that contains cattails and areas of open water, and remains free of RCG.

Figure 2.11 – Reed Canary Grass was removed from Reach E during the summer of 2006 (shown) and 2007. This reach requires routine clearing of the RCG to maintain flow capacity and prevent extensive inundation of adjacent stream banks.

Figure 2.12 – Reach F, partially cleared of RCG in September 2007. This reach is more confined and has higher banks than the upstream reaches. In-channel RCG raises the water level in this reach and prevents the upstream reaches from draining.

Downstream Highway 101

Reach G, Upper Zuber Parcel (Stations 37+30 to 31+50)

Reach G is a 580-foot long reach of Strawberry Creek on the Zuber Ranch, extending from the Highway 101 culvert crossing downstream to the Transfer Station Culvert. The upstream end of the reach is located in CalTrans right-of-way. The channel throughout this reach is more confined than in reaches upstream of the Hiltons Road culvert. The average channel width is 35 feet and the overall reach slope is about 0.20%. Similar to upstream, this reach consists of pasture area with the entire channel and overbank covered with RCG.

Reach H County Transfer Station (31+50 to 15+50)

Reach H is a 1,600-foot reach on the County-owned Transfer Station property that extends from the property line near the Transfer Station culvert to the northwest edge of the parcel. The Transfer Station culvert is a single cell concrete box culvert. This reach has an overall slope of 0.18% and a channel width that averages 30 feet. The stream channel in this reach appears to be moderately stable. A mature riparian area, consisting largely of red alders, is present on both channel overbanks in the upstream portion of this reach. RCG is present in some open canopy areas, but growth is significantly less vigorous than in the sunny areas of the upstream reaches. The wetted channel is largely free of RCG in this reach.

Within the lower 800 feet of the reach the riparian area persists on the east bank of the stream channel. The western overbank, owned by the Zuber family, is covered with RCG and the streambanks are grazed and unstable. RCG grows vigorously throughout much of the wetted channel. However, its growth is significantly less vigorous on the forested side of the channel (Figure 2.13).

Figure 2.13 – RCG grows throughout the active channel and open pasture in the lower portions of Reach H between the Zuber property and Transfer Station parcel. However, the RCG does not grow into the forested riparian areas due to adequate shading caused by a complex canopy.

In the Fall of 2007 two beaver dams were observed in this reach. One was approximately 1.5-feet high and located at the upstream face of the Transfer Station Culvert. The second was 1-foot high and located approximately 200 feet downstream of the culvert. Prior to the presence of the downstream beaver dam, the Transfer Station Culvert outlet was perched above the downstream water surface. Once constructed, the downstream beaver dam raised the water level enough to backwater the culvert and eliminate the outlet drop. The beaver dam at the culvert inlet raised water levels enough to create a backwater effect extending upstream of Highway 101.

Reach I Lower Zuber Parcel (Stations 15+50 to 0+00)

Reach I is a 1,550-foot reach located on the Zuber Ranch, extending from the north boundary of the County Transfer Station, through the Zuber Ranch Culvert, ending where Strawberry Creek enters South Slough. The Zuber Ranch culvert consists of two circular metal pipes with a gravel road fill.

Both channel overbanks in this reach are used for grazing, RCG extends into the stream channel, and the channel banks are unstable.

2.2.3 Vegetation

A visual inspection of existing vegetation within the project area was performed in the fall of 2007 for developing a RCG management plan (Gedik, 2008, Appendix A). The wooded area to the south and west of the project area is characterized by second growth redwood and Sitka spruce forest with red alder in the wetter areas (RNSP, 2006a). The wooded area on the Transfer Station parcel is dominated by mature alder canopy with shrub undergrowth. Young deciduous and coniferous trees are sparse. RCG was observed to grow less vigorously in riparian areas. RCG was observed growing under a dense red alder canopy along the West Tributary adjacent to the SOC Access Road. However, a short distance upstream a dense understory of salmonberry prevents the RCG from growing, likely due to the mixed shade canopy (Figure 2.14).

The remainder of the project area is non-forested floodplain pasture and wetland area dominated by RCG with other species occasionally intermixed. Table 2.1 presents the more common vegetation species found on the open floodplain of Strawberry Creek. Appendix A presents a full list of vegetation species present.

Biology of Reed Canary Grass

Reed canary grass is a perennial rhizomatous grass that thrives in cool climates. It is most often found growing in wetland habitats that receive extended periods of saturation during the growing season. RCG is common in pastures, wet ditches, shallow marshes, wet meadows, along roadsides, lake margins and floodplains, and in riparian areas disturbed by grazing and/or soil movement. This plant is quite adaptable morphologically and established plants can tolerate long periods of inundation in addition to long periods of drought. Reed canary grass also responds favorably to sites with highly variable water levels and periods of drawdown (Miller and Zedler 2003).

Table 2.1 - Common Vegetation Species at Strawberry Creek (From RNSP, 2005 and Gedik, 2008).

Phalaris arundinacea	Reed Canary Grass
Potentilla anserina	Silverweed
Carex obnupta	Slough Sedge
Scirpus microcarpus	Small Fruited Bulrush
Juncus effusus	Soft Rush
Oenanthe sarmentosa	Water Parsley
Lysichiton americanum	Skunk Cabbage
Veronica americana	American Speedwell
Ranuculus repens	Creeping Buttercup
Dactylis glomerata	Orchard Grass
Agrostis stolonifer	Creeping Bentgrass
Holcus lanatus	Velvet Grass
Typha latifolia	Cattail
Alnus oregona	Red Alder
Rubus spectabelis	Salmonberry
Carex obnupta	Slough Sedge
Lysichiton americanum	Skunk Cabbage
Sambucus racconosa, var callicarpa	Elderberry
Rubus discolor	Himalaya Berry
Salix spp.	Willow Species

Figure 2.14 – RCG grows under a dense alder canopy (foreground) but is not present among the salmonberry and alder (background), likely due to the effective shading caused by the mixed-level canopy.

Rapid production of biomass enables reed canary grass to establish a dominant canopy cover, occupy more space along the soil surface, and shade out other seedlings before less competitive species can establish. Reed canary grass cannot thrive in shaded conditions, but has been known to expand via tillers that extend into heavy shade and derive energy from the unshaded parent (Maurer and Zedler 2002 in Miller and Zedler 2003).

Reed canary grass's primary mode of reproduction occurs vegetatively from underground horizontal stem tissue (rhizomes). Rather than probe deeply into the soil, rhizomes creep densely below the soil surface and form thick mats in a sod-like layer. Over time, the layering of rhizomes, leaves, and dead stems can develop a sod layer of reed canary grass 0.5 meters thick (Tu 2004).

Floating mats of reed canary grass have been observed with lightly rooted, floating aerial shoots and development of feathery adventitious roots in water depths of 3 feet to 4 feet, and even as much as 8.5 feet of water depth (LeFor 1987), with some mats rooted to pond bottoms.

2.2.4 Water Quality and Aquatic Habitat

The ditch-like configuration of Strawberry Creek, adjacent agricultural land use, and lack of riparian vegetation have reduced fish habitat and overall quality of Strawberry Creek. The stream channel and overbank wetlands are choked with reed canary grass. The dense mats and root structure of RCG inhibit fish migration, cause water quality impacts, and block streamflow.

Water Quality

Dissolved oxygen (DO) levels below 2 ppm are considered lethal for juvenile salmonids (Water Quality Assessments, 1996). Maximum average weekly temperatures above 15 ^{o} C and short term temperatures above 25 ^{o} C have been found to limit healthy populations and lead to mortality for juvenile Chinook salmon (Armour, 1991).

Dissolved oxygen (DO) levels in Strawberry Creek measured in August and September 2006 ranged from 0.04 to 1.2 ppm in the RCG choked channel within the project area (Appendix B). At the same time, DO levels of approximately 9 ppm were measured in the wooded area of the SOC Tributary upstream of the project site. Water temperatures collected during DO sampling ranged from 10.9^{o} to 13.6 ^{o} C within the RCG choked channel and the SOC Tributary (Appendix B).

After removal of the RCG from the stream channel, September DO levels of 4.5 to 5 ppm were measured (Personal Communication, D. Anderson, 2008). No biological oxygen demand (BOD) testing was preformed at the time of the measurements.

Water temperatures within the Strawberry Creek project area appear to be well suited for rearing of juvenile salmonids and it appears that low DO is not attributable to elevated water temperatures. The dangerously low levels of dissolved oxygen measured in Strawberry Creek in the summer and fall are likely attributable to several factors:

- Annual die-off and decomposing biomass of RCG within the water column (MLA, 2006)

- RCG preventing wind mixing of the water column
- Nutrient loading due to the adjacent land-use activities

Aquatic Habitat

Upstream of the project area on the SOC Tributary, the creek is shaded by dense redwood and spruce riparian overstory and the stream bed is composed of silt with some small gravels. In August 1989, pool depths ranged from 0.4 to 0.85 feet, and riffle depths ranged from 0.1 to 0.2 feet (RCWG, 2006a). There are numerous wood habitat features in the channel.

In the open stream valley, most of the project reach lacks woody riparian vegetation and overstory (RCWG, 2006a). The stream bottom is composed of sand and silt, and the depth is shallow (0.2 to 0.4 feet in late August 1989). Pool and riffle patterns are non-existent and surface flow is dispersed due to the absence of a consolidated channel (RCWG, 2006a). There are few wood habitat features in the channel.

2.2.5 Fisheries

The Redwood Creek estuary, including Strawberry Creek, has been historically, and is presently, a rearing area for coho, Chinook, and steelhead salmonids and cutthroat trout, though not in the numbers reported historically (RCWG, 2006b). Juvenile Chinook and steelhead with fork lengths less than 70 mm have been recently caught in the Redwood Creek estuary when they arrive in the Spring and Summer. The Redwood Creek bar closed before the fish achieved a fork length of 100 mm, and only 7-15% of the populations in the closed Redwood Creek estuary survived summer rearing (RCWG, 2006b).

In the recent past Strawberry creek supported small runs of steelhead and cutthroat trout (RCWG, 2006a). Lamprey were observed in May of 1985 in the creek near the old SOC. Juvenile coho salmon, threespine stickleback, and sculpin found in the South Slough in the 1990s may also indicate their presence in lower Strawberry Creek.

Two 60 mm young-of-the-year trout were electroshocked 20 feet downstream of the Access Road culvert near the Old SOC in August of 1989 (RCWG, 2006a). Upstream of the Old SOC, young-of-the-year trout ranging from 60 to 65 mm (fork length) were found while electroshocking in August of 1989. In March 1994, the West tributary to Strawberry Creek was electroshocked but only Pacific Giant Salamander larvae were found (RNSP, 2005).

2.2.6 Wildlife

Second-growth forests, former pastureland, and wetland support a wide variety of native mammals and birds. Wildlife in the project area include waterfowl and shorebirds, which use the wetlands and pastures; Peregrine falcons, songbirds, black-tailed deer, and Roosevelt elk use the entire valley floor and adjacent forested areas. Elk forage extensively in the grassland and wetland areas around the Old SOC and use the forests for cover. River otter were frequently seen in the channel following vegetation removal and while the channel remained open. Mallard flocks, Canada geese, widgeons, ringnecked ducks, and wood ducks use open ponded areas in the pastures that are seasonally flooded in winter and spring. Redlegged frogs and pacific tree frogs are abundant in the wetlands adjacent to the channel (RCWG, 2006a).

Bald eagles and marbled murrelets are occasionally observed flying overhead in the project area. A bald eagle nest was observed within the watershed of Strawberry Creek in the headwaters. Though surveyed, no northern spotted owls have been detected in the areas adjacent to the Old SOC (RCWG, 2006a).

3 Analysis and Findings

3.1 Project Area Hydrology

Strawberry Creek drains an area of about 1,400 acres (2.1 square miles) at its confluence with the South Slough. Total channel length to the South Slough is roughly three miles and blueline streams total about 3.4 miles in combined length. Elevation in the basin ranges from 10 to 1,250 feet (NGVD29). Most of the 1,240 feet of relief exists within the hillslope surrounding the valley floor. Headwater tributaries are short (2,000 to 3,000 feet long) and steep (30 to 40 percent gradient) (RCWG, 2006a). Figure 3.1 shows the USGS topographic map with drainage areas of Strawberry Creek and its tributaries used for the hydrologic analysis.

Lower Strawberry Creek is a perennial stream with stream flows of 1.5 cfs in measured in June 1988 and 0.25 cfs estimated in August 1988. Minimum flows were observed in September, and were estimated to be typically 0.5 cfs or less (RCWG, 2006a).

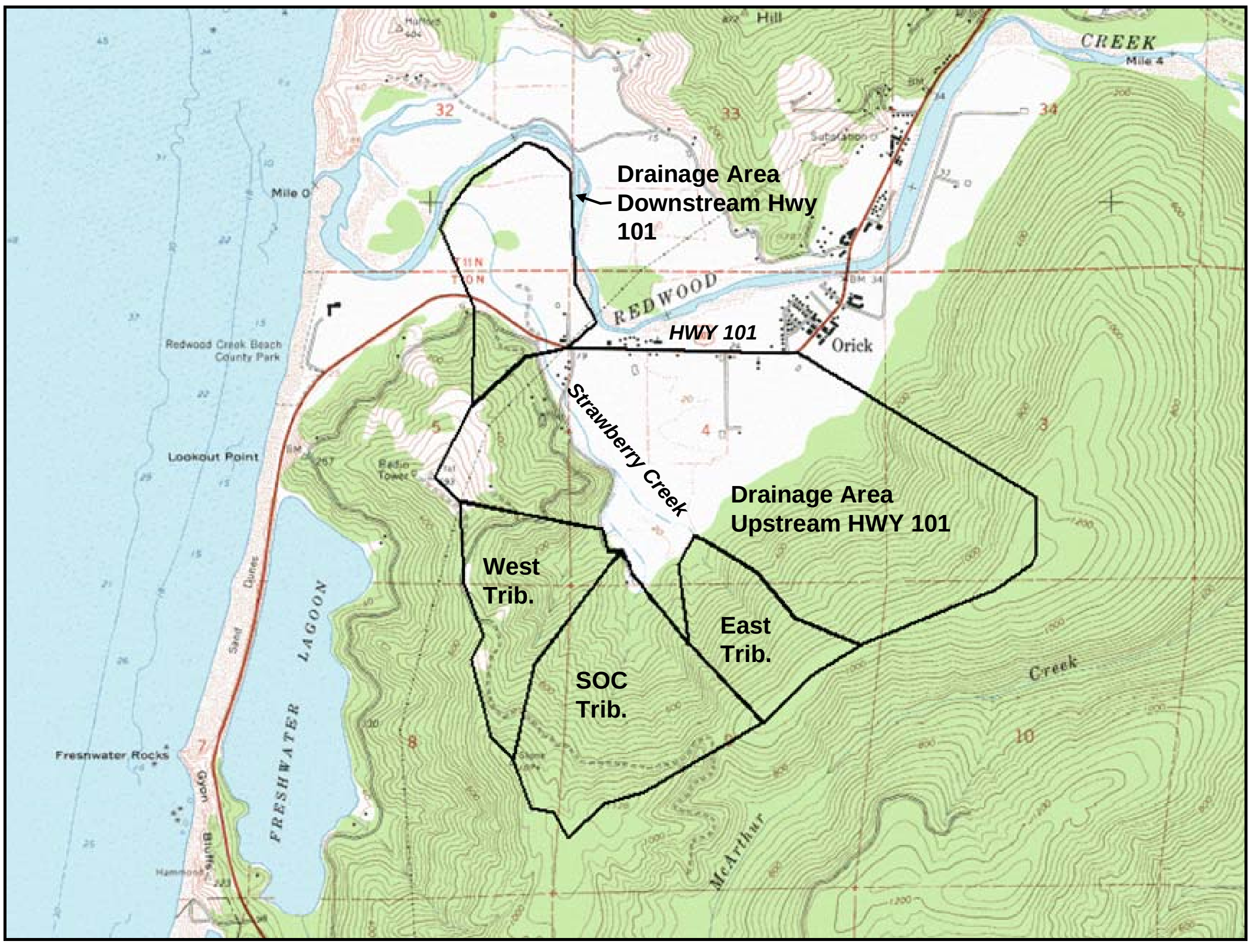


Figure 3.1– Drainage area of Strawberry Creek on the USGS topographic map (Orick Quad). Map represents the area prior construction of the Redwood Creek Flood Control Project.

3.1.1 Peak Flows

Peak flow estimates are necessary to evaluate existing channel and culvert capacities and are used in the hydraulic modeling to assess flood frequency and extent of inundation. There are no USGS gages measuring stream flow on Strawberry Creek so peak flows for the Strawberry Creek study reach were estimated using four methods for ungaged watersheds: USGS gage analyses, Regional Regression Equations, and two Regional Curve analyses. Appendix C summarizes the results of the various methods used to predict peak flows.

This study used peak flows predicted from the USGS stream gages analysis (Table 3.1). However, the predicted peak flows for Lower Strawberry Creek along the valley bottom fail to account for flood storage in the overbanks, which significantly attenuates downstream peak flows. Estimating floodplain storage for Strawberry Creek is difficult because of the complexity of the terrain as well as impacts of RCG on flood conveyance.

Table 3.1 - Peak flow estimates for the Strawberry Creek watershed using average annual peaks from nearby USGS stream gages.

Location	Drainage Area (mi^2)	Strawberry Creek Recurrence Intervals and Associated Peak Flows (cfs)						
		1.5 Year	**2 Year**	**5 Year**	**10 Year**	**25 Year**	**50 Year**	**100 Year**
West Tributary	0.21	12	17	31	41	55	67	78
SOC Tributary	0.38	22	31	55	74	99	120	140
East Tributary	0.16	10	13	24	32	44	52	61
SOC, West and East Tributaries combined	0.75	44	61	111	148	198	238	280
Highway 101 Crossing[1]	1.88	112	155	279	373	501	601	705
Confluence with South Slough[1]	2.13	127	175	315	420	565	678	796

[1] *Estimated peak flows neglect effects of upstream storage and retention associated with wetlands and reed canary grass.*

Estimating floodplain storage was beyond the scope of this project and certain assumptions were made in the hydrologic and hydraulic assessment of the project area:

- Peak flows within the SOC, West and East tributaries were assumed to be un-impacted by Orick Valley floodplain storage because they are steeper headwater tributaries with little overbank floodplain storage. Therefore, flow discharge and frequency in Reaches A and B were assessed using peak flow values in Table 3.1.

- Flows in Reaches C to the South Slough were assumed to be significantly influenced by floodplain (wetland) storage for any flow event that exceeds the channel capacity. Within areas containing floating mats of RCG, the floodplain is completely inundated at baseflow. For Reaches C downstream to the South Slough, the peak flows for return periods greater than 2-years are considered extremely conservative. Because of this, emphasis was placed on evaluating the difference between existing and proposed flow conveyance and predicted changes in water surface elevations.

3.2 Influences on Stream Channel Hydraulics

Water levels and flow conveyance in Strawberry Creek depends on the complex interaction of several variables, including channel slope and shape, floodplain topography, and culvert capacity. A hydraulic analysis of the project reach was conducted to evaluate the combined impacts of these variables on the water surface elevations and flow conveyance throughout the project area. A non-uniform one-dimensional steady-state hydraulic model was developed for the project area using the Army Corps of Engineers' Hydrologic Engineering Center-River Analysis System (HEC-RAS).

3.2.1 HEC-RAS Model Development

The HEC-RAS hydraulic model was developed from the topographic survey of the project area and included channel reaches A through I. Cross sections were spaced at 50 to 500-foot intervals, more closely spaced at significant channel features or changes in channel geometry. Cross sections were based on surveys of existing ground, and included the firm ground beneath the floating RCG. Floating mat surface elevations were not included in the model. Where topographic data was limited, cross sections from adjacent channel areas were copied and shifted to the surveyed thalweg elevation.

Channel roughness values of 0.04 were used for non-forested reaches and 0.045 in forested areas. Overbank roughness of 0.06 was used in non-forested areas and 0.08 in forested areas. However, for the channel reaches between the SOC Tributary confluence and the Hiltons Road Culvert (Reach C through E) flow conveyance along the floodplain was assumed negligible because of wetland storage. Therefore, within these reaches the overbanks were modeled as permanent ineffective flow areas.

The model included the SOC, Hiltons Road, Highway 101, Transfer Station, and Zuber Ranch culverts and roadway profiles as described by the field survey. The tailwater cross sections surveyed at each culvert were included in the HEC-RAS model.

The HEC-RAS model was run in mixed flow regime for a range of discharges from 5 cfs to 796 cfs, the approximate 100-year flood. Upstream, the model used normal depth to allow for localized areas of critical and supercritical flow in the steeper SOC tributary. The downstream boundary conditions were based on tailwater elevations derived from South Slough water levels.

3.2.2 South Slough Water Levels - Downstream Boundary Conditions

The water surface impacts of the South Slough and Redwood Creek potentially affect channel hydraulics, sediment transport, riparian vegetation and fish passage within the Strawberry Creek project area. Therefore, assessment of existing conditions for this project examined variations in water levels within the South Slough and their potential influence on Strawberry Creek.

Water levels in the South Slough are influenced by water levels in Redwood Creek, which in turn affect water levels in the lowermost reaches of Strawberry Creek. Water from Strawberry Creek can flow to Redwood Creek in two ways: over a depositional bar at the oceanside end of the Redwood Creek South Levee or through a manually operated gate that bisects the south levee near the confluence of Strawberry Creek and the South Slough (Figure 3.2). The invert of this gate is placed at elevation 5.05 feet (NAVD 88) and the gate, operated by RNSP, is opened in spring through fall. When open, it allows the South Slough to drain more efficiently during low tide, improving circulation within the South Slough. When the control gate is closed during the winter months, to reduce sedimentation in South Slough, waters from Strawberry Creek must flow through South Slough to the oceanside end of the Redwood Creek.

South Slough water levels are influenced by (1) the water level of Redwood Creek at its mouth, (2) the elevation of the depositional bar across the outlet of the South Slough and mouth of Redwood Creek, and (3) control gate operations between the South Slough levee and Redwood Creek (Figure 3.2).

During summer and early fall, long shore drift results in the formation of a sand bar across the mouth of Redwood Creek and the South Slough, which often closes off these areas from the ocean. The presence of the sand bar can cause water levels in the South Slough to rise dramatically, sometimes reaching a water surface elevation of 14 feet (NAVD 88). This rise in water level occasionally causes flooding of the lower Zuber pastures and creates a backwater effect that can extend up Strawberry Creek as far as the Highway 101 crossing. During fall storms, flows in Redwood Creek will reopen the mouth of Redwood Creek causing water levels to drop.

When the bar at the mouth of Redwood Creek is open, water levels in Redwood Creek generally fluctuate with changes in the tides and stream flow. Because the South Slough is connected to Redwood Creek, its water level tends to follow those of Redwood Creek. When the gate in the levee is closed the depositional sand bar located across the mouth of the South Slough limits tidal exchange in the South Slough by preventing the Slough from draining below elevation 6.9 feet (NAVD 88).

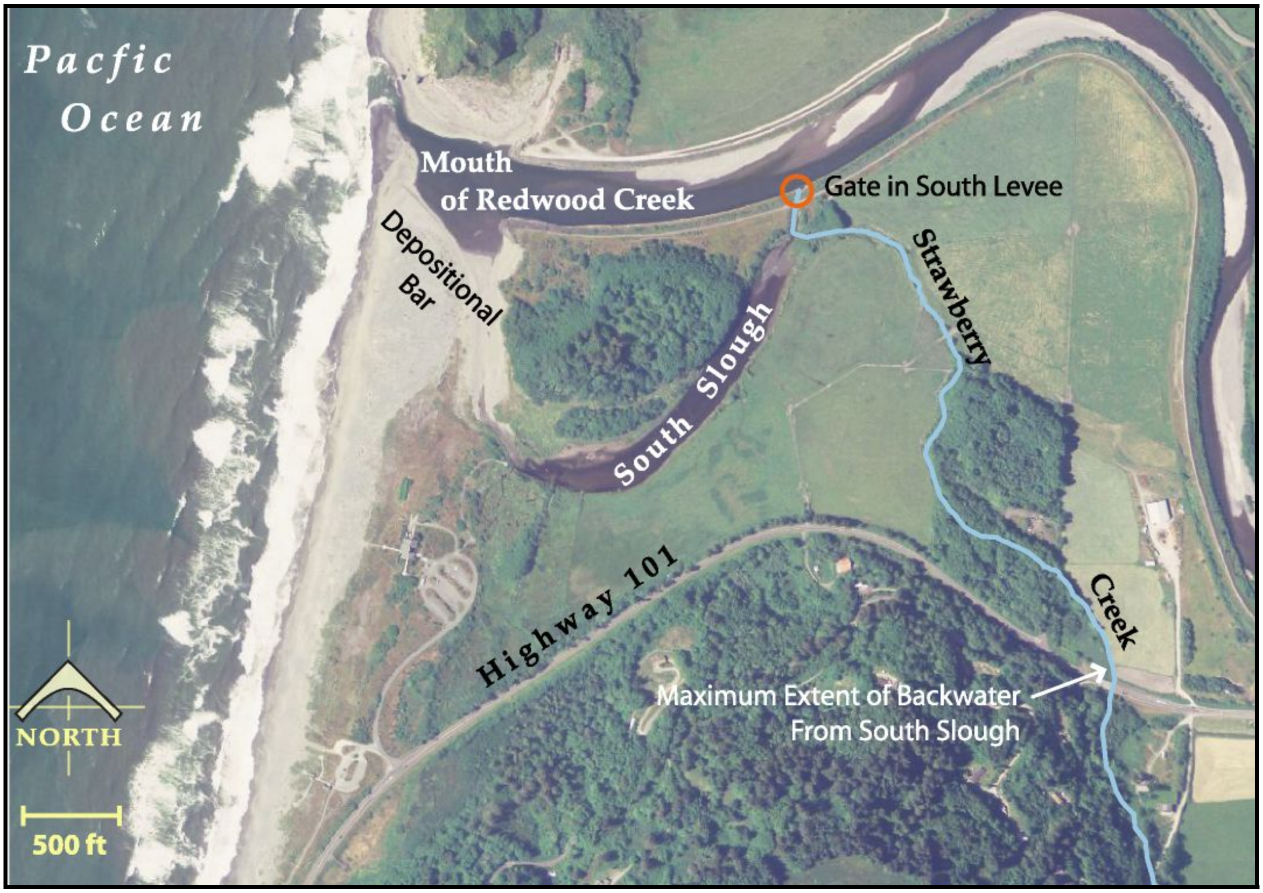


Figure 3.2 - Aerial photograph showing the depositional bar across the mouths of Redwood Creek and South Slough. When the mouth is closed during summer and early fall, water levels in South Slough can rise dramatically, increasing water levels in the lower portions of Strawberry Creek.

RNSP maintains water level recorders on Redwood Creek and the South Slough to monitor water surface elevations. The data collected between 2001 and 2005 was provided by RNSP and used for this assessment. Stage records show that during the Summer months when the Redwood Creek estuary is closed and the gates in the south levee are open, water surface elevations in the South

Slough can reach approximately 14 feet (NAVD 88) before the Redwood Creek bar breaches. After the Redwood Creek estuary has opened, South Slough elevations range from approximately 4 to 14 feet, varying with bar elevation, tides, storm surges and flow.

To assess the variability in water levels within the South Slough and Strawberry Creek during Winter storm flows, peak water surface elevations measured in South Slough between November and March were correlated with the recorded flow in Redwood Creek at the Highway 101 Bridge in Orick (CDEC, 2007). This relationship, along with an estimate of the return period of flows in Redwood Creek, was used to roughly estimate the water level in the South Slough (Figure 3.3). For analysis purposes we assumed that during any individual storm event Strawberry Creek experiences peak flows having a similar return period as peak flows on Redwood Creek. Based on this, the relationship shown in Figure 3.3 was used to estimate water levels in the South Slough at specific return period flows on Strawberry Creek (Table 3.2). The data scatter in Figure 3.3 is likely a result of several factors that may include rainfall pattern variability, remnants of the depositional bar at the mouth of Redwood Creek and the South Slough, tide levels and storm surges.

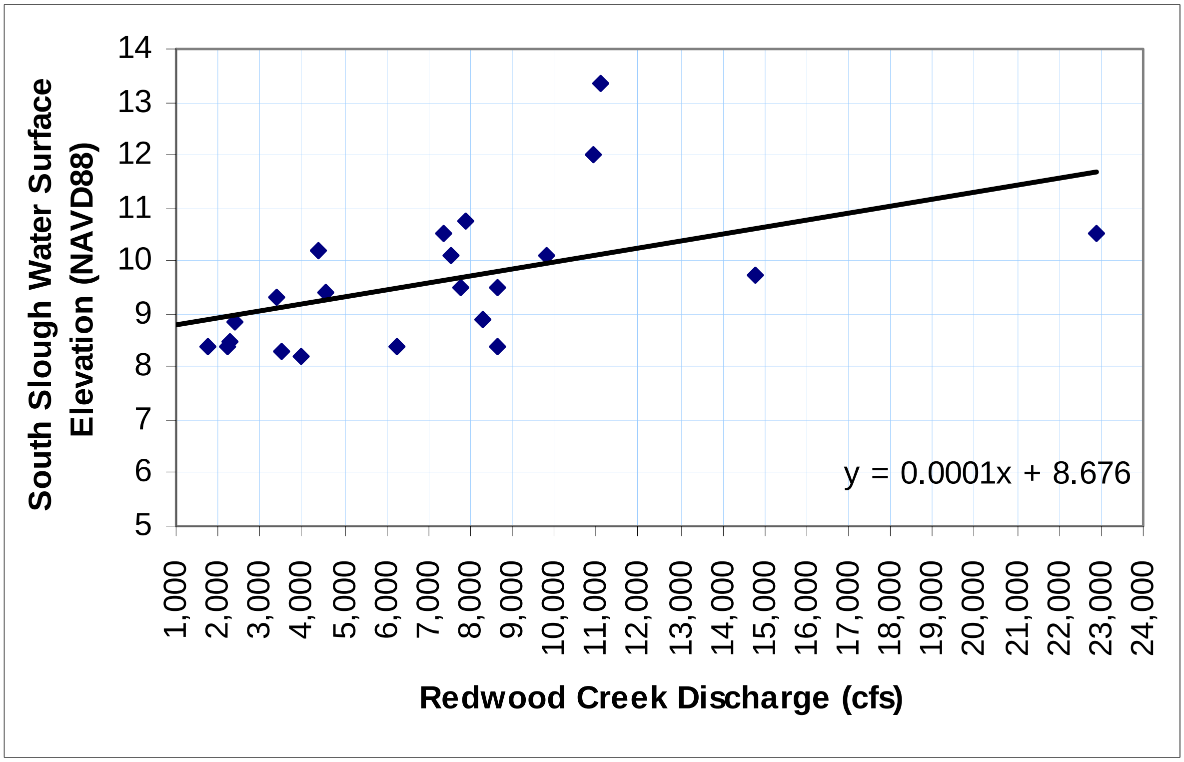


Figure 3.3 - South Slough water surface elevations correlated with peak flows in Redwood Creek during November through March (2002, 2004, 2005), when the estuary mouth is open.

Table 3.2 - Assumed South Slough water surface elevations for design storm events.

Strawberry Creek	Assumed South Slough Water Level
Baseflow	6.48 feet NAVD 88 (Mean Higher High Water)
1.5 Year Return Flow	10.1 feet NAVD 88
2 Year Return Flow and Larger	10.6 feet NAVD 88

3.2.3 Hydraulic Conditions with Strawberry Creek

Predicted water surface profiles for winter baseflow and the approximate 2-year and 10-year flows are shown in Figure 3.4. The "observed" winter baseflow water surface, surveyed in the fall and spring of 2006-2007, is also shown. The impacts of RCG on flow conveyance and overbank/ wetland storage could not be accounted for within the hydraulic model. Instead, the HEC-RAS model results represent flow conditions that would occur if the stream channel was cleared of RCG. During the time of the survey the RCG within the active channel impacted water levels throughout most of the project area.

Model results and field observations point to three key issues that exacerbate flooding and increase channel sedimentation in the Strawberry Creek project area:

1. RCG greatly reduces flow conveyance during winter baseflow conditions, thus slowing the draining of the upstream pastures

2. High points within the stream channel cause extensive backwater effects during winter baseflow conditions, and

3. All of the culverts except Highway 101 have insufficient capacity, leading to increased water levels and extensive backwater effects at the 2-year flow and greater.

Impacts of RCG on Water Levels

The impacts of RCG on channel hydraulics were assessed by comparing the HEC-RAS model results with observed water surface elevations. Water surface profile elevations were originally surveyed throughout the project area during winter baseflow conditions in 2006-2007, when RCG was present throughout most of the active stream channel. In the summer and fall of 2007, subsequent to the project survey, RCG was cleared from the active channel from the Transfer Station to the duck blind on the Barlow property (Reaches E-G). This caused water levels to drop noticeably throughout this 3,400-foot section of channel. Subsequently, the water surface at the Hiltons Road and the Highway 101 culvert was resurveyed during baseflow conditions in November 2007.

Model results show that removing the RCG allows the 2-year flow to be conveyed within the channel banks throughout the stream reaches downstream of RNSP (Figure 3.4). Observations indicate removal of the RCG from the channel lowers the water surface by as much as 3 feet during a winter baseflow of approximately of 5 cfs (Figure 3.5). Maintaining a lower water level during the winter baseflow conditions would improve drainage of the adjacent pasture and make soil conditions more suitable for riparian planting along the streambanks.

Backwater from Channel High Points

The field survey and model results identified four high points in the Lower Strawberry Creek channel which elevate upstream water surfaces during winter baseflow conditions. These high points, shown in Figure 3.4, are located at the Transfer Station culvert (including the culvert invert), upstream and downstream of the Highway 101 culvert, and immediately downstream of the Hiltons Road culvert. The origin of the high points is likely caused by sedimentation caused by RCG growing in the channel and backwater effects from downstream culverts. The high-point at the Transfer Station culvert is a result of the culvert being constructed with an invert well above the existing stream channel, creating a perched condition and water surface drop at the downstream end of the culvert.

Benefits of Lower Transfer Station Culvert and Removing RCG and Channel High Points

Removal of the in-channel RCG within the project area, removal of the four high points, and installation of an at-grade culvert at the Transfer Station was modeled to evaluate impacts on water level during winter baseflow and the frequently occurring 2-year flow (Figure 3.6). These actions would lower the water level between Hiltons Road culvert and the Transfer Station culvert by roughly 2.0 feet during winter baseflow conditions and 0.8 feet during the 2-year flow. Removal of high points in the channel area downstream of the Hiltons Road culvert will also increase the capacity of the culvert. Modeling shows that removal of the high points and RCG may lower 2-year water levels as far upstream as the SOC Tributary confluence on the RNSP property.

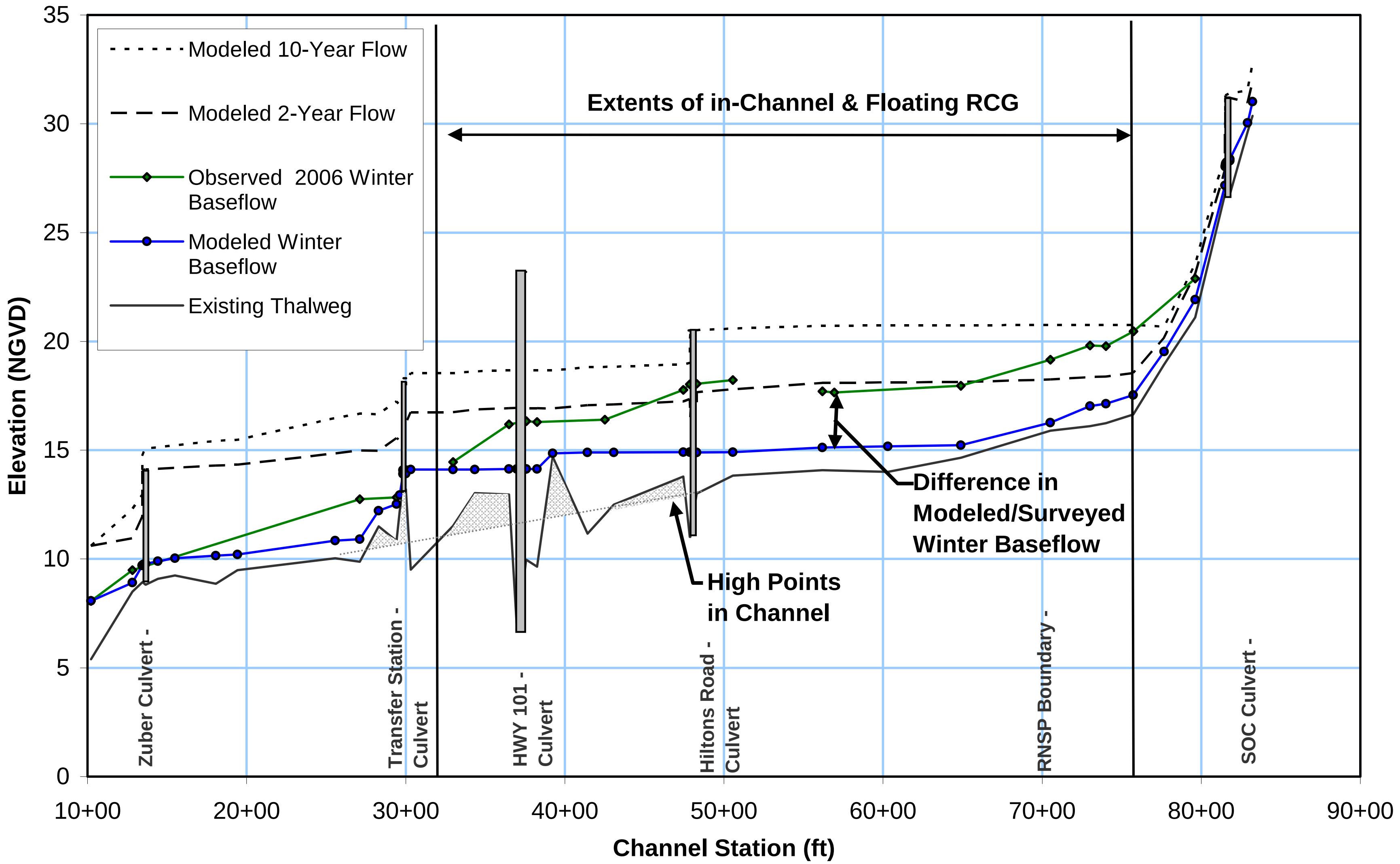


Figure 3.4 - Predicted water surface profiles for baseflow (blue circles) and the approximate 2-year and 10-year flows. The observed 2006 winter baseflow water surface is shown in green diamonds. Identified high points within the channel are indicated with shading below the existing thalweg.

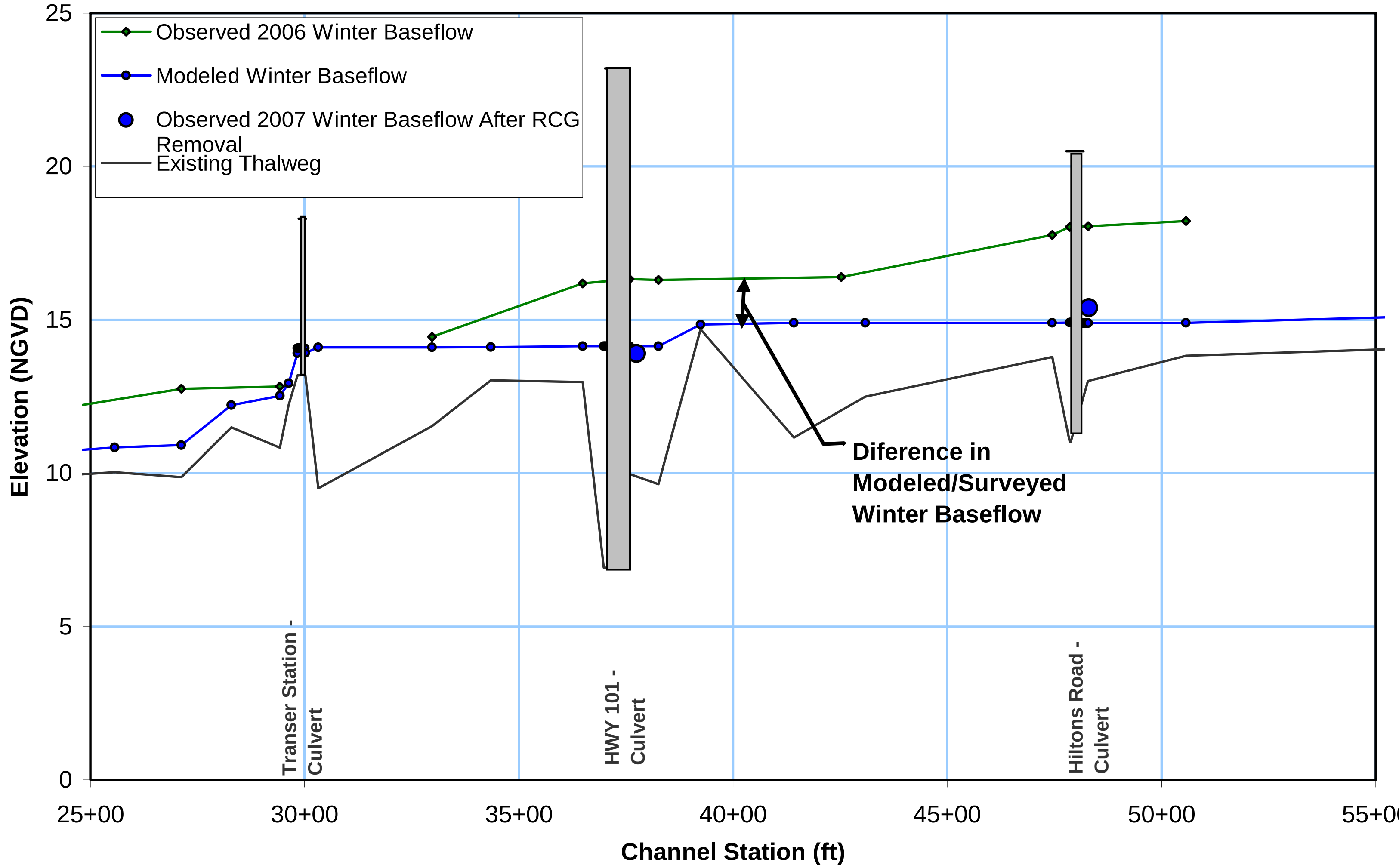


Figure 3.5 – Predicted water surface profile and observed water surface elevations during winter baseflow conditions. The 2006 observations were made prior to clearing of the RCG from the active channel. Water surface observations at the Hiltons Road and Highway 101 culverts in November 2007 were made following removal of in-channel RCG from Reaches E, F, and G.

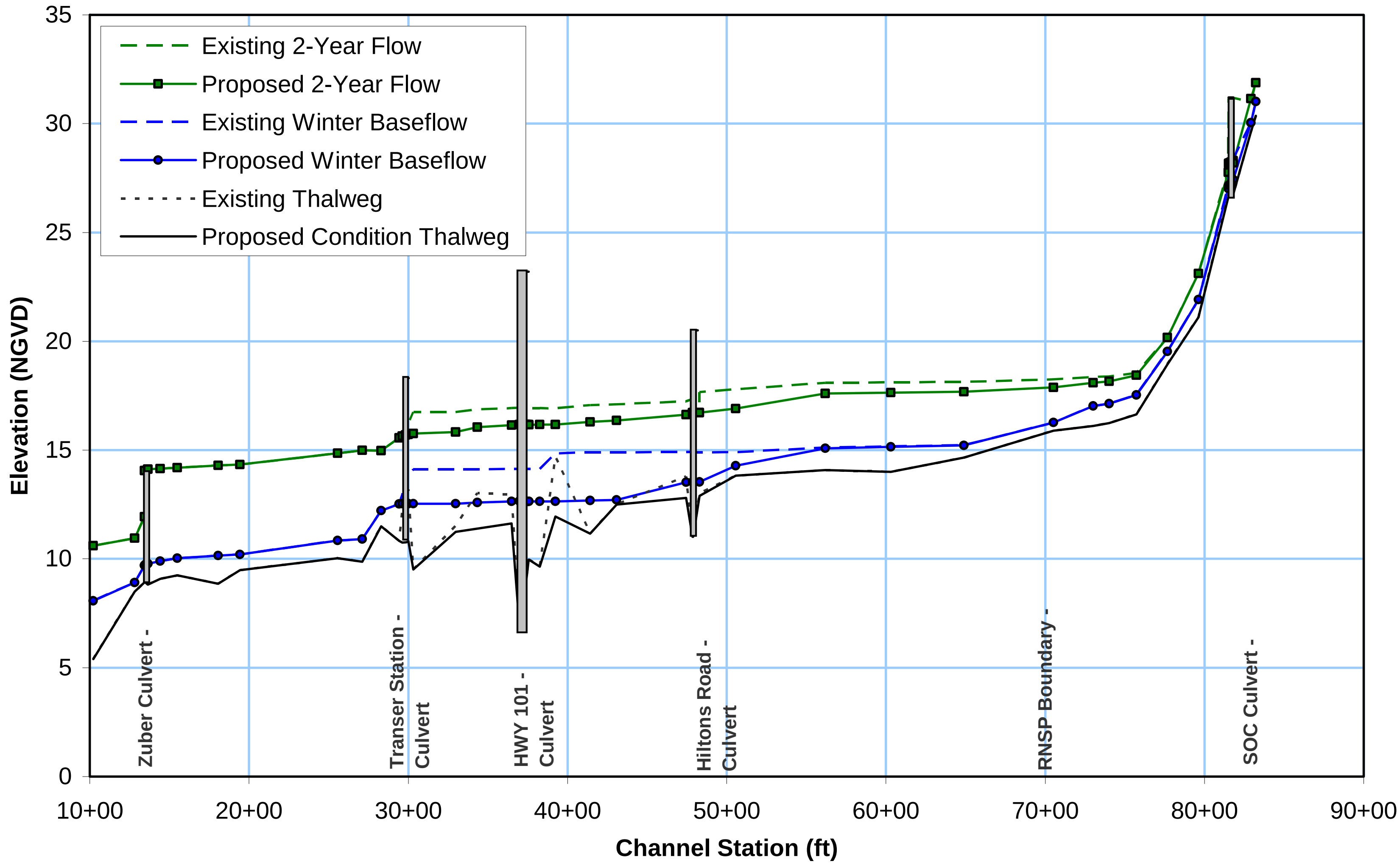


Figure 3.6 - Predicted change in winter baseflow and 2-year water surface elevations following removal of channel high points and lowering of the Transfer Station culvert.

Culvert Capacities and Impacts on Water Surface Elevations

Hydraulic modeling indicates all culverts on Strawberry Creek would convey at a minimum the 2-year flow without causing upstream out-of-bank flooding if the active channel was clear of RCG. A summary of culvert dimensions, flow capacities, and approximate return periods when flows overtop the roadway surface is presented in Table 3.3. Except for the SOC culvert, return period estimates are likely underestimated due to attenuation of peak flows caused by overbank storage upstream of the Hiltons Road culvert.

Table 3.3 - Summary of existing culvert materials and roadway-overtopping flow capacity.

Culvert	Culvert Size	Culvert Capacity (cfs)	Approximate Return Period of Culvert Capacity (Years)[1]
SOC Culvert	Single 2 ft CMP	26	~ 2 Year
Hiltons Road Culvert	Single 8 ft CMP	371	~10-Year
Highway 101 Culvert	Triple Cell Concrete Box with rock bottom 65 ft overall width 12 ft tall	>705	>100 Year
Transfer Station Culvert	Concrete Box 4 ft tall x14 ft wide	350	~10-Year
Zuber Ranch Culvert	4 ft and 3 ft CMP	130	~2-Year

[1] For all crossings besides the SOC culvert, return periods are extremely conservative and do not consider the effect of extensive overbank storage attenuating peak flows occurring upstream of Hiltons Road.

SOC Culvert

The SOC culvert has an approximately 2-year capacity before it overtops the roadway. Its limited capacity creates a backwater that extends approximately 150 feet upstream of the culvert. The backwater has caused sediment accumulation upstream and within the culvert, further reducing its capacity. The culvert backwater is likely the cause of observed sediment deposition immediately upstream of the inlet, and may also exacerbate upstream out-of-bank flooding.

Hiltons Road Culvert

The Hiltons Road culvert has an approximately 10-year capacity before it overtops the roadway. The HEC-RAS model predicts that removal of the culvert would lower upstream water levels by 0.2 feet at the 2-year flow. This change in water level would propagate upstream into the RNSP reaches. Model results also show that streamflows are contained with the existing streambanks up to the approximately 2-year event if the existing culvert is removed or replaced with a channel-spanning crossing structure. Though this culvert is installed with the outlet invert buried into the streambed, model results suggest it does not raise upstream water levels at flows lower than the 1.5-year event.

Highway 101 Culvert

The Highway 101 culvert conveys the estimated 100-year flow without overtopping or raising upstream water levels. The crossing was originally constructed before the Redwood Creek flood control levees and original documentation from CalTrans refers to it as the "Redwood Creek Overflow." It was likely sized to drain overbank flows from Redwood Creek rather than for Strawberry Creek.

Transfer Station Culvert

The Transfer Station culvert conveys approximately the 10-year flow before overtopping the roadway. The upstream and downstream invert elevations of the culvert are approximately two feet higher than the adjacent stream bed. The high invert elevation creates a backwater effect that extends upstream past the Highway 101 culvert during baseflow conditions (Figure 3.4). If the channel high points between the Transfer Station and the Hiltons Road culverts were removed the backwater effect would extend upstream of the Hiltons Road culvert.

Model results show that the backwater effect from the Transfer Station culvert causes out-of-bank flow in Reach G at the 2-year flow. Replacement of the Transfer Station culvert with a channel-spanning structure and lowering the channel invert at the crossing would reduce the frequency of out-of-bank flow in Reach G to approximately the 5-year flow.

Zuber Ranch Road Culvert

The Zuber Ranch road culvert creates a channel backwater during frequently occurring flows. The crossing conveys approximately the 2-year flow before overtopping the road surface. The backwater effect at the 1.2-year flow extends to within 150 feet of the Transfer Station culvert, where there is a distinct depositional area within the channel. This backwater effect slows water velocities and inhibits transport of sediment, possibly leading to the deposition. During larger storm events Redwood Creek has also been observed to backwater through the Zuber Ranch Road culvert, likely contributing to upstream deposition (Pers. Comm. M. Farro, 2008).

3.3 Fish Passage Assessment

Fish passage assessment modeling was performed using FishXing version 3.0. FishXing models the complexities of culvert hydraulics and fish performance for a variety of species and crossing configurations.

3.3.1 Defining Fish Passage Design Flows

Determination of standard fish passage design flows was necessary to assess fish passage at the culvert road crossings within the Strawberry Creek project area. Both the National Marine Fisheries Service (NOAA Fisheries) and the California Department of Fish and Game (CDFG) have design guidelines for fish passage at road-stream crossings (CDFG, 2002; NOAA Fisheries, 2001). The guidelines contain recommended fish passage design flows for juvenile salmonids, resident trout, and adult anadromous steelhead trout. Analyzing fish passage conditions requires defining a range of flows for which passage should be provided. Generally, passage is not required at extremely low or high flows, when fish are not expected to be moving. The lower and upper passage flows are defined in terms of exceedance flows or as a percent of the 2-year flow (Table 3.4).

Table 3.4 - Fish passage design flow criteria defined by NOAA Fisheries (2001) and CDFG (2002).

Species and Lifestage	Lower Passage Flow	Upper Passage Flow
Adult Anadromous Salmonids	50% exceedance flow or 3 cfs	1% exceedance flow or 50% of 2-Year Flow
Adult Resident Trout	90% exceedance flow or 2 cfs	5% exceedance flow or 30% of 2-Year Flow
Juvenile Salmonids	95% exceedance flow or 1 cfs	10% exceedance flow or 10% of 2-Year Flow

There are no USGS gages measuring stream flow on Strawberry Creek, therefore no flow exceedance data are available. However, 2-year peak flows estimated for the project area (Section 3.1.1) were used to estimate the high passage design flows for adult salmon and steelhead, adult rainbow and cutthroat trout, and juvenile salmonids. Low passage design flows of 3 cfs, 2 cfs and 1 cfs were used for adult salmon and steelhead, adult rainbow and cutthroat trout, and juvenile salmonids, respectively. Section 0 presents the Upper Fish Passage flows and resultant fish passage analyses.

3.3.2 Fish Passage Assessment Criteria

The CDFG fish passage assessment protocol prescribes minimum required water depths and maximum swimming and leaping speeds for assessing passage conditions (Table 3.5). Swimming speeds are divided into two categories: prolonged speeds, which can be maintained for long periods of time, and burst speeds, which are equivalent to sprinting and can only be maintained for a few seconds. Leap speed is the speed a fish can jump out of a pool as it attempts to enter a perched culvert outlet. To meet fish passage criteria during low to high passage design flows (1) the fish must be able leap or swim into the culvert, (2) water depths must be adequate throughout the culvert, and (3) the fish must be able to swim through the entire culvert without becoming exhausted by the water velocities.

Table 3.5 - CDFG prescribed water depth and swimming criteria for assessing fish passage at stream crossings using the FishXing software.

Fish Species, and Lifestage	Minimum Water Depth	Prolonged Swimming		Burst Swimming		Maximum Leap Speed
		Maximum Swim Speed	Time to Exhaustion	Maximum Swim Speed	Time to Exhaustion	
Adult Salmon and Steelhead	0.8 ft	6.0 ft/sec	30 min	10.0 ft/sec	5.0 sec	15.0 ft/sec
Adult Rainbow/ Cutthroat Trout	0.5 ft	4.0 ft/sec	30 min	5.0 ft/sec	5.0 sec	6.0 ft/sec
Juvenile Salmonids	0.3 ft	1.5 ft/sec	30 min	3.0 ft/sec	5.0 sec	4.0 ft/sec

The swim speeds and minimum water depths prescribed by CDFG are relatively conservative, and meant to represent the needs and abilities of the weaker swimming individual fish. Many individual fish are able to swim faster and swim through shallower flows than indicated in Table 3.5. Therefore, it is not uncommon for some fish to pass through stream crossings that fail to meet these passage criteria.

3.3.3 Fish Passage Modeling

The fish passage analysis was performed using FishXing version 3.0. FishXing models the complexities of culvert hydraulics and fish performance for a variety of species and crossing configurations. FishXing input included surveyed channel cross sections, surveyed culvert dimensions and elevations, channel slope, and an estimate of hydraulic roughness.

3.3.4 Fish Passage Assessment Results

Table 3.6 presents the results from the fish passage analysis of the Hiltons Road culvert, Transfer Station culvert, and Zuber Ranch culvert. The Highway 101 culvert was not analyzed because it is considered fully passable because it is wider than the channel and fully backwatered by the downstream channel. The SOC culvert is considered a barrier because the outlet is nearly completely buried. The West Tributary culvert was not analyzed.

Table 3.6 - Results from the fish passage analysis of three culverts on Lower Strawberry Creek. Analysis used Fish Xing 3.0 to identify passage limitations during fish passage design flows. Limitations include insufficient depth or excessive velocity in the culvert and excessive leap height at the culvert outlet.

Crossing	Fish Species and Lifestage	Fish Passage Design Flows (cfs)	Passable Flows (cfs)	Percent of Design Flows Passable	Type of Barrier
Hiltons Road Culvert	Adult Salmon and Steelhead	3 - 77.5	3 - 77.5	100	-
	Adult Rainbow/ Cutthroat Trout	2 - 46.5	2 - 46.5	100	-
	Juvenile Salmonids	1 - 15.5	1-15.5	100	-
Transfer Station Culvert	Adult Salmon and Steelhead	3 - 77.5	45.9 - 77.5	42	Depth
	Adult Rainbow/ Cutthroat Trout	2 - 46.5	NONE	0	Depth, Velocity and Leap
	Juvenile Salmonids	1 - 15.5	NONE	0	Depth, Velocity and Leap
Zuber Ranch Culvert	Adult Salmon and Steelhead	3 - 87.5	7.4 - 87.5	95	Depth and Velocity
	Adult Rainbow/ Cutthroat Trout	2 - 52.5	3.5 - 52.5	97	Depth and Velocity
	Juvenile Salmonids	1 - 17.5	1.7 - 11.6	60	Depth and Velocity

SOC Culvert

The culvert outlet is nearly completely buried, creating a velocity barrier for smaller fish and making it impossible for an adult salmon or steelhead to enter the culvert due to their size.

Hiltons Road Culvert

The Hiltons Road culvert is passable for all species across the range of fish passage flows.

Highway 101 Culvert

The Highway 101 culvert was not assessed for fish passage because it is adequately sized and the culvert invert is significantly lower than tailwater channel elevations.

Transfer Station Culvert

The Transfer Station Culvert is only passable for adult salmon and steelhead during 42% of the design flows due to insufficient water depth within the culvert. The lack of depth and excessive velocities, combined with a small outlet drop categorizes this culvert as a complete barrier for adult resident trout and juvenile salmonids.

A beaver dam downstream of the Transfer Station culvert was observed during the fall of 2007. The dam raised downstream water levels enough to backwater the culvert, which eliminated the outlet drop and provided sufficient water depth for fish passage. However, another beaver dam, approximately 1.5 feet high, was built across the culvert inlet. This dam was likely a complete barrier to all fish.

Zuber Ranch Culvert

The Zuber Ranch crossing is passable for adult anadromous and resident salmonids, but only provides suitable passage conditions for juvenile salmonids during the lower 60% of design flows, primarily due to excessive velocities. The larger of the two pipes acts as a velocity barrier at higher flows, but fish, except for juveniles, can pass through the smaller pipe.

3.3.5 Reed Canary Grass as a Fish Blockage

RCG grows densely throughout the active channel of Strawberry Creek and forms a floating mat across the channel within the RNSP. This undoubtedly hinders fish passage at low and moderate flows. Additionally, the low levels of dissolved oxygen resulting from the presence of dense mats of the grass in the channel, combined with nutrient inputs from cattle also create a water quality condition that prevents fish from rearing in, or migrating through, Lower Strawberry Creek during summer and fall.

3.4 Summary of Findings

Site observations and hydraulic analyses identified numerous factors that limit habitat and stream function in Lower Strawberry Creek within the project Area (Figure 3.7). In general, the issues at Lower Strawberry Creek can be classified into two major categories: Vegetation Issues and Physical Issues.

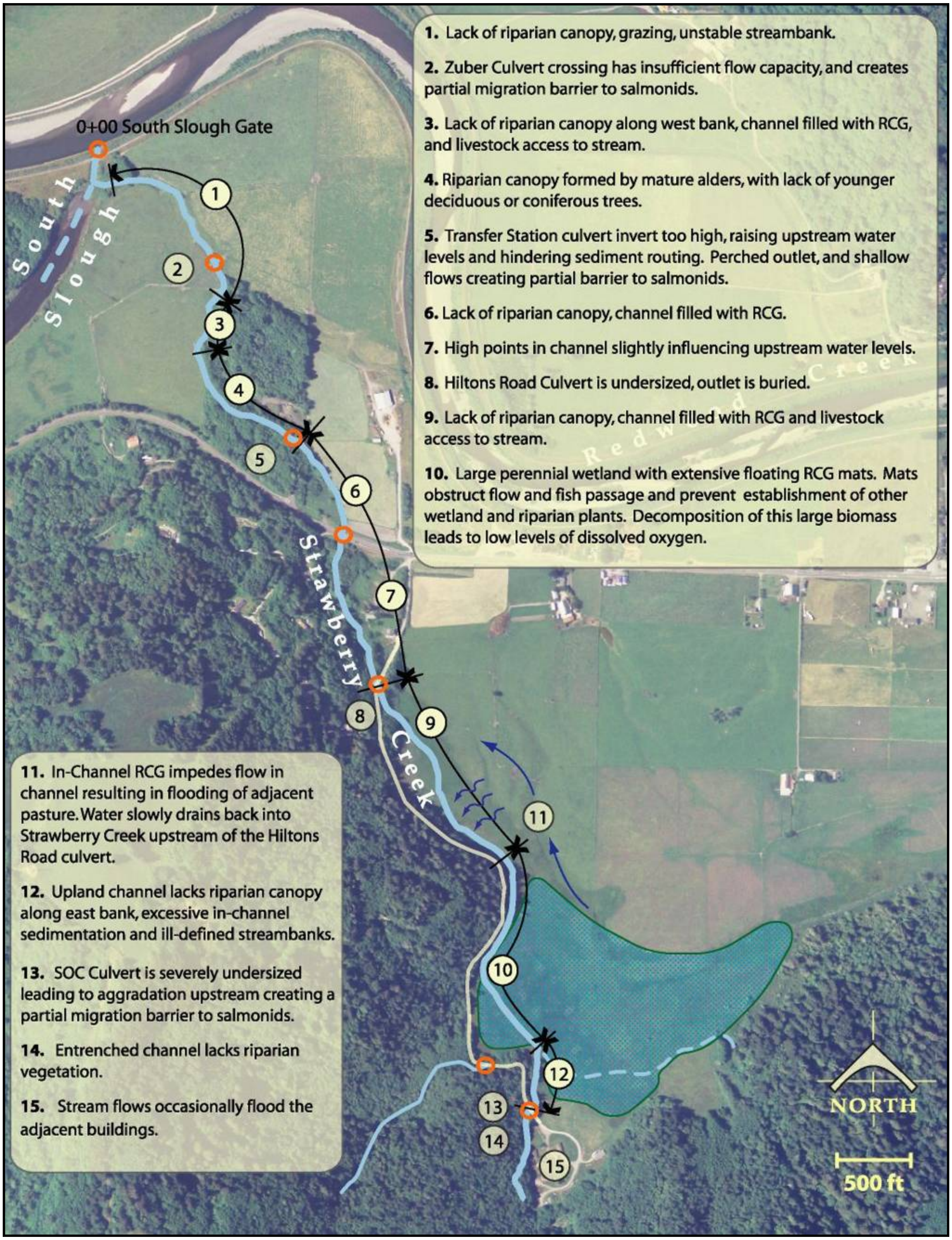


Figure 3.7 - Summary of issues impacting water quality and fisheries habitat on Strawberry Creek.

3.4.1 Physical Site Issues

The channel, floodplain and wetland morphology have been dramatically altered as a result of past land use practices. Flow conveyance and sediment transport within the channel downstream of RNSP is reduced due to high points in the channel, including the culvert invert at the Transfer Station. Additionally, the Hiltons Road, Transfer Station, Zuber Ranch Road and SOC culverts are undersized and cause backwater effects that raise upstream water levels and lead to sedimentation during frequently occurring storm flows.

The Old SOC is located on an alluvial fan formed by the SOC Tributary. The tributary has been moved and levied, but continues to aggrade and overtop the levee. If left in its current state the channel will likely avulse; a tendency of deltaic channels.

3.4.2 Vegetation Issues

The conversion of the Sitka spruce covered floodplain and complex wetlands to pasture allowed invasive reed canary grass to colonize much of the stream channel, riparian areas and wetlands. Reed canary grass prohibits riparian growth, chokes the stream channel, provides poor to non-existent habitat for fish and other native aquatic wildlife, inhibits the mobility of fish at lower flows, increases sedimentation, and contributes to low levels of dissolved oxygen. It also reduces flow conveyance and causes overbank flooding during winter and spring baseflow conditions.

Removal of the riparian vegetation in the upland areas of the SOC Tributary has allowed invasive Himalaya berry to become established along the stream banks, preventing riparian vegetation from growing.

4 Recommendations

Site observations and hydraulic analyses have identified numerous issues along the Strawberry Creek project area that degrade aquatic habitat and stream function. In general, the two major issues at Strawberry Creek can be addressed as follows:

1. **Vegetative Improvements**
    a. Reed Canary Grass Management
    b. Riparian/Streambank Stabilization Planting
2. **Physical Site Improvements**
    a. Stream Channel Improvements
    b. Culvert Upgrades
    c. Permanent Cattle Exclusion Fencing

Removal of RCG and re-establishment of a native riparian area will result in numerous improvements to the project area. Removing the RCG from the active stream channel will lower water levels and improve flow and sediment conveyance within the channel. Removing the floating RCG mat from the stream and wetlands, combined with cattle exclusion, will improve water quality and aquatic habitat.

Establishment of a self maintaining native riparian area will shade out encroaching RCG, keeping it from re-growing in the stream channel and on the adjacent riparian area. Maintaining a channel free of RCG will also provide an unobstructed channel for migrating fish. The native riparian area will provide both terrestrial and aquatic habitat, providing cover and better food sources. The riparian area will also shade the channel and maintain a lower water temperature.

Minor channel grading and bank stabilization, combined with replacement of poorly sized culverts, will further reduce water levels and improve flow conveyance, sediment transport, and fish passage. Land use improvements, such as cattle exclusion fencing will reduce nutrient inputs and improve water quality. Permanent cattle exclusion will also limit impacts to the streambank and allow establishment of native riparian vegetation.

Over the long-term, the biologically rich and productive wetland habitat that once existed in Lower Strawberry Creek largely on the present-day RNSP lands may be re-established. This type of wetland habitat, once plentiful in the Lower Redwood Creek basin, could provide extremely productive rearing habitat for coho salmon, and other salmonids.

The following sections present a general RCG Management Plan and Reforestation Plan that can be implemented across the project area. Recommendations for Reach specific RCG Management and Physical Site Condition improvements are then presented.

4.1 Reed Canary Grass Management and Revegetation Plan

The Enhancement Planting Plan for Management of Reed Canary Grass prepared by Gedik BioLogical as part of this project (Appendix A) recommends three distinctive planting schemes to control RCG and establish native riparian vegetation within the project area. In this report they are referred to as the (1) *Streambank Area Planting Scheme*, (2) *Flat Area Planting Scheme*, and (3) *Ponded Area Planting Scheme*. The appropriate scheme for a location is dependent on its proximity to the stream channel and depth and duration of inundation it is expected to experience.

All of the recommended treatments rely on shading to control RCG within the stream channel, adjacent streambanks, along the floodplain and within the perennial wetlands of Lower Strawberry Creek. To maximize shading effects, the treatments use trees and shrubs combined with occasional herbaceous material to fill gaps and provide seasonal low canopy. According to Maurer et al. (2003), a complex canopy structure of herbaceous plants, shrubs, and trees of varying heights will limit RCG access to light, which compromises its ability to reestablish. In addition, a high variation in microtopography within the planting area will further facilitate the establishment of species-rich native vegetation. This dense multi-layer canopy must be established relatively quickly to avoid reed canary grass recolonizing and outcompeting the new plantings. This requires more intensive ground cover than standard planting and mulching methods, and a dense planting with live-plants from pots rather than seed.

The actual species used in each planting scheme and for each reach will depend on the amount of inundation experienced in that reach. Actual inundation elevations and plant species will need to be determined after removal of the channel high points and in-channel RCG. Table 4.1 presents a list of the dominant tree, shrub and herbaceous species recommended for the Strawberry Creek project area. Though native to the Pacific Northwest, these species are not necessarily a dominant species in the Strawberry Creek watershed, but were chosen because of their effectiveness to form a diverse structured canopy that will successfully shade out RCG (Personal Communication, T. Gedik, 2008). Table 4.1 also identifies species that tolerate wetter conditions, which exist in some of the planting areas. The recommended native species for planting include coniferous trees that grow rapidly and create dense shade year-round, combined with native deciduous and evergreen shrubs that provide forage, are characterized by rapid growth, and often form thickets that create dense shade year-round. See Appendix A for a full list of recommended plant species associated with each planting scheme.

4.1.1 Streambank Area Planting Scheme

The *Streambank Area Planting Scheme* was developed to create areas of dense shade on both sides of the stream to greatly limit growth of RCG in the channel and on the banks. The treatments incorporated into this scheme are also designed to withstand frequent inundation from storm events. It uses a cardboard and burlap ground cover and an overall plant spacing of approximately 3 feet (Figure 4.1). Antieau (1998, 2000) has suggested planting conifers in dense, wide blocks in both wetland and adjoining vegetation buffers to minimize side-lighting that would enable colonization of reed canary grass. It is also critical that RCG material present in the channel be removed to prevent encroachment into the newly planted areas.

Table 4.1 - Recommended tree, shrub and herbaceous species that are expected to be the most effective in combination to form a structured canopy that will successfully shade out RCG.

Plant Form	Common Name	Latin Name
CONIFERS	Sitka Spruce*	*Picea sitchensis*
	Coast Redwood	*Sequoia sempervirens*
	Western Red Cedar*	*Thuja plicata*
HARDWOODS	Red Alder*	*Alnus rubra*
	California Bay Laurel	*Umbellularia californica*
SHRUBS AND/OR SMALL TREES	Labrador Tea*	*Ledum glandulosum*
	Wax Myrtle	*Myrica californica*
	Thimbleberry*	*Rubus parviflorus*
	Salmonberry*	*Rubus spectabilis*
	Douglas' Spirea*	*Spirea douglasii*
HERBACEOUS SPECIES	Wild Ginger	*Asarum caudatum*
	Slough Sedge*	*Carex obnupta*
	Tufted Hairgrass*	*Deschampsia cespitosa*
	Skunk Cabbage*	*Lysichiton americanum*
	Sword Fern	*Polystichum munitum*

* Species tolerate wetter soils

To plant streambank areas, reed canary grass should first be mowed/ weed-whacked to the ground surface where feasible, then covered with staked corrugated cardboard and burlap bags (pers. comm. M. Knox, 2007). This combination serves to suppress RCG growth by limiting light while allowing water to penetrate the cardboard and burlap. Because this planting method will hold materials in place, it is well suited for areas that will be frequently inundated. While both materials will biodegrade over time, burlap extends the life of the cardboard covering long enough for planted native species to become established. Species should be planted in small holes cut into both materials, and materials should be staked-down using a combination of live willow stakes and hardwood stakes. At lower elevations along the streambanks coir wattles may be staked in place and planted with live plants into the coir.

Figure 4.1 - Dense planting along streambanks using cardboard and burlap bags held in-place with 12 inch long hardwood stakes. Photos courtesy City of Kent, WA.

Species proposed for streambank areas include a mix of wetland plants suitable for inundated and saturated conditions, but that can also tolerate drier conditions.

Streambank plantings in the project area pose a challenge due to topographic variation, hydrologic uncertainty, and the potential need for equipment access to conduct maintenance on the channel during the first few years following planting. Streambank planting should extend from the winter baseflow elevation to outside the limits of persistent inundation. The width of the streambank planting can vary, but a minimum width of 20 feet is recommended to establish a canopy that can maximize shading of the stream channel.

4.1.2 Flat Area Planting Scheme

The *Flat Area Planting Scheme* is targeted for the low elevation bottomlands in Strawberry Creek that have minimal relief and receive seasonal saturation and some inundation. This planting treatment is recommended for lands adjacent to the streambank planted areas, and is intended to provide a sufficiently wide vegetation buffer to prevent RCG from recolonizing the restored areas (Figure 4.2). Optimally, a dense planting, such as the *Streambank Area Planting Scheme*, would be used in these areas to shade-out the RCG. However, the size of the project area and limited funding availability requires an alternative approach.

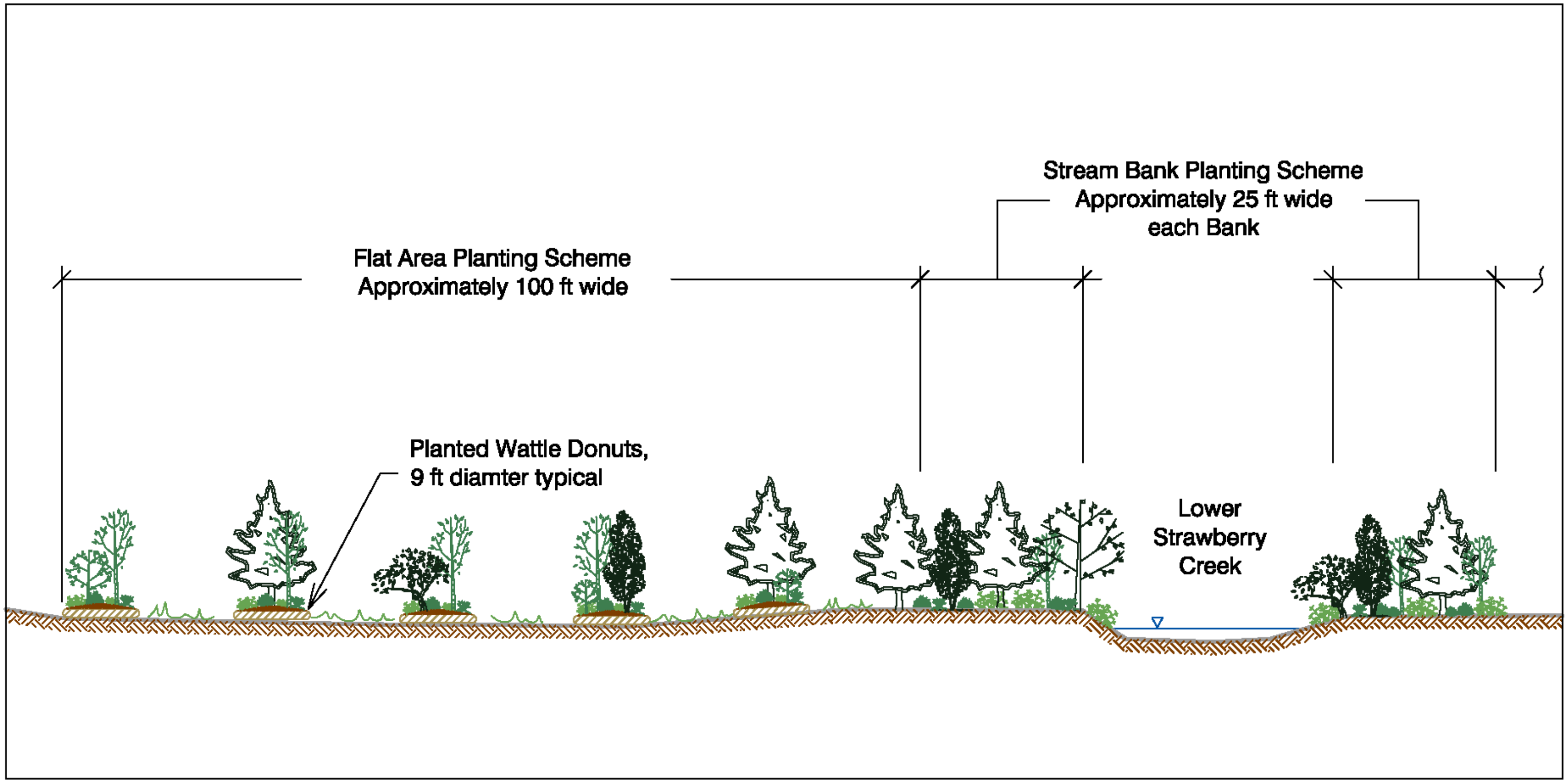


Figure 4.2 – Typical revegetated cross section demonstrating use of the Streambank and Flat Area Planting Schemes to create a dense multilayered canopy to shade-out reed canary grass.

Figure 4.3 - Dense planting in wattle "donuts" placed on chipboard and filled with nutrient-rich well-draining soils.

The *Flat Area Planting Scheme* creates localized areas of dense shade using small densely planted islands of native plantings with overall plant spacing of approximately 2 feet. Over time, these islands will shade out adjacent areas of RCG and allow re-colonization by native species. Elimination of RCG from areas planted with this method is expected to take longer than if a denser planting scheme were used, but initial planting costs will be substantially less. It is recommended that the *Flat Area Planting Scheme* have a minimum length and width of 100 to 150 feet to maximize shading effects and prevent RCG from reaching the streambanks and channel.

This scheme uses planted islands formed by 25-foot long, 12-inch diameter coir wattles wrapped into a donut-shape circle and filled with a compost-sand-topsoil mix. The wattle donuts are placed on chipboard and staked (Figure 4.3 and Figure 4.4). Prior to installing the wattle donuts, the area is mowed or weed-whacked. Wattle donut should be spaced a maximum of 20 feet, on-center.

This treatment has proven successful in Northwest Washington, which has a similar climate (pers. comm. M. Knox, 2007). It denies RCG access to light which suppress growth, while giving native species a jump-start from nutrient-rich, well-draining soil that facilitates root establishment. The 12-inch tall wattles help prevent loss of planting material during periods of shallow-water inundation. This makes them suitable for use in areas that are expected to be inundated with less than 6 to 8 inches of water.

Figure 4.4 - Planting in a RCG infested field in January 2004 (a) utilizing both wattle donuts and cardboard and burlap covering. Subsequent photo monitoring (b) in April 2007 shows a dense riparian area becoming established. Photos courtesy City of Kent, WA.

Flat Area Planting Scheme Width and Available Grazing Land

It is recognized the land adjacent to the stream channel is valuable pasture to the landowner, and limiting the *Flat Area Planting Scheme* width will likely be desirable to the landowner. However, the *Flat Area Planting Scheme* is necessary to provide a buffer to the *Streambank Area Planting Scheme* so that sufficient shade is provided to prevent RCG growth in and adjacent to the stream channel. Keeping the stream channel clear of RCG will then reduce the frequency and depth of inundation of adjacent pasture areas, allowing grazing in areas currently not available earlier in the season.

Preferably, the *Flat Area planting Scheme* should be installed at the recommended width along the entire length of *Streambank Planting Area*. However, to minimize loss of pasture land, project implementers can work with each landowner to adjust the width of the *Flat Area Planting Scheme* based on site conditions.

Cattle exclusion fencing should be placed along the outside perimeter of the Flat Area plantings. However, it is recognized that fencing-out a 100 to 150-foot width of previously available pasture may not be acceptable. Though possibly more costly and higher maintenance, it may be feasible to identify innovative methods of fencing to allow grazing access between individual or clusters of planted islands, but still protect the vegetation in the islands. Grazing along the fence lines will likely help control RCG growth around the edges of the islands, speeding the riparian recovery.

Additionally, an important benefit derived from Adaptive Management (Section 4.1.7) will include determining the optimal widths of effective *Streambank and Flat Area Planting Schemes*. A specific goal of Adaptive Management will be to identify minimum planting widths to reduce the loss of quality pasture while ensuring that the treatments are successful.

4.1.3 Ponded Area Planting Scheme

The *Ponded Area Planting Scheme* was developed to treat areas within Reach C that are semi-permanently inundated and currently contain floating mats of RCG. The perennial inundation of this area and lack of stable ground pose challenges for removing reed canary grass because heavy equipment cannot stage in areas beyond the stable road surface and levees. Difficulty and costs of construction access, the large area of floating mat, and limited project funding will likely not allow this area to be densely planted.

The *Ponded Area Planting Scheme,* similar to the *Flat Area Planting Scheme*, is aimed at creating localized areas of shade formed by native plant species. Over time, these areas will shade out adjacent areas of RCG and allow re-colonization by native species. Elimination of RCG from areas planted with this method is expected to take longer than if a denser planting scheme were used, but initial planting costs will be dramatically less.

One proposed treatment method for the inundated floating mat areas includes auguring holes in logs or rootwads, filling them with soil and planting species that are adapted to wet conditions, such as Sitka spruce and western red cedar (pers. comm. T. Taylor 2005, in Gedik 2006; Beach 2001). The logs or rootwads raise the plants above the inundation level, preventing waterlogging of newly establishing roots. It may prove feasible to lower logs into the ponded site by heavy equipment working from drier ground, or even by helicopter. Use of techniques to deter grazing by elk should be considered in this treatment area.

In addition to use of downed logs as planting mediums, woven mats of dormant live willow branches ("willow mattress") or floating wetland mats may be used to create a living plant base that can adapt to fluctuating water levels. Wattle mats can be staked in place using 2 to 4-foot long willow branches staked vertically. While willow is not the best species for shading reed canary grass due to its deciduous nature and slower leaf-out time, it is ideal for its ease of planting and rapid establishment.

4.1.4 Upland Riparian Planting

Several reaches within the project area are relatively free of RCG and more suitable for using standard riparian planting techniques. In these areas the recommended planting densities of 14-foot plant spacing are much lower than in reaches with RCG and frequent inundation. Additionally, ground covering treatments and planting of understory species may not be necessary. As a result, unit planting costs are far less in areas that upland riparian planting is recommended.

4.1.5 Use of Redwood Mulch or Wood Chip

While use of redwood mulch or wood chips may be a more cost effective alternative to suppress RCG growth, they may ultimately be detrimental to new plantings due to a combination of high natural acidity and tannins from the redwood material and reduced availability of nitrogen for new plantings, which is taken from the soil to facilitate decomposition of the wood chip. Wood chip or redwood mulch also has a tendency to be washed away. Furthermore, wood chips may retain too much moisture and minimize drainage at a site already prone to water retention. If wood chips must be used to minimize cost, it is recommended that they be used in upland planting areas and in combination with a compost and sand mixture, using additional fertilizer to replace the nitrogen that is depleted in the mulch decomposition process.

4.1.6 Long Term Issues

Browsing

Consideration should be given to the risk of herbivory at the site, particularly with regards to potential damage caused by deer and elk. It may prove necessary to temporarily fence-off or place exclosures around planted areas until plants become established enough to withstand grazing (approximately 1 to 2 years). Because fencing is merely temporary and serves to exclude grazers, long-term fence maintenance should not be an issue. Planting larger, older plants may serve as a more cost-effective solution in some areas, and would provide the added benefit of more rapid shading of reed canary grass. This may primarily be an issue for the RNSP reaches of Strawberry Creek because there is already an elk exclusion fence between the Park's land and Barlow property.

Maintenance

Planted areas will undoubtedly require maintenance until plants are well established. Maintenance may include, but is not limited to, removal of RCG, additional mulching, replanting unsuccessful areas, maintenance of temporary elk exclusion fencing, and weed removal. A concerted effort will be necessary in the first few years to remove reed canary grass re-sprouts from areas that have been treated and replanted. Figure 4.5 presents the number of hours per year necessary to successfully eradicate RCG from a 30-acre demonstration project. Maintenance requirements are high within the first few years, then decrease over time as native plant density and size increases. Therefore, it is critical to provide sufficient funding for maintenance of the project area to ensure project success.

It should be emphasized that even when accompanied by native species planting, clearing efforts may not result in long term native species establishment. Cleared areas should be immediately replanted with native revegetation, or the effort of clearing will be lost. (Reinhardt and Galatowitsch 2004). To adequately gage control efforts and scale, pilot tests on smaller plots of land (1 to 10 acres) are recommended prior to any large scale treatment efforts.

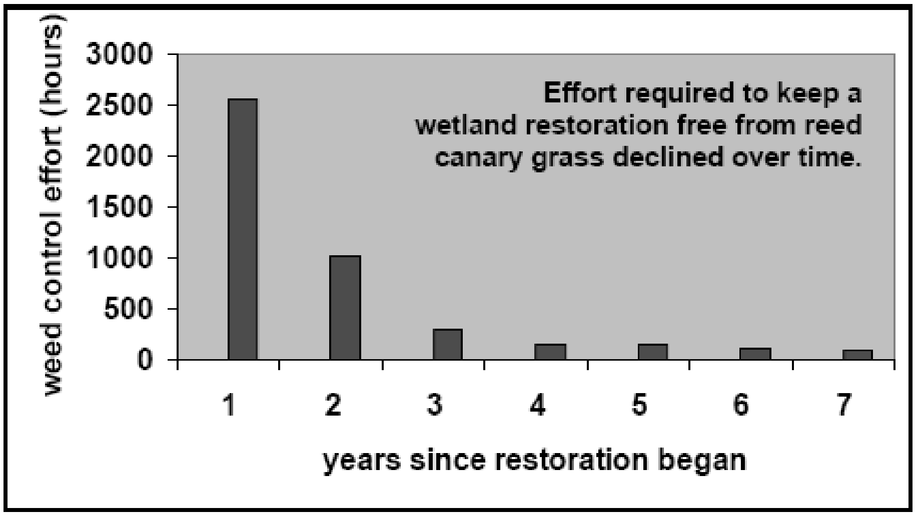


Figure 4.5 - Long-Term Efforts are Necessary to Effectively Control Reed Canary Grass in a 30-acre wetland. From Spring Peeper Meadow Wetland Restoration Demonstration at University of Minnesota Landscape Arboretum, in Reinhardt and Galatowitsch 2004.

Access Points for Channel Maintenance

Providing access points alongside the streambank for maintenance equipment presents an additional challenge. Periodic removal of reed canary grass from the channel during the first several years following planting may be required. If RCG re-grows within the channel before vegetation becomes established, it will once again choke the channel and raise water levels. This will further saturate and inundate the streambanks, making it difficult for the streambank planting to become established and create adequate shade. Therefore, access points for heavy equipment used to clear RCG from the channel should be considered.

Access points should be planted with low-growing species such as soft rush (*Juncus effusus*-FACW+) and slough sedge (*Carex obnupta*-OBL), which is more likely to withstand the stresses of soil compaction and equipment traffic. Because heavy equipment use will compact soils, use of construction mats and selection of equipment that minimizes pressure and impacts on the ground surface are recommended. Access points will limit the ability to use multilayered vegetation communities and in turn reduce site shading opportunities; therefore, the size of equipment access area should be minimized. Lastly, access points should be staggered along streambank sites such that some shading of a creek segment can occur from plantings on the opposite bank.

4.1.7 Adaptive Vegetation Management

Due to the scale of the project and funding constraints, the Strawberry Creek project will likely be implemented over multiple years. A staged implementation will allow adaptive management of the restoration methods using lessons learned from previously restored areas. Planting area width, planting densities, plant size and species will likely change as the project progresses and lessons are learned from the performance of planting areas in other reaches. Short pilot reaches can be planted to identify the most successful species and configuration of each planting scheme. Adaptive management will be a key tool to identify minimum planting widths to reduce the loss of pasture while ensuring that the treatments are successful at eliminating RCG growth in and adjacent to the stream channel.

The methods recommended in this report to address vegetation control in RCG infested wetlands were derived from experiences in similar climate areas of Washington and Oregon (Gedik, 2008), but have not been applied within coastal Northern California and require additional development. It is recommended that various methods and species selection be tested in small areas, and the more successful methods be used for more extensive areas.

Most critical for project success is keeping RCG from encroaching into the stream channel, which would raise baseflow water levels and cause detrimental flooding of new plantings. Therefore, the recommended planting schemes should be implemented immediately after RCG excavation from the stream channel.

If the project area is limited by funding, shorter reaches of stream can be restored using the proposed planting schemes. Careful attention must be paid to maintain the full planting width, plant density, and plant sizing. Restoring a longer reach of stream using a narrower planting width, looser plant spacing, or smaller plants may result in less effective shade generation, and a less effective RCG eradication from the project area.

4.2 Recommendations by Reach

This section presents detailed recommendations for physical and vegetative site improvements for each reach in the Strawberry Creek project area. Table 4.2 presents a summary of recommendations by reach. Table 4.2 does not indicate temporary grazing exclusion fencing or maintenance activities necessary to maintain a restored site. See Section 4.1.6 for a discussion of herbivory control and site maintenance issues.

The magnitude of this project is such that implementation of all recommendations concurrently will likely be infeasible. Generally, it is recommended that the restoration of Strawberry Creek progress from downstream to upstream. The success of the Strawberry Creek restoration project is dependent on planting species and methods sensitive to inundation, which is influenced by conditions within the downstream channel.

4.2.1 Redwood National and State Park Property (Reaches A-C)

The recommended restoration approach for Reaches A through C on the lands managed by RNSP involve creating a more geomorphically stable channel that remains free of RCG and provides fish passage and habitat. Due to funding and staffing limitations within RNSP, the scale of the proposed restoration on the RNSP property is limited to the lower section of Reach A, Reach B, Reach C and the lower-most section of the West Tributary. It does not address the removal of RCG and restoration of the East Tributary or restoration of the extensive (approximately 25 acres) of RCG infested perennial wetland that exists across the valley bottom. It is anticipated that following restoration of Reaches A-C, RNSP will begin developing restoration plans for the East Tributary and untreated wetland areas.

Physical Site Restoration recommendations include:

1. Realignment of the SOC Tributary combined with modifications to the channel profile to stabilize the stream channel, improve channel capacity and sediment transport, and allow for a larger culvert to be installed under the SOC Access Road

2. Construction of a new channel with a gradually decreasing slope that eliminates the existing slope discontinuity near the SOC culvert and moves the depositional reach downstream, closer to the valley bottom

3. Replacement of the SOC Tributary and West Tributary culverts with stream simulation culverts sized for the 100-year flow

4. Relocation of the channel in Reach C to provide improved site conditions suitable for establishing a wide riparian buffer

Table 4.3 lists the proposed length of realigned channel by reach and the anticipated volume of excavation.

Table 4.2 - Summary by Reach of proposed improvements for Strawberry Creek. This table does not indicate temporary maintenance measures necessary to sustain a restored site.

Project Reach	Vegetative Improvements	Physical Improvements		
		Stream Channel Improvements	Culvert Upgrades	Land Management Strategy
A. SOC Tributary	Upland Riparian Planting	1. Stabilize Incising Channel 2. Realign Channel to Improve Sediment Routing 3. Install Large Wood and Rock Features to Control Chanel Profile and Provide Habitat	Replace SOC Culvert to Improve Sediment Routing, Flood Capacity and Fish Passage	-
B. Alluvial Fan	Streambank and Flat Area Planting		Replace West Tributary Culvert to Improve Sediment Routing, Flood Capacity and Fish Passage	-
C. Floating Mat	Streambank, Flat Area and Ponded Planting		-	-
D. Barlow Ponded Area	Flat Area and Streambank Planting	-	-	Cattle Exclusion Fencing
E. Barlow Pasture	Streambank and Flat Area Planting	-	Replace Hiltons Road Culvert to Improve Flow Conveyance and Lower Upstream Water Levels	Cattle Exclusion Fencing
F. Cook Property	Streambank and Flat Area Planting	1. Remove High Points in Channel 2. Installation of Large Wood Habitat Structures	-	Cattle Exclusion Fencing
G. Upper Zuber Parcel	Streambank and Flat Area Planting	1. Remove High Points in Channel 2. Installation of Large Wood Habitat Structures	-	Cattle Exclusion Fencing
H. Transfer Station	Streambank and Upland Riparian Planting, and Supplemental Riparian Planting	Remove High Points in Channel	Replace Transfer Station Culvert to Improve Flow Conveyance and Fish Passage, and Lower Upstream Water Levels	Cattle Exclusion Fencing
I. Lower Zuber Parcel	Upland Riparian Planting	-	Replace Zuber Culvert to Improve Flood Capacity	Cattle Exclusion Fencing

Table 4.3 – Realigned channel length and estimated excavation volume by reach in RNSP.

Reach	Realigned Channel Length	Channel Excavation
A	285 feet	430 cubic yards
B	390 feet	710 cubic yards
C	825 feet	4,220 cubic yards

Dense vegetation adjacent to the stream channel, the extensive floating RCG mat that masks the underlying topography, and the persistent standing water in Reach C currently make it difficult to finalize all recommendations for Reach C. Downstream restoration efforts will likely lower the high seasonal baseflow in this reach and reduce the area of floating mat, but the actual extents, elevation, and timing of inundation should be assessed after downstream restoration. Additional topographic survey is needed to develop final engineering designs for the SOC Tributary and West Tributary crossings and realigned stream channel reaches.

Recommended Vegetative Restoration includes:

1. Upland riparian planting along Reaches A and B
2. Reed canary grass removal
3. Revegetation schemes in Reach C to create a native riparian area and prevent recolonization of the channel by reed canary grass

Table 4.4 lists the proposed channel length and area of planting for each of the reaches. RNSP has indicated they may choose to use less intensive, less low canopy planting treatments than recommended due to budget constraints (Personal Communication, L. Arguello, 2008). As described in the revegetation report (Appendix A) and in Gedik (2006), using standard revegetation techniques in areas infested with RCG have often proven ineffective. If RNSP chooses to use less aggressive revegetation techniques, we suggest using pilot planting plots combined with monitoring to determine the most effective method of treatment for different locations.

Table 4.4 – Proposed planting areas and length of treated channel in RNSP Reaches.

Reach	Revegetated Channel Length	Streambank Planting	Flat Area Planting	Ponded Area Planting	Upland Riparian Planting
A	280 feet	-	-	-	0.30 acres
B	400 feet	0.26 acres	0.41 acres	0.16 acres	0.28 acres
C	880 feet	0.95 acres	1.55 acres	0.73 acres	-

Reaches A and B

Physical Site Restoration

As part of the proposed Strawberry Creek restoration project on RNSP properties, the channel is realigned throughout Reach B and C and the lower portion of Reach A (Figure 4.6). Currently the channel in Reach A and B is ditched and levied and follows the toe of the hillslope. Realignment would move the stream away from the toe of the adjacent hillslope and towards the low point on the alluvial fan. It also provides suitable flat overbank areas along both sides of the stream for planting riparian vegetation.

The proposed profile of the realigned channel gradually transitions the stream from the steeply sloping wood-forced step-pool morphology of the SOC Tributary to a gently sloping channel on the valley bottom (Figure 4.7). The proposed channel slope within Reach A decreases from 4.0% to 3.5% and would be constructed with a wood and boulder step-pool morphology. Downstream of the SOC Access Road, Reach B transitions from a 2.5% slope to a slope of 1.0%. The intent of the design is to maintain a steep sloped stream through the upper portions of the existing alluvial fan and through the SOC culvert, moving the depositional reach further downstream. The gradual slope transition in the channel profile eliminates the abrupt discontinuity in sediment transport that presently occurs at the SOC culvert. The improved sediment transport conditions should maintain an open stream channel for fish passage and minimize channel avulsions.

The proposed channel profile lowers the channel by more than 2 feet at the SOC Access Road crossing, allowing for a larger culvert to be installed at a steeper slope to improve sediment routing and culvert capacity. The proposed SOC culvert, designed using the Stream Simulation Approach (CDFG, 2002), is an 11' 10" wide x 7' 7" high, 36' long pipe-arch (squashed-pipe) culvert embedded 2.5 feet below the finished channel grade (Figure 4.8). To maintain 18 inches of cover over the new SOC culvert, the Access Road may need to be raised up to six-inches along a 20-foot length. Embedding the culvert allows construction of a natural channel within the culvert. Similar to the upstream channel, the channel bed within the culvert would be constructed at a 3.5% slope and have a step-pool morphology, which will provide suitable passage for native fish and other aquatic organisms. The culvert size, including embedment, is adequate to convey the 100-year flow with the headwater 1.9 feet below the culvert soffit (HW/D = 0.63). The increased channel slope and culvert capacity will allow sediment to be transported from upstream though the culvert, and deposited further downstream along the valley floor.

Lowering the stream channel elevation upstream of the SOC Access Road and installing a culvert with larger capacity will reduce localized flooding just upstream of the present culvert. However, flooding may still occur as a result of the deteriorating levee upstream of the Old SOC buildings. This area should be further evaluated during final design to ensure that flooding issues are addressed.

The steepness of the stream channel in reaches A and B necessitates installation of log and boulder steps to control the channel profile and facilitate fish passage. These profile controlling features should be designed based on similar features found throughout the upstream channel in Reach A. When realigning the stream channel it may be necessary to import gravel to form the substrate of the new stream channel. River-run gravel is currently readily available from channel maintenance activities occurring within Lower Redwood Creek.

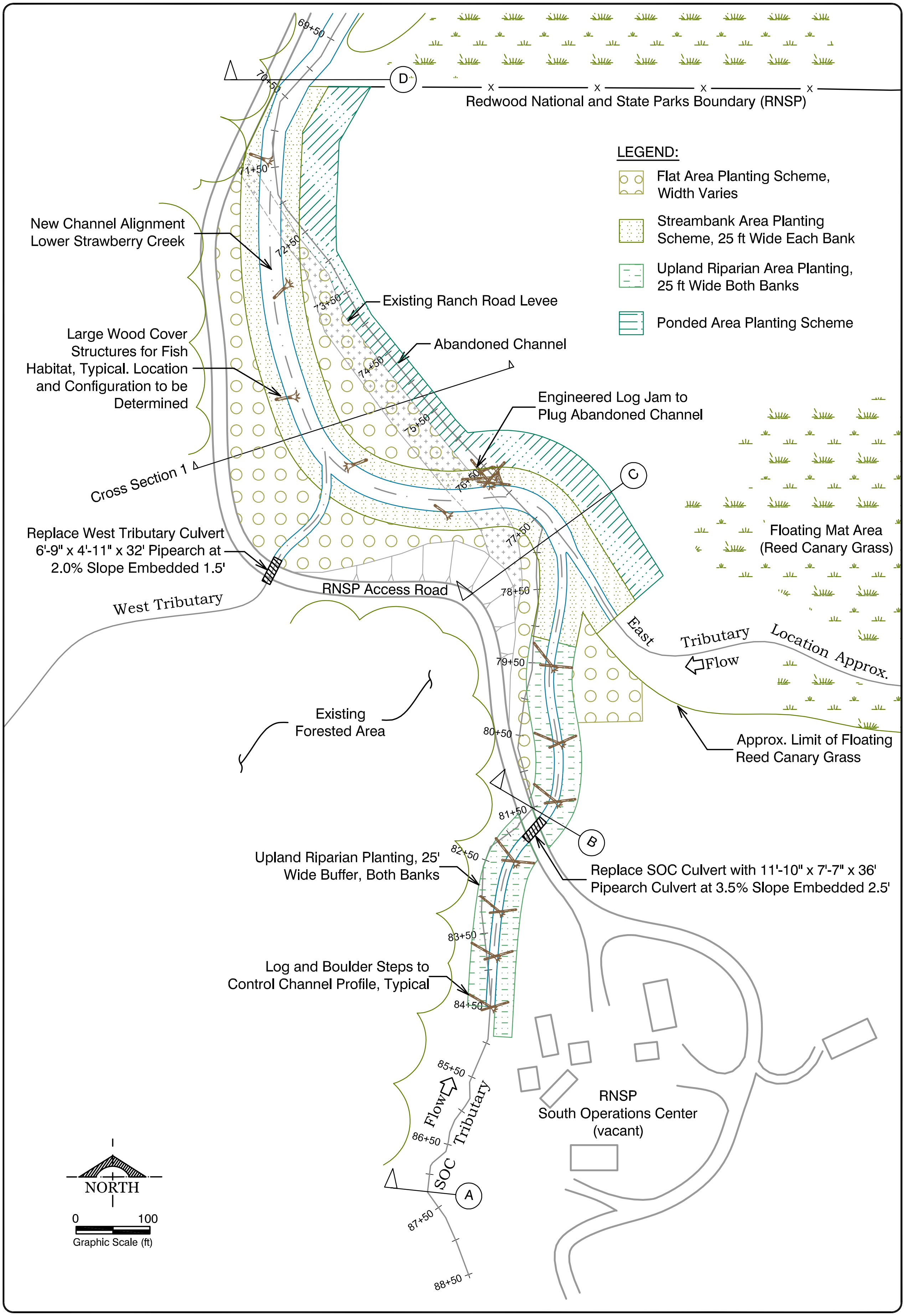


FIGURE: 4.6

Reaches A - C
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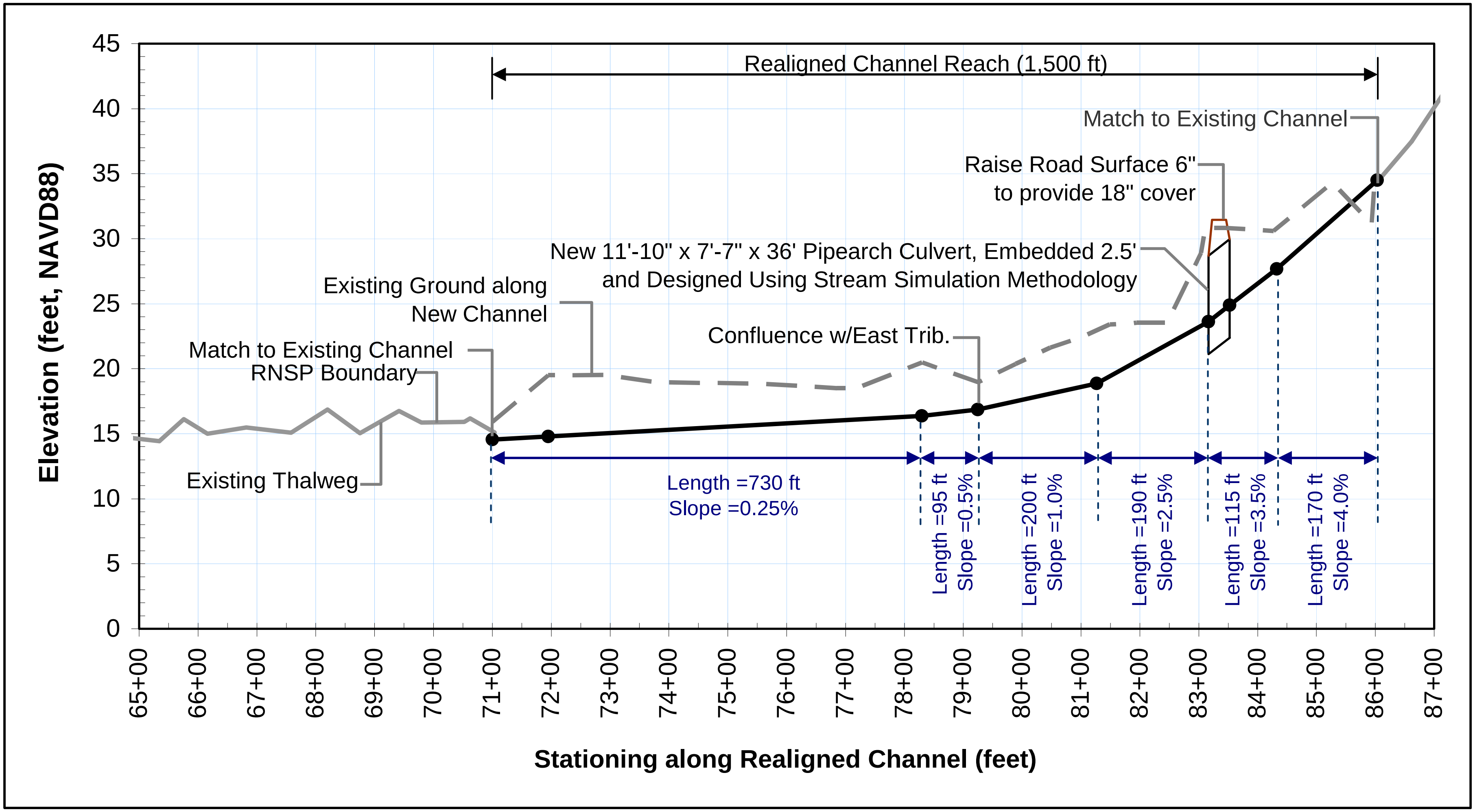

Figure 4.7 - Proposed channel profile in Reaches A-C. The proposed channel profile gradually transitions from the steep sloping upland SOC Tributary to a more gently sloping stream on the valley bottom, moving the depositional area towards the lower portion of Reach B and Upper portion of Reach C.

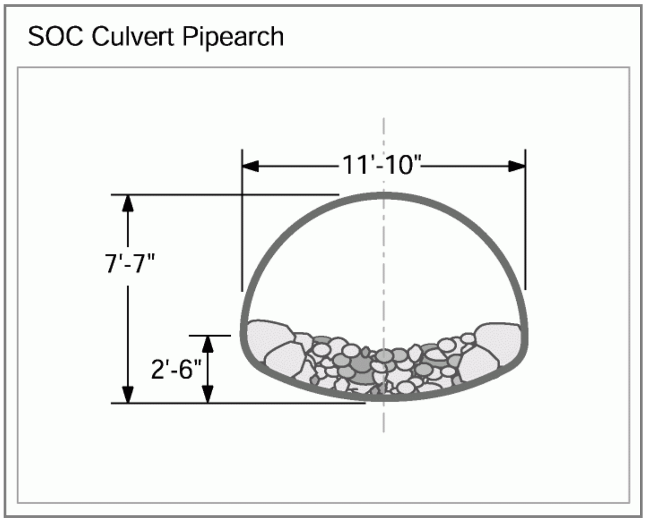

Figure 4.8 – Cross section of proposed embedded culvert with stream simulation bed and banks.

Vegetative Restoration

RCG is not as invasive in Reaches A and B as in downstream reaches because the overbank areas are well drained and inundation is infrequent. However, the lower portion of Reach A and all of Reach B have minimal riparian cover, and the stream banks are currently filled with invasive Himalaya berry. Restoration planting should include a minimum 25-foot width of *Upland Riparian Planting* on each streambank in the realigned stream reaches. Himalaya berry growing in Reach A where work is not proposed for this project can also be replaced with *Upland Riparian Planting* at the judgment of the RNSP botanist. *Upland Riparian Planting* should consist of upland area trees, shrubs, and herbaceous material planted at spacing appropriate for the size and growth habit of the plant.

The lower-most portion of Reach B enters the wetland and is covered with mats of floating RCG. This area, along with a short section of the East Tributary is proposed to receive *Streambank, Flat Area*, and *Ponded Area* planting.

Reach C

Physical Site Restoration

Reach C currently contains extensive areas of floating RCG mats that obscure the stream channel and overbank areas. Construction access will be extremely difficult in this area because of year-round standing water and soft ground. Recommendations in Reach C include realigning the stream channel to the west of the existing Ranch Road levee that parallels the stream channel (Figure 4.6). The Ranch Road levee and the RNSP Access Road to the west of the realigned channel form a contained area where RCG can be managed more. The Ranch Road levee and embankment of the RNSP Access Road are at higher elevations and have drier soils for planting. These planting "platforms" can be used to create a shade barrier to RCG encroachment and provide good access for maintenance.

Realigning the stream channel will allow the creation of a defined stream channel free of RCG, where the fish can move about without encountering obstructions created by an undefined stream channel or floating mats of RCG. The land within this area is higher than on the east side of the levee, which will provide higher streambanks that are better drained and accepting of riparian planting.

The existing Ranch Road levee will need to be breached to realign the stream channel. To maintain a single levee breach, it is recommended that it be located just downstream of the confluence of the East Tributary and Strawberry Creek. The existing stream channel to the east of the levee should be abandoned and allowed to convert to a backwater channel in the overbank. An engineered log jam installed across the head of the abandoned channel will act as a plug to prevent upstream flows from entering the abandoned channel. Large wood habitat structures sprigged with Sitka spruce seedlings can be installed in the abandoned stream channel in an effort to reestablish a riparian canopy and create in-channel habitat. Woven willow mattresses or floating wetland mats may also be used to create a living plant base that can adapt to fluctuating water levels. It is recommended that the abandoned stream channel not be filled with excavate from the proposed channel realignment because it is expected to provide backwater rearing habitat and may be difficult to permit if considered wetland fill.

The culvert under the SOC Access Road on the West Tributary will be replaced with an embedded pipe-arch culvert sized to fit the channel and have a 100-year flow capacity. The tributary channel will be shaped from the culvert outlet to the confluence with Lower Strawberry Creek.

The gentle slope of the proposed stream channel in Reach C will not require any grade control structures. However, large wood habitat structure should be installed along the stream channel to create habitat complexity and cover.

Vegetative Restoration

RCG removal and vegetation management will be challenging within the realigned channel in Reach C. The area to the west of the Ranch Road levee is presently a floating mat of RCG, though it is expected that restoration efforts in downstream reaches will lower the seasonal high baseflow elevation to below the elevation of the existing ground in this reach, stranding the floating mat. However, unlike the reaches downstream, the RCG will still be present in the form of a thick mat of decomposing vegetation that will likely impede growth of new plantings. Before replanting in this area, it is recommended that the floating mat be removed as much as feasible. It may be feasible to compost the excavated RCG in the center of the gravel turnaround in the SOC area. This area provides an easily accessible stockpile area, and the gravel road will act at a barrier to limit the grass from spreading. During composting the RCG should be covered to control its spread and dry it out.

Planting in this area should include a minimum 25-foot width of *Streambank Area Planting Scheme* on both streambanks. The *Streambank Area Planting Scheme* should be bordered with *Flat Area Planting Scheme* on both streambanks. To the west, the *Flat Area Planting Scheme* should extend to the edge of the Access Road. To the east, the *Flat Area Planting Scheme* should extend to the top of the Ranch Road levee. Additionally, the levee should be densely planted with Sitka spruce trees to act as an additional barrier to RCG encroachment. Though the *Flat Area Planting Scheme* in this reach is less than 100-feet wide in many areas, it is anticipated that the upland area adjacent to the Access road and the drier areas on top of the levee will serve as barriers to RCG encroachment.

Maintaining a clear stream channel for fish migration requires controlling RCG at the upstream and downstream limits of Reach C. Dense vegetation adjacent to the stream channel, the extensive floating RCG mat, and deep water currently make it difficult to finalize all recommendations in these areas. RCG control in these wet areas will likely necessitate application of treatments listed under the *Ponded Area Planting Scheme*. Restoration in downstream reaches will likely lower the seasonal water levels in these areas of Reach C, and reduce the area of floating mat, which may affect the type of planting appropriate for these areas.

Restoration in Areas of Floating Reed Canary Grass Mats

Treatments to control RCG and eliminate floating mats to the east of the Ranch Road levee can be implemented as construction access and budget allows. Ultimately, it is desirable to remove the floating mat and restore the area to a forested freshwater wetland that would be highly productive for fish and wildlife. Restoration of this area would also allow fish access to the East Tributary, which has a drainage area only slightly smaller than the West Tributary. The persistence of the floating mat to the east of the Ranch Road levee will continue to act as a sink for dissolved oxygen. Because the East Tributary will continue to flow through the floating mat area before entering the realigned area, water quality in the East Tributary and Strawberry Creek may be compromised when low DO conditions occur.

It also may be desirable to remove the Ranch Road levee to restore floodplain access in this area. However, levee removal should be carefully considered as it is expected to maintain a physical barrier to RCG encroachment between the floating mat area, and the realigned channel reach in Reach C.

Restoration of downstream reaches and the resultant drop in seasonal baseflow may allow construction access into some of the floating RCG mat area, potentially allowing for implementation of treatments outlined in the *Flat Area Planting Scheme*. However, the topographic survey identified that most of the floating mat area to the east of the Ranch Road levee is characterized by low ground that is expected to remain inundated, even after restoration efforts downstream. It is anticipated that construction access to the ponded area will be severely limited by soft ground and standing water. For these areas, the *Ponded Area Planting Scheme* will likely be necessary. This planting method creates islands of dense plantings similar to the *Flat Area Planting Scheme*. Historical accounts of this area and early aerial photos suggest that Sitka Spruce was the climax species that once covered this area. By planting Sitka spruce saplings combined with shrubs, like salmon berries, in logs and rootwads placed throughout this area may then slowly shade-out the RCG and reestablish the once complex and diverse wetland environment that once existed in this area.

4.2.2 Reach D - Barlow Property Upstream

Reach D is dominated by an existing cattail pond and wetland area bounded by floating mat of RCG (Figure 4.9). The topography and vegetation in this reach may also be creating a ponding effect on the RNSP and Barlow property. RCG management and possibly some grading in this reach is recommended, but dense vegetation adjacent to the stream channel, the extensive floating RCG mat, and deep water in this reach currently make it difficult to determine a restoration scheme that will be successful. The restoration of downstream reaches will likely lower the high seasonal baseflow in this reach and reduce the area of floating mat. The actual extents and timing of inundation should be assessed after downstream restoration efforts to aid in development of an appropriate restoration plan for this area.

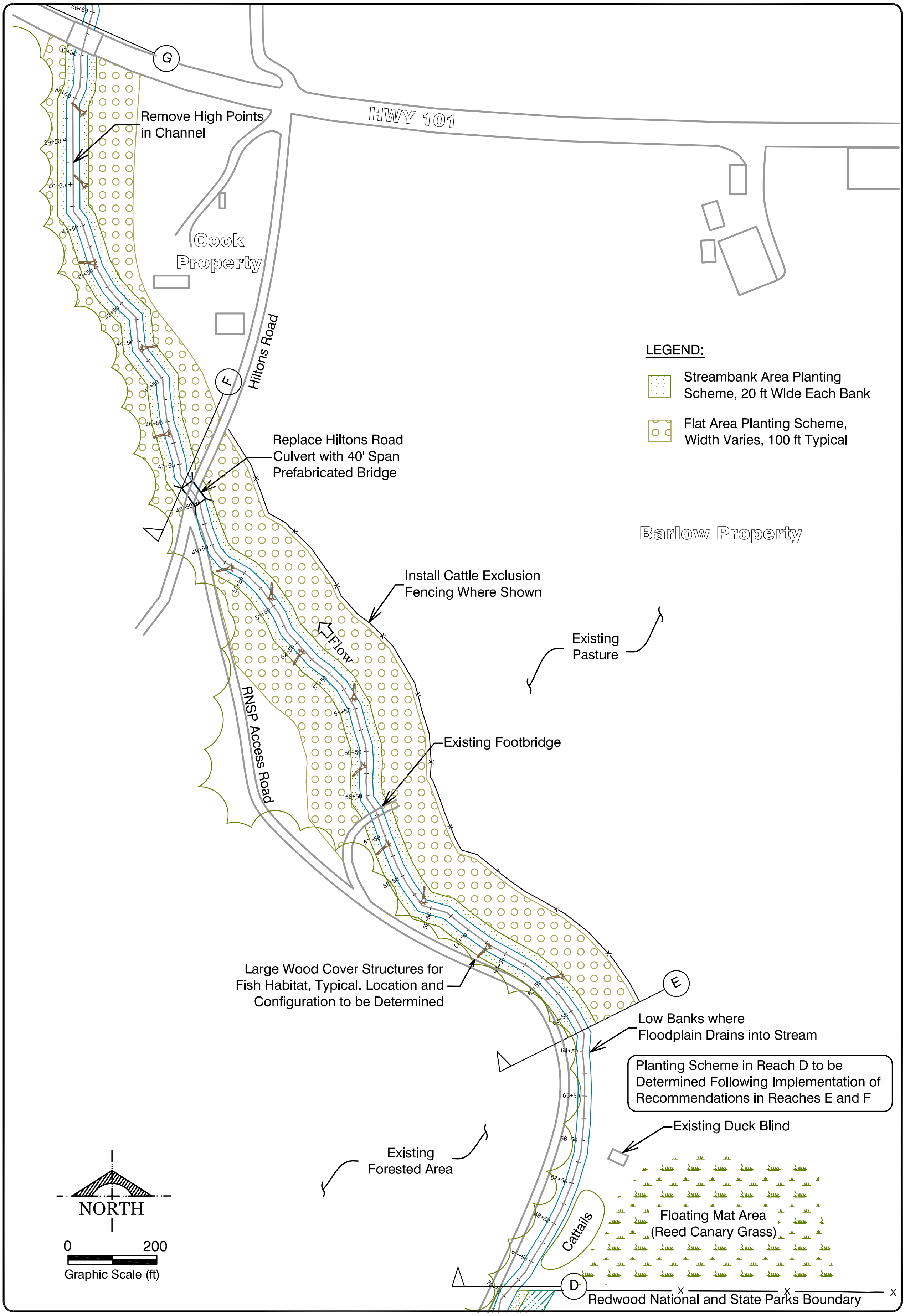

FIGURE: 4.9

Reaches D - F
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4.2.3 Reach E - Barlow Property Downstream

Recommendations for Reach E include upgrading the culvert at Hiltons Road to increase flood capacity, removal of RCG from the channel, implementation of revegetation schemes to create riparian areas with a dense multilayered canopy to limit RCG regrowth, and installing cattle exclusion fencing along the pasture to the east of the stream (Figure 4.9).

Seasonal flooding during winter baseflow and frequent storm events will be reduced with downstream restoration. The lowered water level will decrease inundation of the streambanks in this reach, allowing for riparian planting. Planting should include a minimum 20-foot width of *Streambank Area Planting Scheme* on both streambanks. The *Streambank Area Planting Scheme* should be bordered with a minimum 100-foot width of *Flat Area Planting Scheme*, except where existing forested areas provide enough shading to limit RCG growth. Table 4.5 provides areas designated for each planting scheme and the length of cattle exclusion fencing.

The ground along the west side of the channel near the footbridge appears to be less inundated than adjacent areas, and does not support vigorous growth of RCG. A more loosely spaced *Upland Area Riparian Planting Scheme* may be more appropriate than the more intense *Flat Area Planting Scheme*.

The Hiltons Road culvert can be replaced with a two lane, 40-foot span prefabricated bridge that will span the bankfull channel. This design will provide 100-year flow capacity and eliminate culvert backwater effects that currently impact the upstream channel.

The gentle slope of the proposed stream channel in Reach E will not require any grade control structures. However, large wood habitat structures should be installed along the stream channel to create habitat complexity and cover. These structures will alter flow patterns and create variability in the streambed, which is currently lacking.

Table 4.5 – Proposed Reach E planting areas and length of treated channel and exclusion fencing

Revegetated Channel Length	Streambank Planting	Flat Area Planting	Cattle Exclusion Fencing
1,740 feet	1.37 acres	5.16 acres	1,670 feet

4.2.4 Reach F - Cook Property

Recommendations for Reach F include excavation of high points along the stream channel, removal of RCG from the channel, and implementation of revegetation schemes to create riparian areas with a dense multilayered canopy to limit RCG regrowth (Figure 4.9). Channel high points located between stations 39+20 and 41+00 and between stations 43+00 and 47+75 should be removed to improve flow conveyance and lower winter baseflow water levels (Table 4.6). Removal of these high points will also increase the capacity of the existing Hiltons Road culvert by removing the channel obstruction at the downstream end of the culvert. Before conducting any in-stream channel work, these areas need to be checked for utilities. The Orick Community Services District has a water line located a short distance upstream of the Highway 101 crossing.

Seasonal flooding during winter baseflow and frequent storm events will be reduced with downstream restoration and removal of the channel high points in this reach, exposing the streambanks above the seasonal high water surface elevation and allowing planting. Planting should include a minimum 20-foot width of *Streambank Area Planting Scheme* on both streambanks. RCG should be excavated from within the stream channel of Strawberry Creek before planting. The *Streambank Area Planting Scheme* should be bordered with *Flat Area Planting Scheme* that is at least 100 feet wide, except where site conditions limit its width. The location of the existing residences on the east channel bank may limit the width of the *Flat Area Planting Scheme* to approximately 50 feet. Existing forest to the west of the stream may also reduce the necessary planting width. Table 4.6 provides areas designated for each planting scheme and estimated volume of channel high-point removal.

Table 4.6 – Proposed Reach F planting areas, length of revegetated channel, and volume of material removed from channel high points.

Revegetated Channel Length	Streambank Planting	Flat Area Planting	Removal of High Points	
			Channel Length	Estimated Volume
1,050 feet	0.98 acres	2.56 acres	630 feet	350 cubic yards

The gentle slope of the proposed stream channel in Reach F will not require any grade control structures. However, large wood habitat structures should be installed along the stream channel to create habitat complexity and cover. The structures will alter flow patterns and create variability in the streambed, which is currently lacking.

4.2.5 Reach G - Upper Zuber Parcel

The landowners in Reach G (Figure 4.10) have not indicated whether they will support riparian planting to control RCG along their reach of Strawberry Creek. Lowering baseflow water surface elevations in Reach G is the key to the success of the Strawberry Creek restoration project because the restoration revegetation treatments are sensitive to frequency and duration of inundation, which is controlled by downstream water surface elevations. In Reach G the in-channel RCG and the high-point in the channel prevent water from flowing freely, consequently raising water surface elevations in the upstream reaches.

At a minimum, project success upstream can be facilitated with the excavation of in-channel RCG from this reach approximately every 2 to 3 years in the same manner that it was performed in the summer of 2007. This excavation will keep the channel flowing freely and lower the baseflow water surface elevation. Removal of the high point in the stream channel would improve conveyance of winter baseflow and reduce upstream backwater effects. Excavation of RCG from the stream channel would require obtaining permits on a regular basis to perform the in-stream work.

Use of riparian vegetation to shade and outcompete RCG in and adjacent to the stream channel is the most beneficial and cost effective method of managing in-channel RCG in Reach G. The methods recommended in this report provide a long-term, low maintenance, less costly, and less disruptive approach than routine excavation of RCG from the stream channel. If Reach G were to be restored in a similar manner as Reach E, approximately 630 feet of stream channel could be planted with a 20-foot width of *Streambank Area Planting Scheme* on both the east and west channel banks. A 100-foot width of *Flat Area Planting Scheme* could be installed on the east channel bank and a portion of the west bank where the overbank is not forested. Fencing would prevent riparian area grazing. Removal of the high point in the channel from stations 33+00 to 37+00 would improve conveyance of winter baseflow and reduce upstream backwater effects.

4.2.6 Reach H - County Transfer Station

The upstream portion of Reach H flows through forested lands of the Waste Transfer Facility owned by Humboldt County before flowing along the north-south property boundary (Figure 4.10). In this section the County property along the east bank is forested while the cattle pasture owned by the Zuber family along the west bank is unforested and contains RCG. The Zuber family has not indicated whether they will participate in riparian revegetation efforts, as recommended for upstream reaches.

In pasture areas of the Zuber Parcel that run along the western streambank, RCG is present, though not growing as vigorously as in the other reaches. RCG growth is likely not as dense because the overbanks of this reach are at a higher elevation, well drained and grazed. RCG is present within the stream channel, but grazing limits its growth in some locations. A dense growth of RCG is present in the stream channel between approximate stations 20+50 to 22+50 (Figure 4.10), which is affecting fish passage and water quality. The presence of this grass does not create significant ponding impacts to upstream reaches.

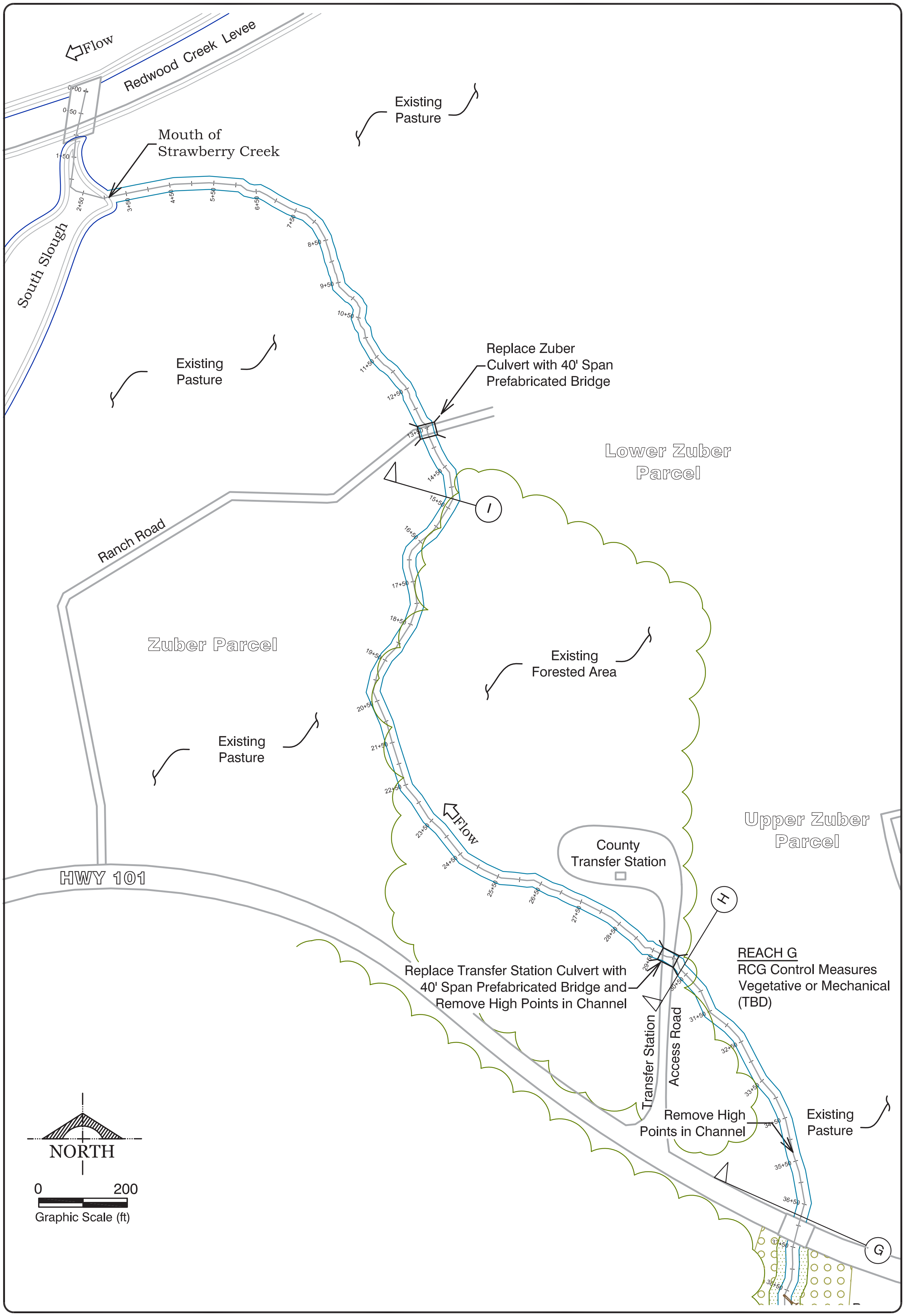

FIGURE: 4.10

Reach G - I
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Recommendations for Reach H include the replacement of the Transfer Station culvert (Figure 4.10) and RCG management along the stream channel. The existing Transfer Station culvert was constructed with its invert substantially higher than the adjacent stream channel. The culvert functions as a high-point in the channel, raising upstream water levels and reducing flow conveyance. The Transfer station culvert should be replaced with a minimum 40-foot span bridge to span the existing width of the stream channel and prevent upstream backwater effects. Final engineering design may identify the necessity for a larger span to pass the 100-year flow. When the existing Transfer Station culvert is removed, the foundation of the culvert and stream channel can be graded to remove the high-points in the channel. It is anticipated that approximately 83 cubic yards of material along a 60-foot channel length will be excavated when removing the culvert and channel high point. Installation of a bridge with a natural channel bottom at grade will allow passage of all age classes of salmonids. It will also address current issues with beaver dams that are routinely constructed across the inlet of the existing box culvert.

Existing forest on the east side of this reach provide sufficient shading to keep RCG growth in check, except in localized areas where cattle have accessed the forested side of the streambank. Supplemental riparian plantings can be used in these areas.

Water quality and aquatic habit in the approximately 775 feet of stream channel to the east of pasture area would benefit from installation of a 20-foot width of S*treambank Planting Scheme*, a 20-foot width of *Upland Riparian Planting Scheme*, and fencing to minimize riparian area grazing. If riparian planting is not implemented in this area, fencing to exclude grazing access to the forested area on the east streambank is recommended. Additionally, occasional manual removal of RCG from the channel may be necessary to maintain fish passage.

4.2.7 Reach I - Lower Zuber Parcel

The landowner in Reach I (Figure 4.10) has not indicated whether they will participate in the project and development of a planting plan for this reach was beyond the scope of this project.

The stream overbanks in this reach do not receive as much inundation during storm events because the stream channel is deeper in this reach and in-channel RCG is not obstructing flows as in the upstream reaches. In pasture areas on both stream overbanks, RCG is present though not growing as vigorously as in the other reaches. RCG growth is likely not as dense in the overbanks of this reach because the overbanks are drier and grazed. RCG is present within the eroding stream channel, but grazing limits its growth.

If Reach I were to be restored, planting with a 20-foot width of Upland Riparian Planting and cattle exclusion from the planting area would benefit stream function and water quality.

The Zuber culvert should be replaced with a minimum 40-foot long bridge to span the existing width of the stream channel. Final engineering design may identify the necessity for a larger span to pass the 100-year flow. Replacement of the culvert with a bridge will improve fish passage and eliminate any culvert-related backwater effects that may impact the upstream channel during large flows.

5 Project Phasing and Costs

5.1 Project Phasing

The magnitude of this project is such that implementation of all recommendations concurrently will likely be infeasible. Also, the success of the Strawberry Creek restoration project is dependent on revegetation treatments that are sensitive to frequency and duration of inundation determined by water surface elevations in downstream reaches. If restoration is not implemented from downstream to upstream, it may be difficult to predict the proper elevations of plantings and plant species selection that will be most successful.

Table 5.1 presents a recommended sequence of restoration for Strawberry Creek.

5.1.1 Phase 1 – Reaches D-G: Revegetation and In-Channel Work

Phase 1 implementation covers Reaches D through G (Upper Zuber, Cook, and Barlow properties), but does not include replacement of the County culverts. Phase 1 involves removal of the channel high points and in-channel RCG, installation of large wood cover structures for fish, and extensive riparian planting. Actions in Reach G are contingent on landowner participation, and are anticipated to include either manual removal of RCG from the stream channel or riparian area planting.

Where feasible, this phase should be implemented from downstream to upstream to lower baseflow water levels upstream, which will help dry-out saturated streambanks prior to planting. At the initiation of Phase 1, plant propagation should be contracted to a local nursery and pilot revegetation plots should be planted and monitored to determine the treatments, implementation techniques, and plant species that are most effective at meeting project objectives. This can begin concurrently with development of the final revegetation design and project permitting of in-channel work.

Phase 1 revegetation should include a monitoring component to determine planting effectiveness and identify areas needing maintenance or replanting. Periodic maintenance during the first few years following planting, such as weed-removal, should be budgeted.

Phase 2 revegetation should include a monitoring component to determine planting effectiveness, identify areas needing maintenance or replanting. Periodic maintenance during the first few years following planting, such as weed-removal, should be budgeted.

Table 5.1 - Proposed project phasing resulting in project implementation from downstream to upstream.

<table>
<tr><th>REACH</th><th colspan="2"><u>PHASE 1</u>
D, E, F, and G[1]
Upper Zuber, Cook, Barlow Properties</th><th colspan="2"><u>PHASE 2</u>
A, B, and C
RNSP</th><th><u>PHASE 3</u>
County Culverts</th><th><u>PHASE 4</u>
H and I[2]
Lower Zuber and Transfer Station</th></tr>
<tr><td>DESCRIPTION</td><td colspan="2">Revegetation, Channel Excavation and Large Wood Habitat Structures</td><td colspan="2">Channel Construction, Revegetation, and Two Culvert Replacements</td><td>Hiltons Road and Transfer Station Culvert Replacements</td><td>Revegetation and One Culvert Replacement</td></tr>
<tr><td colspan="7">PROPOSED TIMING OF PHASES</td></tr>
<tr><td>YEAR 1</td><td rowspan="2">Vegetation Design and Permitting of In-Channel Work</td><td>Start Plant Propagation</td><td>Final Engineering & Vegetation Design</td><td>Start Plant Propagation</td><td></td><td></td></tr>
<tr><td>YEAR 2</td><td>Install Pilot Revegetation Plots and Monitor</td><td colspan="2">Permitting of In-Channel Work</td><td rowspan="2">Obtain Grant Funding</td><td>Start Plant Propagation</td></tr>
<tr><td>YEAR 3</td><td rowspan="2">Monitoring and Maintenance</td><td rowspan="2">Revegetation and In-Channel Work</td><td colspan="2">Implement Reach A and B and SOC Culvert Replacements</td><td>Vegetation Design</td></tr>
<tr><td>YEAR 4</td><td colspan="2">Implement Reach C and West Tributary Culvert Replacement</td><td>Final Design and Permitting</td><td rowspan="2">Revegetation and In-Channel Work</td></tr>
<tr><td>YEAR 5</td><td colspan="2" rowspan="2">Monitoring and Maintenance</td><td colspan="2" rowspan="2">Monitoring and Maintenance</td><td>Replace Culverts</td></tr>
<tr><td>YEARS 6 & 7</td><td>Monitoring</td><td>Monitoring and Maintenance</td></tr>
</table>

[1] *Actions in Reach G are contingent on landowner participation, and are anticipated to include either riparian area planting or manual removal of RCG from the stream channel.*
[2] *Actions in portions of Reach H and Reach I are contingent on landowner participation.*

5.1.2 Phase 2 – Reaches A-C: RNSP Property

Phase 2 implementation involves restoration in Reaches A-C on RNSP property. This includes reconstruction of 1,500 feet of channel within the three reaches, replacement of two culverts, and revegetation. It is expected that Phase 2 of the project will progress nearly concurrently with Phase 1. However, water levels in Reach C are expected to lower following downstream restoration, which may impact location of proposed planting schemes in Reaches B and C. Therefore, it is recommended that the proposed channel restoration and planting methods on the RNSP property not be finalized until after restoration of downstream reaches.

Construction is expected to take two seasons. Reach C will be the most challenging due to persistent areas of standing water and large areas of floating RCG mats. It is recommended that during the first season restoration work focus on Reaches A and B and clearing of the RCG mat in Reach C. This will help lower water levels in Reach C, making revegetation less challenging during the following season. Also, removal of the RCG will expose the underlying topography, allowing for adjustments to the final design, if needed.

5.1.3 Phase 3 - County Culvert Replacements

Phase 3 implementation consists of replacement of the Hiltons Road and Transfer Station County-maintained culverts. Replacement of the Transfer Station culvert will remove a channel high-point and lower upstream water levels, and replacement of the Hiltons Road culvert will eliminate backwater effects that impact water levels and sediment routing in the upstream channel. Given Humboldt County's aggressive action over the past 10 years in replacing culverts that block fish passage and degrade fish habitat, it is expected that the County will be the lead for Phase 3. Replacement of these culverts follows upstream restoration, which is intended to create rearing habitat for juvenile coho and provide cutthroat and steelhead trout access to the West and SOC Tributaries for spawning and rearing. Completion of the upstream channel and riparian restoration may ultimately improve grant funding opportunities for Phase 3.

5.1.4 Phase 4 - Lower Reach Revegetation and Culvert Replacement

Phase 4 consists of restoration of the Lower Zuber (Reach I) and Transfer Station (Reach H) parcels. Growth of RCG in these two reaches is less aggressive than in upstream reaches and has less impact on upstream seasonal flooding.

The proposed actions in portions of Reach H and Reach I area contingent on landowner participation and possibly include *Streambank* and *Upland Riparian Plantings* and cattle exclusion. This phase also includes replacement of the Zuber culvert, which is undersized and is a partial fish migration barrier. Implementation of Phase 4 can occur at any time in the project.

If implemented, Phase 4 revegetation should include a monitoring component to determine planting effectiveness, and identify areas needing maintenance or replanting. Periodic maintenance during the first few years following planting, such as weed-removal, should be budgeted.

5.1.5 Other Factors in Project Phasing

Project design and permitting are time consuming tasks that require up-front planning. In-channel work for the Hiltons Road and downstream reaches may require a Coastal Development Permit, in addition to permits from the California Department of Fish and Game, Army Corps of Engineers, Water Quality Control Board, and Humboldt County. The project will also need to meet NEPA/CEQA compliance. It is recommended that design and permitting of Phases 1 and 2 begin immediately, so implementation can occur as soon as possible.

Installed plantings should be as large as possible to maximize their shading benefits immediately, and to reduce the possibility of becoming overtaken by RCG grass growth. The minimum recommended age of trees to be installed is 2 years, and vegetation to be installed should be "locally native" to preserve the local vegetation genome. Obtaining trees of sufficient age, as well as local genome plants will necessitate immediate coordination to start collecting plant material in Year 1 if planting is proposed to start in Year 3.

5.2 Estimated Project Costs

The Strawberry Creek project has been divided into four phases based on anticipated project timing and property ownership. Table 5.2 presents estimated project costs for each of the four project phases. Costs were derived based on the unit cost per acre of the proposed planting schemes and the combined costs of the proposed restoration measures including stream channel restoration, culvert replacements, and cattle excluding fencing. Costs also include design and permitting efforts required for the project, post-project effectiveness monitoring of the vegetation and periodic maintenance. Final design will require a botanist to finalize plant species selection, planting elevations and treatments. Final design engineering will also be required for the RNSP channel restoration and culvert replacements, and the Hiltons Road, Transfer Station, and Zuber culverts. A detailed itemization of cost estimates for each Phase is included in Appendix D.

Table 5.2 - Estimated Project Costs and area of RCG management

Project Phase		Revegetation Area	Estimated Cost
1	Reaches D-G[1,2] Barlow, Cook and Upper Zuber Properties	12.6 acres	$732,000
2	Reaches A-C RNSP Property	4.6 acres	$527,000
3	Hiltons Road and Transfer Station Culvert Replacements	-	$368,000
4	Reaches H-I[2] Transfer Station and Lower Zuber Parcel	2.3 acres	$263,000
		TOTAL PROJECT COST	**$1,890,000**

[1] *Phase 1 does not include costs for Reach D because planting methods cannot be determined at this time due to site conditions.*
[2] *Costs for vegetative restoration of Reaches D, H, and I are included in cost estimates.*

The estimated implementation costs presented in Table 5.2 are conservative. The project cost estimate does not include obtaining materials from donations or reused materials, such as recycled cardboard or burlap bags from local coffee roasters or feed mills. Planting material may possibly be contract grown at less than the budgeted wholesale prices. Pilot vegetation plots may indicate that planting density can be reduced, which would lower overall cost. To keep costs low, it is recommended that construction materials such as logs and rootwads, mulch, compost, rock, and planting materials be obtained from a local source to reduce hauling costs. Volunteers, California Conservation Corps, and other groups can be a valuable source of labor for planting and maintenance.

References

Antieau, C. 2000. Emerging themes in reed canarygrass management. Reed Canarygrass *Working Group Conference Proceedings*, March 15, 2000, Olympia Washington.

Antieau, C. 1998. Biology and Management of reed canarygrass, and implications for ecological restoration. Washington State Department of Transportation. Seattle, WA. Bornstein, Carol, D. Fross, and B. O'Brien. 2005. *California Native Plants for the Garden*. Cachuma Press. Los Olivos, CA.

Armour, Carl L. 1991. *Guidance for Evaluating and Recommending Temperature Regimes to Protect Fish*. U.S. Fish Wildlife Service, *Biol. Rep*. 90(22). 13 pp.

Beach, Eric. 2001. "Reestablishing Conifer Overstory in Wetlands: the Importance of Coarse Woody Debris as Rooting Substrate for Planted and Natural Conifer Regeneration." Reed canarygrass session at the *Proceedings for the Society of Ecological Restoration, Northwest Chapter*. Eric.beach@ci.seattle.wa.us, Seattle Public Utilities Watershed management Division.

California Data Exchange Center (CDEC). 2007. Historic Hourly Streamflow data for Redwood Creek at Orick (ORK). http://cdec.water.ca.gov.

California Department of Fish and Game. 2004. Recovery strategy for California coho salmon. Report to the California Fish and Game Commission. 594 pp. Copies/CDs available upon request from California Department of Fish and Game, Native Anadromous Fish and Watershed Branch, 1416 9th Street, Sacramento, CA 95814, www.dfg.ca.gov/nafwb.cohorecovery.

California Department of Fish and Game (CDFG). 2002. *Culvert criteria for fish passage*.

Gedik, Tamara. 2006. Biological Report for Management of Reed Canary Grass (*Phalaris arundinacea*) at Yontocket Slough and Tryon Creek. Unpublished report prepared by Gedik BioLOGICAL Associates for Michael Love and Associates. Westhaven, CA.

Holtby, L. B., B. C. Andersen, and R. K. Kadowaki. 1990. Importance of smolt size and early ocean growth to inter-annual variability in marine survival of coho salmon (*Oncorhynchus kisutch*). *Canadian Journal of Fisheries and Aquatic Sciences* 47: 2181-2194.

Knox, Matthew. Environmental Biologist, City of Kent Public Works Engineering, Washington. Telephone and email communication in October 2007 with Tamara Gedik, Principal Biologist, Gedik BioLOGICAL Associates, Trinidad, CA.

Knox, Matthew. 2004. "Controlling Reed Canarygrass: Field Trials and Lessons Learned." 25th Anniversary Meeting of the Society of Wetland Scientists. Sheraton Hotel, Seattle Washington. July 20, 2004.

LeFor, M. W. 1987. *Phalaris arundinacea L.* (reed canarygrass- Gramineae) as a hydrophyte in Essex, Connecticut, USA. *Environmental Management* 11(6): 771-773.

Maurer, D.A., R. Lindig-Cisneros, K.J. Werner, S. Kercher, R. Miller, and J.B. Zedler. 2003. The replacement of wetland vegetation by Reed canarygrass (*Phalaris arundinacea*). *Ecological Restoration*. 21 (2): p. 116-119.

Michael Love & Associates (MLA). 2006. Yontocket Slough Fish Passage and Habitat Enhancement Planning Project. Final Report. May 2006. Michael Love & Associates, Arcata CA.

Miller, R.. C. and J.B. Zedler. 2003. Responses of native and invasive wetland plants to hydroperiod and water depth. *Plant Ecology* 167: 57-69.

NOAA Fisheries. 2001. Guidelines for salmonid passage at stream crossings. NMFS SW Region, 14 pages.

Pollock, Michael M., George R.. Pess, and Timothy J. Beechie. 2004. The importance of beaver ponds to Coho salmon production in the Stillaguamish River Basin, Washington, USA.. *North Amer. J. of Fisheries Management*, 24:749-760.

Redwood Creek Watershed Group (RCWG). 2006a Watershed-wide Aquatic and Riparian Habitat Restoration Strategy for Basinwide Aquatic Riparian Habitat Restoration Strategy Strawberry Creek Near Orick, Humboldt County: United States March 2006. Orick, CA. 18 pp.

Redwood Creek Watershed Group (RCWG). 2006b. Redwood Creek Integrated Watershed Strategy. June 2006. co.humboldt.ca.us/planning/Prop50/01_RWC_IWS%20Final.pdf.

Redwood National Park (RNP). 1986. South Operation enter Natural Area Subzone. Recent Vegetation/Habitat and Human Use History. Division of Resource Management, Redwood National Park.

Redwood National and Sate Parks (RNSP). 1981. Interview narrative with Savina Antonioli Barlow by Cindy Ricks and Randy Feranna.

Reinhardt, C. H. and S. Galatowitsch. October 20, 2000. Best management practices for minimizing reed canarygrass prior to wetland restoration. Final report to Minnesota Department of Natural Resources.

Ricks, Cynthia. 1995. *Effects of Channelization on Sediment Distribution and Aquatic Habitat at the Mouth of Redwood Creek, Northwestern California.* U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1454-Q.

Tu, Mandy. June 2004. Reed canarygrass: control and management in the Pacific Northwest. The Nature Conservancy Wildland Invasive Species Team, Oregon Field Office.

USGS. 1982. *Guidelines for determining flood flow frequency. Bulletin #17B of the Hydrology Subcommittee.* Interagency Advisory Committee on Water Data, US Dept. of Interior, Geological Survey, Virginia.

Wannanan A. O. and J. R. Crippen, 1977. *Magnitude and frequency of floods in California.* U. S. Geological Survey, Water resources Investigation 77-21, Menlo Park, CA .96 p.

Water Quality Assessments. 1996. *Water Quality assessments: A guide to the use of biota, sediments and water in environmental modeling*. Ed. D. Chapman. Published on behalf of UNESCO United Nations Education, Scientific, and Cultural Organization; WHO World Health Organization; UNEP United Nations Environmental Program. Chapman & Hall, London.

Appendix A

Enhancement Planting Plan for Management of Reed Canary Grass at Strawberry Creek

Appendix B

RNSP Dissolved Oxygen and Water Temperature Report

United States Department of the Interior
California Department of Parks and Recreation

Redwood National and State Parks
121200 Highway 101
Orick, California 95555

CALIFORNIA STATE PARKS

December 14, 2006

To: Mitch Farro – PCFWWRA
From: David Anderson – Fishery Biologist RNSP
Subject: Dissolved Oxygen measurements in Strawberry Creek, Orick, California –Summer 2006

As a condition of removing the floating mats of reed canarygrass (*Phalaris arundinacea)* from the channel of Strawberry Creek (a tributary to Redwood Creek estuary), dissolved oxygen and temperature measurements were measured at several locations along the project area. The removal area is west of the RNSP boundary at the elk fence to the Hilton Road culvert. A threshold of 2.0 mg/l or above was established in the CDFG 1600 for having a fish biologist on site during grass removal with an excavator.

I took dissolved oxygen (mg/l) and water temperature (°C) readings with a YSI Model 55 meter on August 29, 2006 and September 27, 2006 in the vegetation choked channel. Dissolved oxygen values were very low, below the CDFG 2 mg/l threshold, and indicative of poor salmonid habitat. To check the meter was reading correctly, measurements were taken above the mainstem channel locations at the Strawberry Creek tributary behind the old RNSP South Operations Center (SOC). They showed high readings consistent with a well aerated salmonid bearing stream.

Strawberry Creek Location	Date/Time	Dissolved Oxygen (mg/l)	Water Temperature (°C)
Wood Bridge in Barlow's Pasture			
Wooden Bridge in Barlow's pasture @ 1 foot depth	8/29/2006 @ 4:11 pm	0.04	12.8
Upstream edge of wooden bridge	9/27/2006 @1:45 pm	<0.14	10.9
Downstream edge of wood bridge	9/27/2006 @1:45 pm	0.09	10.8
Hilton Road Culvert			
Upstream side immediately above culvert	8/29/2006 @ 3:55 pm	1.2	13.6
2 ft upstream of culvert in vegetation	9/27/2006 @ 2:05 pm	0.25	11.4
In standing water *inside* the culvert (no vegetation) and outside the project area.	9/27/2006 @ 2:05 pm	2.83	11.4
Tributary at Old SOC			
Tributary behind upper parking lot of old SOC	8/29/2006 @ 4:25 pm	9.5	11.8
Upstream side of culvert in front of old SOC buildings	9/27/2006 @ 1:55 pm	8.9	11.6

The reed canarygrass completely covered the channel and formed a thick mat.

If you have any questions, please contact me at (707) 465-7771 or email
david_g_anderson@nps.gov

/s/ David Anderson

Appendix C

Peak Flow Hydrology

Summary of methods to determine peak flood frequency for the Strawberry Creek Watershed.

Drainage Area Name	Drainage Area (sq mi)	Strawberry Creek Recurrence Intervals and Associated Peak Flows (cfs)						
		1.5 Year	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
West Tributary								
USGS Average Peak Flow[1]	0.21	12	17	31	41	55	67	78
North Coast Regression Equation[2]		-	35	56	76	99	121	136
Leopold North Coast[3]		14	27	65	-	-	-	-
Leopold Eel River[3]		14	19	35	-	-	-	-
SOC Tributary								
USGS Average Peak Flow[1]	0.38	22	31	55	74	99	120	140
North Coast Regression Equation[2]		-	60	94	127	165	201	225
Leopold North Coast[3]		22	41	98	-	-	-	-
Leopold Eel River[3]		22	28	52	-	-	-	-
East Tributary								
USGS Average Peak Flow[1]	0.16	10	13	24	32	44	52	61
North Coast Regression Equation[2]		-	28	45	61	80	98	110
Leopold North Coast[3]		12	24	56	-	-	-	-
Leopold Eel River[3]		12	16	30	-	-	-	-
SOC, West and East Tributaries Combined								
USGS Average Peak Flow[1]	0.75	44	61	111	148	198	238	280
North Coast Regression Equation[2]		0	111	174	233	300	366	411
Leopold North Coast[3]		38	73	173	0	-	0	0
Leopold Eel River[3]		38	50	92	0	-	0	0
Total Drainage Upstream Highway 101								
USGS Average Peak Flow[1]	1.89	112	155	279	373	501	601	705
North Coast Regression Equation[2]		-	256	396	527	672	819	920
Leopold North Coast[3]		89	169	401	-	-	-	-
Leopold Eel River[3]		89	116	214	-	-	-	-
Total Drainage to Sough Slough								
USGS Average Peak Flow[1]	2.13	127	175	315	420	565	678	796
North Coast Regression Equation[2]		-	285	441	586		910	1022
Leopold North Coast[3]		100	190	449	-	-	-	-
Leopold Eel River[3]		100	130	239	-	-	-	-

[1]USGS, 1982
[2]Waananen and Crippen, 1977
[3]Leopold, 1994

Appendix D

Cost Estimates

Lower Strawberry Creek Habitat Restoration
Vegetation Scheme

Per Acre Cost Sheet

Streambank Area Planting Scheme

Item	Description	Qty	Unit	Unit Cost	Total Cost
1	Mowing/Weedwhacking RCG	1.0	ACRE	$ 500	$ 500
2	Corrugated Cardboard/stakes	43560.0	SF	$ 0	$ 8,712
3	Burlap	43560.0	SF	$ 0	$ 13,068
4	Live Stakes	1089.0	EA	$ 2	$ 2,178
5	Trees (2-year) at 6' Spacing*	1210.0	EA	$ 20	$ 24,200
6	Shrubs (1 gal.) at 4' Spacing*	2723.0	EA	$ 6	$ 16,338
7	Herbaceous Plants (4" Pots) at 5' spacing*	1743.0	EA	$ 4	$ 6,101
	Total				**$ 71,097**
	*Overall Plant Spacing 2.8 '				

Flat and Ponded Area Planting Scheme

Item	Description	Qty	Unit	Unit Cost	Total Cost
1	Mowing/Weedwhacking RCG	1.0	ACRE	$ 500	$ 500
2	Wattle (8' diam), soil, and plants*	109.0	EA	$ 272	$ 29,653
	Total				**$ 30,153**
	*Plant Spacing: Trees 4', Shrubs, 3', Herbaceous 4'. Overall Spacing 1.9'				

Upland Riparian Area

Item	Description	Qty	Unit	Unit Cost	Total Cost
1	Trees (2-year) at 20' Spacing*	109.0	EA	$ 12	$ 1,308
2	Shrubs (1 gal.) at 20' Spacing*	1.0	EA	$ 6	$ 654
3	On-Site Wood Chip Mulch	1.0	AC	$ 500	$ 500
	Total				**$ 2,462**
	*Overall Plant Spacing 14 '				

Item	Description	Qty	Unit	Unit Cost	Total Cost
Lower Strawberry Creek Habitat Restoration					
Strawberry Creek Improvements on RNSP Property (Reaches A-C)					
Cost Summary Sheet					
Item	**Description**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**
Implementation Phase					
1.	Mob/Demob/Cleanup	1.0	LS	$ 15,000	$ 15,000
2.	Water Diversion, erosion sediment control	1.0	LS	$ 10,000	$ 10,000
3.	Fish Removal	2.0	LS	$ 2,000	$ 4,000
4.	SOC Culvert Replacement (See SOC Culvert Replacement Cost Sheet for detail)	1.0	LS	$ 23,920	$ 23,920
5.	West Tributary Culvert Replacement (See West Tributary Culvert Replacement Cost Sheet for detail)	1.0	LS	$ 22,030	$ 22,030
6.	RCG Mat Excavation	4.0	AC	$ 5,000	$ 20,000
7.	Clearing Vegetation (Upland)	1.0	AC	$ 1,000	$ 1,000
8.	Streambank Area Planting Scheme (See Vegetation Scheme Cost Sheet)	1.2	AC	$ 71,097	$ 86,062
9.	Flat Area Planting Scheme (See Vegetation Scheme Cost Sheet)	2.0		$ 30,153	$ 59,215
10.	Upland Area Riparian Planting (See Vegetation Scheme Cost Sheet)	0.6	AC	$ 2,462	$ 1,420
11.	Ponded Area Planting (See Vegetation Scheme Cost Sheet)	0.2	AC	$ 30,153	$ 4,692
12.	Channel Realignment (See Channel Realignment Cost Sheet for detail)	1.0	LS	$ 111,000	$ 111,000
13.	Elk Exclusion Fencing	3000.0	LF	$ 10	$ 30,000
	Estimating Contingency @ 10%				$ 39,000
Subtotal					**$ 427,339**
Construction Management and Inspection					
13.	Construction Inspection	1.0	DAY	$ 850	$ 850.00
14.	Construction Management	15.0	DAY	$ 600	$ 9,000.00
15.	Cultural Monitoring	5.0	DAY	$ 800	$ 4,000.00
SUBTOTAL CONSTRUCTION					**$ 441,189.04**
Monitoring and Maintenance					
15.	Vegetation Monitoring (Two monitoring events per area planted)	27.0	HOUR	$ 75	$ 2,025
16.	Maintenance (CA Cons. Crew 3 years)	10.0	DAY	$ 1,040	$ 10,400
Subtotal					**$ 12,425.00**
SUBTOTAL CONSTRUCTION & MONITORING					**$ 453,614.04**
Final Design and Environmental Documentation					
17.	Project Management	1.0	LS	$ 4,000	$ 4,000
Engineering and Design					
18.	Additional topographic survey	1.0	LS	$ 5,000	$ 5,000
19.	Final Engineering Design of Culvert Crossings	2.0	LS	$ 8,500	$ 17,000
20.	Final Realigned Channel Design	1.0	LS	$ 25,000	$ 25,000
21.	Revegetation Design	1.0	LS	$ 12,000	$ 12,000
Permitting and Environmental Documents					
22.	Permitting and Environmental Documentation	1.0	LS	$ 10,000	$ 10,000
SUBTOTAL DESIGN AND DOCUMENTATION					**$ 73,000**
TOTAL					**$ 526,614**

Lower Strawberry Creek Habitat Restoration					
RNSP SOC Culvert Replacement					
Cost Sheet					
Item	**Description**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**
Replace Crossing with 11' 10" x 7' 7" Corrugated Metal Pipe Arch Culvert					
1	Culvert Disposal	1.0	LS	$ 500	$ 500
2	Excavation for Installation	200.0	CY	$ 5	$ 1,000
3	11' 10" x 7' 7" CMPA	36.0	LF	$ 175	$ 6,300
4	Install New Culvert	1.0	EA	$ 5,000	$ 5,000
5	Bedding Stone	11.0	CY	$ 20	$ 220
6	Placement of Streambed Material Inside Culvert	90.0	CY	$ 60	$ 5,400
7	Roadway Gravel	20.0	CY	$ 25	$ 500
8	Erosion Control and Soil Stabilization	1.0	LS	$ 5,000	$ 5,000
				Total	**$ 23,920**

Lower Strawberry Creek Habitat Restoration					
RNSP West Tributary Culvert Replacement					
Cost Sheet					
Item	**Description**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**
Replace Crossing with 6' 9" x 4' 1" Corrugated Metal Pipe Arch Culvert					
1	Culvert Disposal	1.0	LS	$ 500	$ 500
2	Excavation for Installation	130.0	CY	$ 5	$ 650
3	6' 9" x 4' 1" CMPA	32.0	LF	$ 150	$ 4,800
4	Install New Culvert	1.0	EA	$ 5,000	$ 5,000
5	Bedding Stone	9.0	CY	$ 20	$ 180
6	Placement of Streambed Material Inside Culvert	90.0	CY	$ 60	$ 5,400
7	Roadway Gravel	20.0	CY	$ 25	$ 500
8	Erosion Control and Soil Stabilization	1.0	LS	$ 5,000	$ 5,000
				Total	**$ 22,030**

Lower Strawberry Creek Habitat Restoration

RNSP Channel Realignment

Cost Sheet

Item	Description	Qty	Unit	Unit Cost	Total Cost
1	Excavation for 1,500 LF new channel	6000.0	CY	$ 8	$ 48,000
2	Streambed material 0.5' thick (assume from Redwood Creek)	150.0	CY	$ 20	$ 3,000
3	Rock/Log Profile Control Structures	20.0	EA	$ 2,000	$ 40,000
4	Log Cover Structures	10.0	EA	$ 2,000	$ 20,000
5	Rock Slope Protection		TON	$ 65	$ -
				Total	**$ 111,000**

Lower Strawberry Creek Habitat Restoration					
Reaches D-F Improvements (Excluding Culvert Replacements)					
Cost Summary Sheet					
Item	**Description**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**
Implementation Phase					
1.	Mob/Demob/Cleanup	1.0	LS	$ 10,000.00	$ 10,000.00
2.	Water Diversion, erosion sediment control	1.0	LS	$ 10,000.00	$ 10,000.00
3.	Fish Removal	2.0	LS	$ 2,000.00	$ 4,000.00
4.	RCG Mat Excavation	0.5	AC	$ 10,000.00	$ 5,000.00
5.	In-Channel RCG Excavation	1.0	LS	$ 6,000.00	$ 6,000.00
6.	Streambank Area Planting Scheme (See Vegetation Scheme Cost Sheet)	2.4	AC	$ 71,096.50	$ 167,502.77
7.	Flat Area Planting Scheme (See Vegetation Scheme Cost Sheet)	7.7	AC	$ 30,153.45	$ 232,657.82
8.	Upland Area Riparian Planting (See Vegetation Scheme Cost Sheet)	0.0	AC	$ 2,462.00	$ -
9.	Ponded Area Planting (See Vegetation Scheme Cost Sheet)	0.0		$ 30,153.45	$ -
10.	Removal of High Points In Channel	350.0	CY	$ 10.00	$ 3,500.00
11.	Cattle Exclusion Fencing	1670.0	LF	$ 10.00	$ 16,700.00
	Estimating Contingency @ 10%				$ 46,000.00
Subtotal					**$ 501,360.58**
Construction Management and Inspection					
12.	Construction Inspection	15.0	DAY	$ 850.00	$ 12,750.00
13.	Construction Management	1.0	DAY	$ 600.00	$ 600.00
14.	Cultural Monitoring	2.0	DAY	$ 800.00	$ 1,600.00
SUBTOTAL CONSTRUCTION					**$ 516,310.58**
Monitoring and Maintenance					
14.	Vegetation Monitoring (Two monitoring events per area planted)	81.0	HOUR	$ 75.00	$ 6,075
15.	Maintenance (CA Cons. Crew 3 years)	31.0	DAY	$ 1,040.00	$ 32,240
Subtotal					**$ 38,315.00**
SUBTOTAL CONSTRUCTION & MONITORING					**$ 554,625.58**
Final Design and Environmental Documentation					
16.	Project Management	1.0	LS	$ 1,000.00	$ 1,000.00
Engineering and Design					
17.	Engineering	1.0	LS	$ 5,000.00	$ 5,000.00
18.	Revegetation Design	1.0	LS	$ 8,000.00	$ 8,000.00
Permitting and Environmental Documents					
19.	Permitting and Environmental Documentation	1.0	LS	$ 5,000.00	$ 5,000.00
SUBTOTAL DESIGN AND DOCUMENTATION					**$ 19,000.00**
TOTAL					**$ 573,625.58**

Lower Strawberry Creek Habitat Restoration					
Reach G Improvements					
Cost Summary Sheet					
Item	**Description**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**
Implementation Phase					
1.	Mob/Demob/Cleanup	1.0	LS	$ 2,000.00	$ 2,000.00
2.	Water Diversion, erosion sediment control	1.0	LS	$ 3,000.00	$ 3,000.00
3.	Fish Removal	1.0	LS	$ 2,000.00	$ 2,000.00
4.	In-Channel RCG Excavation	1.0	LS	$ 2,000.00	$ 2,000.00
5.	Streambank Area Planting Scheme (See Vegetation Scheme Cost Sheet)	0.5	AC	$ 71,096.50	$ 38,337.60
6.	Flat Area Planting Scheme (See Vegetation Scheme Cost Sheet)	2.0	AC	$ 30,153.45	$ 59,241.56
7.	Upland Area Riparian Planting (See Vegetation Scheme Cost Sheet)	0.0	AC	$ 2,462.00	$ -
8.	Ponded Area Planting (See Vegetation Scheme Cost Sheet)	0.0		$ 30,153.45	$ -
9.	Removal of High Points In Channel	220.0	CY	$ 10.00	$ 2,200.00
10.	Cattle Exclusion Fencing	720.0	LF	$ 10.00	$ 7,200.00
	Estimating Contingency @ 10%				$ 12,000.00
Subtotal					**$ 127,979.16**
Construction Management and Inspection					
11.	Construction Inspection	15.0	DAY	$ 850.00	$ 12,750.00
12.	Construction Management	1.0	DAY	$ 600.00	$ 600.00
13.	Cultural Monitoring	2.0	DAY	$ 800.00	$ 1,600.00
SUBTOTAL CONSTRUCTION					**$ 142,929.16**
Monitoring and Maintenance					
13.	Vegetation Monitoring (Two monitoring events per area planted)	21.0	HOUR	$ 75.00	$ 1,575
14.	Maintenance (CA Cons. Crew 3 years)	8.0	DAY	$ 1,040.00	$ 8,320
Subtotal					**$ 9,895.00**
SUBTOTAL CONSTRUCTION & MONITORING					**$ 152,824.16**
Final Design and Environmental Documentation					
15.	Project Management	1.0	LS	$ 500.00	$ 500.00
Engineering and Design					
16.	Engineering	1.0	LS	$ 2,000.00	$ 2,000.00
17.	Revegetation Design	1.0	LS	$ 2,000.00	$ 2,000.00
Permitting and Environmental Documents					
18.	Permitting and Environmental Documentation	1.0	LS	$ 1,000.00	$ 1,000.00
SUBTOTAL DESIGN AND DOCUMENTATION					**$ 5,500.00**
TOTAL					**$ 158,324.16**

Item	Description	Qty	Unit	Unit Cost		Total Cost	
Lower Strawberry Creek Habitat Restoration							
Reaches H-I Improvements, Including Zuber Culvert Replacement							
Cost Summary Sheet							
Implementation Phase							
1.	Mob/Demob/Cleanup	1.0	LS	$	5,000	$	5,000
2.	Water Diversion, erosion control	1.0	LS	$	2,000	$	2,000
3.	Fish Removal	2.0	LS	$	2,000	$	4,000
4.	Streambank Area Planting Scheme (See Vegetation Scheme Cost Sheet)	0.5	AC	$	71,097	$	38,551
5.	Flat Area Planting Scheme (See Vegetation Scheme Cost Sheet)	0.4	AC	$	30,153	$	11,266
6.	Upland Area Planting Scheme (See Vegetation Scheme Cost Sheet)	1.4	AC	$	2,462	$	3,388
7.	Roadway Gravel	0.0	AC	$	30,153	$	-
8.	Cattle Exclusion Fencing	3430.0	LF	$	10	$	34,300
9.	Clearing and Grubbing for culvert replacement	1.0		$	5,000	$	5,000
10.	Demo and dispose existing culvert	1.0	LS	$	5,000	$	5,000
11.	Excavation for culvert installation and streambed grading	50.0	CY	$	5	$	250
12.	16' x 40' Kernan Bridge	1.0	LS	$	77,220	$	77,220
13.	Placement of Streambed material inside culvert	93.0	CY	$	60	$	5,580
14.	Gravel Roadway	67.0	CY	$	25	$	1,675
	Estimating Contingency @ 10%					$	19,000
Subtotal						**$**	**212,230**
Construction Management and Inspection							
15.	Construction Inspection	10.0	DAY	$	850	$	8,500
16.	Construction Management	10.0	DAY	$	600	$	6,000
17.	Cultural Monitoring	1.0	DAY	$	800	$	800
SUBTOTAL CONSTRUCTION						**$**	**227,530**
Monitoring and Maintenance							
18.	Maintenance (3 years)	8.0	HOUR	$	75	$	600
19.	Maintenance (CA Cons. Crew 3 years)	3.0	DAY	$	1,040	$	3,120
Subtotal						**$**	**3,720**
SUBTOTAL CONSTRUCTION & MONITORING						**$**	**231,250**
Final Design and Environmental Documentation							
20.	Project Management	1.0	LS	$	1,000	$	1,000
Engineering and Design							
21.	Additional topographic survey	1.0	LS	$	3,000	$	3,000
22.	Geotechnical Investigation	1.0	LS	$	4,000	$	4,000
22.	Final Bridge Design	1.0	LS	$	10,000	$	10,000
23.	Revegetation Design	1.0	LS	$	6,000	$	6,000
Permitting and Environmental Documents							
24.	Permitting and Environmental Documentation	1.0	LS	$	8,000	$	8,000
SUBTOTAL DESIGN AND DOCUMENTATION						**$**	**32,000**
TOTAL						**$**	**263,250**

Lower Strawberry Creek Habitat Restoration					
Hiltons Road Culvert Replacement					
Cost Summary Sheet					
Item	**Description**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**
Replace Crossing with 40' Span Prefabricated Bridge					
1.	Mob/Demob/Cleanup	1.0	LS	$ 5,000	$ 5,000
2.	Water Diversion, erosion sediment control	1.0	LS	$ 2,000	$ 2,000
3.	Fish Removal	2.0	LS	$ 2,000	$ 4,000
4.	Signs and Traffic Control	1.0	LS	$ 5,000	$ 5,000
5.	Clearing and Grubbing	1.0	LS	$ 5,000	$ 5,000
6.	Demo and Dispose Existing Culvert	1.0	LS	$ 1,000	$ 1,000
7.	Excavation for Bridge Installation and Streambed Grading	83.0	CY	$ 5	$ 415
8.	16' x 40' Kernan Bridge Installed	1.0	LS	$ 77,220	$ 77,220
9.	Placement of Streambed material under crossing	93.0		$ 60	$ 5,580
10.	Bankline Rock	119.0	TON	$ 100	$ 11,900
11.	Gravel Roadway	67.0	CY	$ 25	$ 1,675
12.	Erosion control and soil stabilization	1.0	LS	$ 5,000	$ 5,000
13.	Water Line Relocation	1.0	LS	$ 5,000	$ 5,000
	Estimating Contingency @ 10%				$ 13,000
Subtotal					**$ 141,790**
Construction Management and Inspection					
14.	Construction Inspection	1.0	DAY	$ 850	$ 850
15.	Construction Management	10.0	DAY	$ 600	$ 6,000
16.	Cultural Monitoring	1.0	DAY	$ 800	$ 800
SUBTOTAL CONSTRUCTION					**$ 149,440.00**
Final Design and Environmental Documentation					
17.	Project Management	1.0	LS	$ 2,000	$ 2,000
Engineering and Design					
18.	Additional topographic survey	1.0	LS	$ 4,000	$ 4,000
19.	Geotechnical Investigation	1.0	LS	$ 4,000	$ 4,000
20.	Final Bridge Design	1.0	LS	$ 20,000	$ 20,000
Permitting and Environmental Documents					
21.	Permitting and Environmental Documentation	1.0	LS	$ 5,000	$ 5,000
SUBTOTAL DESIGN AND DOCUMENTATION					**$ 35,000**
				TOTAL	**$ 184,440**

Lower Strawberry Creek Habitat Restoration					
Transfer Station Culvert Replacement					
Cost Summary Sheet					
Item	**Description**	**Qty**	**Unit**	**Unit Cost**	**Total Cost**
Replace Crossing with 40' Span Prefabricated Bridge					
1.	Mob/Demob/Cleanup	1.0	LS	$ 5,000	$ 5,000
2.	Water Diversion, erosion sediment control	1.0	LS	$ 2,000	$ 2,000
3.	Fish Removal	1.0	LS	$ 2,000	$ 2,000
4.	Signs and Traffic Control	1.0	LS	$ 5,000	$ 5,000
5.	Clearing and Grubbing	1.0	LS	$ 5,000	$ 5,000
6.	Demo and Dispose Existing Culvert	1.0	LS	$ 5,000	$ 5,000
7.	Excavation for Bridge Installation, Lowering Streambed and Streambed Grading	104.0	CY	$ 5	$ 520
8.	16' x 40' Kernan Bridge Installed	1.0	LS	$ 77,220	$ 77,220
9.	Placement of Streambed material	93.0		$ 60	$ 5,580
10.	Bankline Rock	119.0	TON	$ 100	$ 11,900
11.	Asphalt Pavement	9.0	TON	$ 250	$ 2,250
	Estimating Contingency @ 10%				$ 12,000
Subtotal					**$ 133,470**
Construction Management and Inspection					
12.	Construction Inspection	10.0	DAY	$ 850	$ 8,500
13.	Construction Management	10.0	DAY	$ 600	$ 6,000
14.	Cultural Monitoring	1.0	DAY	$ 800	$ 800.00
SUBTOTAL CONSTRUCTION					**$ 148,770**
Final Design and Environmental Documentation					
15.	Project Management	1.0	LS	$ 2,000.00	$ 2,000
Engineering and Design					
16.	Additional topographic survey	2.0	LS	$ 2,000	$ 4,000
17.	Maintenance (3 years)	1.0	LS	$ 4,000	$ 4,000
18.	Final Bridge Design	1.0	LS	$ 20,000	$ 20,000
Permitting and Environmental Documents					
19.	Permitting and Environmental Documentation	1.0	LS	$ 5,000	$ 5,000
SUBTOTAL DESIGN AND DOCUMENTATION					**$ 35,000.00**
TOTAL					**$ 183,770**