FINAL

LOWER SALMON CREEK DELTA
SALMONID HABITAT ENHANCEMENT OPPORTUNITIES

HUMBOLDT BAY NATIONAL WILDLIFE REFUGE
HUMBOLDT COUNTY, CALIFORNIA

A Feasibility Scoping Report for the California Department of Fish and Game and Humboldt Bay National Wildlife Refuge

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1 Introduction

This project was funded through a planning grant from the California Department of Fish and Game's **Coastal Salmon Recovery Fund**. The project began in January 2002.

1.1 Project Location

The project's primary focus was the portion of the Salmon Creek Delta that lies within the Salmon Creek Unit of the Humboldt Bay National Wildlife Refuge. However due to the intricacies involved in the hydrologic, sediment transport and other connectivity issues within the lower reaches of the former tidal salt marsh area, topographic mapping and other evaluative efforts were also conducted on adjacent private lands. The topographic analysis conducted as part of this project included the surveying and mapping of over one hundred and ten (110) acres of land contained in two private parcels, both located alongside Salmon Creek between the boundary of the HBNWR and the county bridge on Hookton Road. Approximately one-third (1/3) of the ninety-seven (97) acre parcel adjacent to HBNWR, referred to as the "Vance Dairy", has an elevation below the range of normal tide cycles in South Humboldt Bay, and was particularly important to include in the analysis.

1.2 Overall Goals and Objectives

The overall goal of restoration efforts within the Salmon Creek Delta is to enhance habitat values for fish and wildlife. Pursuant to achieving this goal, this project has the specific objective of developing a planning document for the US Fish and Wildlife Service (USFWS) and the California Department of Fish and Game (CDFG) that presents options for improving salmonid access and habitat within the HBNWR portion of the Salmon Creek Delta.

1.3 Roles and Responsibilities of Project Team

The non-profit organization, Pacific Coast Fish Wildlife, and Wetlands Restoration Association (PCFWWRA), received the grant for this project. Mitch Farro from PCFWWRA was project manager, responsible for coordination between the HBNWR staff, the advisory group, and project consultants.

Michael Love, from Michael Love & Associates, was the project's engineering hydrologist and responsible for site investigations and monitoring, hydrologic analysis, and development of restoration alternatives.

Graham Mathews & Associates provided topographic surveying, digital mapping, CADD services, and assisted in site investigations and monitoring. Jeff Anderson, their principal engineer, was responsible for survey and mapping oversight, hydrologic/hydraulic modeling, and development and analysis of design elements and restoration alternatives.

At the beginning of the project an advisory committee was assembled to provide guidance. The committee was composed of local, State, and Federal resource agencies staff, representatives from local environmental restoration groups, and landowners from within the watershed. It met twice to provide input into development of the project's goals and objectives and various restoration options to be considered.

1.4 Overview of Document Structure

This report is organized to provide the reader with an understanding of the information and guiding goals and objectives that entered into the development of conceptual restoration options.

Section 1 describes the roles and responsibilities of the project team and broadly states the overall goals and objectives of the project.

Section 2 gives an overview of relevant research, reviews current Refuge management objectives as they pertain to the Salmon Creek Delta, and describes specific methods used in this report.

Section 3 discusses the historic conditions in Humboldt Bay and the Salmon Creek Delta, and summarizes the land use activities that lead to the current state of the delta.

Section 4 provides an overview of the findings resulting from the project's site investigations.

Section 5 outlines in detail the project goals, objectives, limitations and constraints.

Section 6 describes different design elements that can be implemented to achieve the stated goals and objectives.

Section 7 describes conceptual alternatives for access improvements and habitat enhancement for salmonids. These conceptual alternatives were placed into three categories: short-term, near-term, and long term alternatives.

Section 8 summarizes the alternatives, describes potential risks associated with each alternative, and discusses phasing between implementation of the alternatives.

2 Methodology

2.1 Review of Literature

2.1.1 Salmonid Usage of Tidal Estuaries

Until recently, the use of estuaries by juvenile salmonids received little attention. As research begins to focus on the role of the intertidal estuary in the lifecycle of anadromous salmonids, the importance of this habitat type is becoming evident.

One of the most comprehensive research studies to date was performed by Miller and Sadro (2000). They investigated juvenile coho usage of the estuarine portion of Winchester Creek, a tributary to South Slough, Coos Bay, Oregon. During a 16-month period they found at least three different life-stages of juvenile coho used the estuary: age-0 fry entering in spring, pre-smolts entering in fall and winter, and age-1 smolts entering in spring.

In all cases growth rates within estuarine habitat was significantly more than that measured upstream. Age-0 fry in the upper estuarine habitat had growth rates almost double of fish sampled in the upper watershed. The highest growth rates were found in a tidal marsh adjacent to the main channel and in an off-channel brackish beaver pond. No spawning habitat existed upstream of the pond, indicating that the juveniles had migrated through the tidal estuary and into the pond.

Dye marked age-0 coho were found to utilize the estuarine habitat for more than three months during spring. Results suggest that the age-0 fry may have reentered the upper portions of the stream as summer water temperatures and salinity increased within the upper estuary. During summer months no salmonids were found rearing in the estuary.

2.1.2 Vegetation Characteristics of Tidal Wetlands

The make-up and function of tidal marshes are highly dependent on site specific dynamics of the tide cycle. The duration soil is inundated by saltwater is a governing factor in what plant species, if any, become established. For restoration purposes, it is important to establish the range of tidal elevations in which specific salt marsh species are found. With this information restoration designs can attempt to create tidal wetlands with predictable species composition. Also, careful selection of constructed wetland elevations can sometimes be used to hinder colonization by a targeted invasive species.

Eicher (1987) performed a survey of vascular plants within the salt marshes of Humboldt Bay and related the distribution of commonly found species to a tidal datum (Table 2.1). The study sites were located within the salt marshes of Arcata and Entrance Bay. Findings indicate that salt marsh plants in Humboldt Bay are found between tidal elevations of 5.7 and

Table 2.1 - Vascular salt marsh species found in Humboldt Bay and the range of tidal elevations they inhabit (Eicher, 1987). Elevations are measured from the mean lower low water (MLLW) datum.

		Entrance[1] & Arcata Bays	
Species	**Common Name**	**Min Elev. (ft)**	**Max Elev. (ft)**
Salicornia virginica	pickleweed	5.7	8.4
Spartina densiflora	cordgrass	5.8	8.0
Jaumea carnosa	jaumea	6.5	8.4
Triglochin maritimum	common arrowgrass	5.8	8.4
Triglochin concinnum	slender arrowgrass	7.0	8.4
Spergularia canadensia	sand-spurrey	7.1	7.7
Cordylanthus maritimus ssp. *palustris*	bird's beak	7.0	8.4
Atriplex patula ssp. *hastata*	orache, saltbrush	6.8	7.9
Distichlis spicata	saltgrass	6.2	8.4
Limonium californicum	sea lavender, marsh rosemary	7.0	8.4
Plantago maritima var. *juncoides*	sea plantain	7.2	8.2
Custuta salina	marsh dodder	7.2	8.4
Carex lyngbyei	Lyngby's sedge	7.4	7.7
Grindelia stricta ssp. *blakei*	Humboldt Bay gum plant	6.6	8.4
Scirpus cernuus ssp. *californicus*	slender club rush	7.5	7.9
Spergularia macrotheca	sand-spurrey	7.5	8.4
Scipus maritimus	saltmarsh bulrush	7.7	7.7
Juncus lesueurii	salt rush	7.7	7.7
Parapholis	curved sea hard-grass	7.3	7.9
Orthocarpus castillejoides var. *humoldtiensis*	Humboldt Bay owl's clover	7.7	8.4
Deschampsia caespitosa	tufted hairgrass	6.8	6.9

[1] Tidal elevation for species surveyed in the Elk River slough were adjusted by +1.9 feet to correct for a downstream control that produced a backwater effect at MLLW.

8.4-feet (MLLW datum). Mudflats persisted at elevations below 5.7-feet and freshwater vegetation was found at elevations above 8.4-feet.

Creating a rating-curve relating the average daily duration various elevations are covered by saltwater can be used to determine the amount of inundation a saltmarsh species can endure (Masters et al., 2002). Overlaying the minimum and maximum tidal elevations that local saltmarsh species inhabit onto this curve will provide the upper and lower duration of inundation the species needs to survive. This relationship can then be applied to wetland designs that use an engineered muted tide cycle.

2.1.3 Muted Tide cycle

A muted tide cycle is a means of introducing or reintroducing a tidal cycle into an area that has either been diked and drained, subsided, or where upstream flood constraints limit the volume of tidal flux (tidal prism) that can inundate an area. As Haltiner and Williams (1987) point out, salt marsh restoration may be accomplished in former tidal areas which have subsided by re-introducing a muted tidal cycle. The rate of tidal flux in diked areas can be limited by designing the capacity and elevation of drainage structures to limit the ebb and flow of bay water into and out of a site. Hydraulic calculations are used to determine the specification necessary to create an artificial tidal inundation regime which is lower in elevation and of shorter duration than in the bay. New tidegate technologies may also be used to fine tune or seasonally adjust the artificial tidal regime to close tolerances. The muted tidal regime concept could be used in the lower Salmon Creek project area to restore tidal wetland/estuary habitat without extensive construction of new levees and without further impacting upstream flood conditions.

2.2 Review of Humboldt Bay NWR Existing Management Plan

The mission statement of the National Wildlife Refuges system is:

> *"To provide, preserve, restore, and manage a national network of lands and waters sufficient in size, diversity, and location to meet society's needs for areas where the widest possible spectrum of benefits associated with wildlife and wildlands is enhanced and made available."*

The Humboldt Bay National Wildlife Refuge (HBNWR) Management Plan was completed in October 1989 (USFWS, 1989). At that time the existing and proposed Refuge boundaries encompassed 8,935 acres. The Refuge was divided into ten management units. The historic range of the Salmon Creek Delta, the focus of this report, falls within the Salmon Creek, Hookton Slough, and White Slough Units. Under existing conditions the Salmon Creek stream corridor lies within the southern portion of the Salmon Creek Unit.

The HBNWR management plan specifically lists seven management objectives. Those that support or constrain the development of habitat enhancement options for the Salmon Creek Delta include:

- Restore the lower end of Salmon Creek to a more natural state and thereby increase opportunity for anadromous fish passage upstream as well as increase habitat diversity.
- Maintain a tideland ecosystem in which there will be limited disturbance to habitat, wildlife, and fisheries.
- Provide optimum wintering and migratory waterbird use through habitat management of formal tidal marsh which is now diked seasonal wetlands.
- Obtain optimum levels of habitat diversity which are compatible with other Refuge objectives.

The remaining three objectives are focused on public education and brant habitat, which lies outside of the Salmon Creek Delta.

The Management Plan provides a broad outline for guiding habitat development. Prescribed actions that directly support fisheries include restoration of Salmon Creek into a natural stream course and modification of tidegates to allow fish passage and promote development of estuarine conditions. The plan proposes recreating saltmarsh and intertidal habitat within the existing lower Salmon Creek corridor.

The enhancement and enlargement of the Salmon Creek estuary is limited to the southern portion of the Salmon Creek Unit. Within the remaining portions of the unit the management plan proposes maintaining and developing freshwater ponds, grasslands, and woodlands to broaden habitat diversity and encourage usage by migratory and over-wintering waterbird populations.

Since the completion of the HBNWR Final Management Plan in 1989, several of its proposed actions for habitat enhancement within the Salmon Creek Unit have been implemented. They include creating a small permanent opening in the Salmon Creek tidegate to improve fish passage, relocating the lower portion of the Salmon Creek channel out of the linear leveed channel and into a more natural channel, and creation of numerous seasonal freshwater wetlands for bird usage.

This project has attempted to work within the framework of the existing management plan through assessing the effectiveness of previous habitat enhancement projects within the Refuge associated with Salmon Creek, and by developing design elements and conceptual alternatives that improve salmonid access and habitat while striving to preserve a diverse range of habitat types.

2.3 Tidal Routing Model

For each of the conceptual alternatives developed and described in Section 7, a hydrologic/hydraulic analysis was conducted to demonstrate the effects of providing a larger tidal prism (muted tide cycle) on existing site conditions, tidal wetland habitat, and flooding. The analysis of each conceptual alternative was done with a developed model which dynamically simulates the marsh tidal cycle from a typical tidal cycle in Hookton Slough (or Humboldt Bay) by analyzing tidal flow hydraulics through different marsh openings (i.e.

culverts or levee breaches), gated culverts, and levee overtopping (Anderson, 2001). This type of analysis, also known as tidal routing, consists of determining the volume of water that flows through an opening for a given time increment, and then adding (for flood tides) or subtracting (for ebb tides) this volume to the existing volume of water in the marsh (Haltiner and Williams, 1987). With the model, the effects of different damped tidal elevations in the marsh can be evaluated with respect to existing and proposed topographic conditions in the marsh restoration site. The model also allows a flood hydrograph to be routed through the marsh area to determine the effects of different marsh openings and elevation/surface-area/volume relationships on the outflow hydrograph and upstream water surface elevations.

The model is based on the principals of lumped flow routing (hydrologic routing), and predicts the change in flow (i.e., the flow hydrograph) at a particular location as a function of time alone (Chow *et al*., 1988). Lumped flow routing can be described by the following form of the continuity equation

$$\frac{dH}{dt} = \frac{Qin(t) - Qout(t)}{A(H)} \qquad (1)$$

where H is the water elevation in the marsh, $A(H)$ is the marsh water surface area at elevation H, and $Qin(t)$ is the inflow and $Qout(t)$ is the outflow as a function of time(t), respectively.

For this analysis, $Qin(t)$ is composed of Salmon Creek discharge, and tidal inflow from Hookton Slough through the marsh openings (tidegates) and levee overtopping during extreme high tides or flood events. $Qout(t)$ is composed of outflow from the marsh to Hookton Slough through the marsh openings and levee overtopping.

The continuity equation (eq. 1) was solved using a fourth order Runge-Kutta numerical method to solve the differential equation. The model was developed as a Fortran program, and executed on a personal computer. Model output consists of predicted marsh tidal elevations, areas, and storage volumes; along with estimated inflow and outflow hydrographs. Required input and boundary conditions to the model consists of 1) initial conditions (depth, volume, area) in the marsh, 2) Salmon Creek hydrograph, 3) rating surface tables for the marsh opening and gated culverts, 4) length and average elevation of the levee, 5) Hookton Slough (Humboldt Bay) tidal elevations, and 6) a stage/surface-area and stage/volume table for the marsh area. A 0.1-hour (6-minute) time step was used in all model computations.

The developed model was used to evaluate the potential effects of modified outlet drainage facilities and restored intertidal marsh plain on water surface elevations during both winter base flow conditions, and flood discharge conditions in Salmon Creek synchronized with higher high water (HHW) conditions (i.e. higher high tides) at Hookton Slough (the lower boundary of the project reach). Tidal elevations developed by NOAA for the Humboldt Bay North Spit (Station No. 9418767) were corrected to represent conditions in Hookton Slough. Although there will be variations in tidal elevations between the two locations, they are likely to be minor (on the order of about 0.1-0.3 feet) and were considered insignificant for this preliminary assessment.

3 Project Setting

Humboldt Bay is located along the northern California coast, approximately 250 miles north of San Francisco Bay. It is one of the largest coastal estuaries within California, and is the only deep-water commercial port between San Francisco and Coos Bay, Oregon. The largest city on the bay is Eureka, with smaller communities located along its eastern and western shores (Figure 3.1).

The bay is commonly broken into three separate units, Arcata Bay, Entrance Bay, and South Bay. Both Arcata and South Bay consists primarily of shallow mudflats.

No large rivers enter the bay. However, it does have four tributaries of substantial size supporting viable runs of anadromous salmonids. These tributaries also provide most of the freshwater inputs to the bay. From north to south they are Jacoby Creek, Freshwater Creek, Elk River, and Salmon Creek. All four flow into the bay along its eastern shore. A number of smaller tributaries also drain into the bay, but most are highly altered and no longer sustain salmon or steelhead runs.

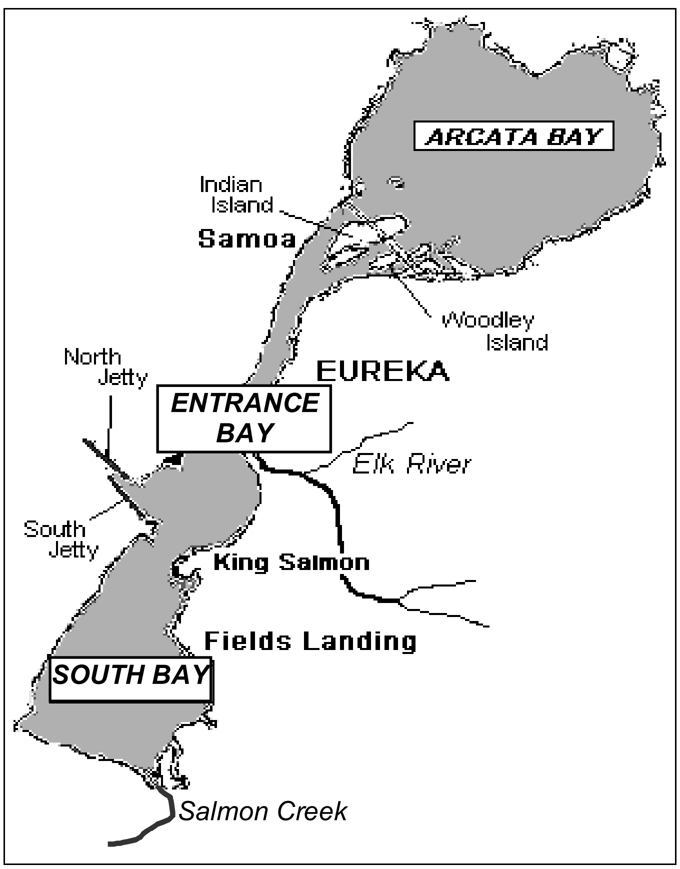

Figure 3.1 - Overview map of Humboldt Bay (adapted from Bartosh and Phelps, 2001).

Salmon Creek Delta is located at the southeast corner of South Bay. It is bordered to the east by Highway 101, to the southwest by Hookton Road, and to the northwest by the mudflats and tidal channels of South Bay. The delta, as defined, covers approximately 2.8 square miles (mi^2).

3.1 Land Use within the Salmon Creek Watershed

The Salmon Creek Watershed is approximately 18 mi^2 in size. Land use within the lower portion of the watershed consists primarily of pasture for livestock. Much of the upper portion of the watershed consists predominately of redwood and Douglas fir forests. Timber harvesting began within the watershed after the construction of the first lumber mill along Salmon Creek in 1856 (Humboldt Times, 1856). By 1875 a couple additional mills had been erected along Salmon Creek. By the early 1900's much of the forests within the basin had been logged (PWA, 2000). In the 1940's a second round of timber harvesting began. With the harvesting came extensive road building.

In March of 1999 the upper one-third (1/3)of the watershed was publicly acquired in an effort to protect the privately owned old growth coastal redwood groves in what is now known as the Headwaters Forest Preserve. The upper 3,500 acres of the Salmon Creek watershed are now managed by The Bureau of Land Management for protection and restoration of the late seral redwood forest and its dependent aquatic and terrestrial wildlife while allowing compatible public use. Simpson Resource Company and several small parcel owners manage most of the remaining upland portion of the watershed for timber production. The lower "bottom" lands are used extensively for livestock grazing in both naturally occurring and converted grasslands.

3.2 Historic Usage of Salmon Creek Delta

In the 1850's, when settlers of European origin began arriving in Humboldt Bay, people of the Wiyot tribe inhabited the surrounding lands. The tribe's population was estimated to be about 1,000 persons in the 1850's (Barnhart et al., 1992). The Wiyot maintained a seasonal fishing village adjacent to the Salmon Creek Delta, and tribal history places South Bay as one of their best fishing areas (Nina Hapner with Table Bluff Rancheria, Per. Comm. 2/13/02 meeting).

In 1870, the United States Coastal Survey mapped in detail the entire bay and associated mudflats and salt marshes (USFWS, 2002). By 1870 Arcata Bay had already experienced diking and draining of saltmarsh. However, no such activities had yet occurred in South Bay.

Growth in the logging industry along Salmon Creek in the 1880's initiated the modification of the delta area. To accommodate for the influx of lumber, the Hookton channel was dredged in 1883 (ACOE, 1977). This became one of the main channels in South Bay, running past the lumber outpost of Field's Landing.

In 1901 the Northwestern Pacific Railroad was completed. It ran along the eastern margins of Humboldt Bay and led to a rapid increase in diking and filling of saltmarsh. The construction of Highway 101 in 1927 also aiding in the reclamation effort, with the fill used to build the road functioning as an additional levee in numerous locations around the bay. By then most of the saltmarsh along the eastern shores of the bay had been diked, drained and converted to agricultural lands. The more than 7,000 acres of saltmarsh that had historically existed in Humboldt Bay in 1870 had been reduced to less than 970 acres by 1980, (Shapiro et al. 1980).

The Salmon Creek Delta did not escape reclamation (Figure 3.2). In 1900, the Z. Russ and Sons Company, created a reclamation district for 1,500 acres of saltmarsh within the Salmon Creek Delta. By 1907 hundreds of cattle were pastured on newly reclaimed lands and the Z. Russ and Sons Company requested to construct additional levees to increase their pasturelands (Van Kirk, 1998).

During the conversion of saltmarsh to agricultural lands, Salmon Creek and its former tributary, Willow Brook, were channelized. Prior to agricultural conversion, Salmon Creek's main channel flowed north through White Slough. However, during the conversion the main channel was relocated to exit directly into Hookton Slough through a set of tidegates. A series of irrigation ditches and three diversion structures were also constructed to use water from Salmon Creek for sub-irrigating pasture and farmlands and provide drinking water for livestock during dry months. The system of ditches also maximized drainage and was operated to promote siltation within the lower portions of the ranch in an effort to raise the land's overall elevation.

In September 1971 proposed Refuge boundaries where establish, which included the Salmon Creek Delta. In 1988 the land was purchased by the Federal Government and placed under the management of the USFWS.

3.3 Basin Hydrologic Characteristics

The Salmon Creek Watershed lies in the coastal hills of northwestern California. Its watershed area encompasses approximately 18 mi^2. As is characteristic throughout the region, significant precipitation falls between November and April, with drier weather persisting for the remaining months. Due to its low elevation and proximity to the Pacific Ocean, the Salmon Creek Watershed receives almost all of its precipitation in the form of rainfall. On average, the lower lying portions of the basin receive approximately 40 to 45 inches of rainfall annually. Due to orographic effects, the upland areas within the watershed receive between 50 and 65 inches of rainfall annually (PRISM, 2001).

Salmon Creek is the only sizable stream that flows into South Bay. As with most streams within coastal Northern California, Salmon Creek experiences its peak flow events between November and March. The stream is highly responsive to rainfall events, with flows both rising and falling rapidly. The average annual flood (1.2-year recurrence interval) is roughly 1,100 cubic feet per second (cfs). Within the low-lying portions of the basin the stream frequently overtops its banks and inundates adjacent pasturelands. Hookton Road is

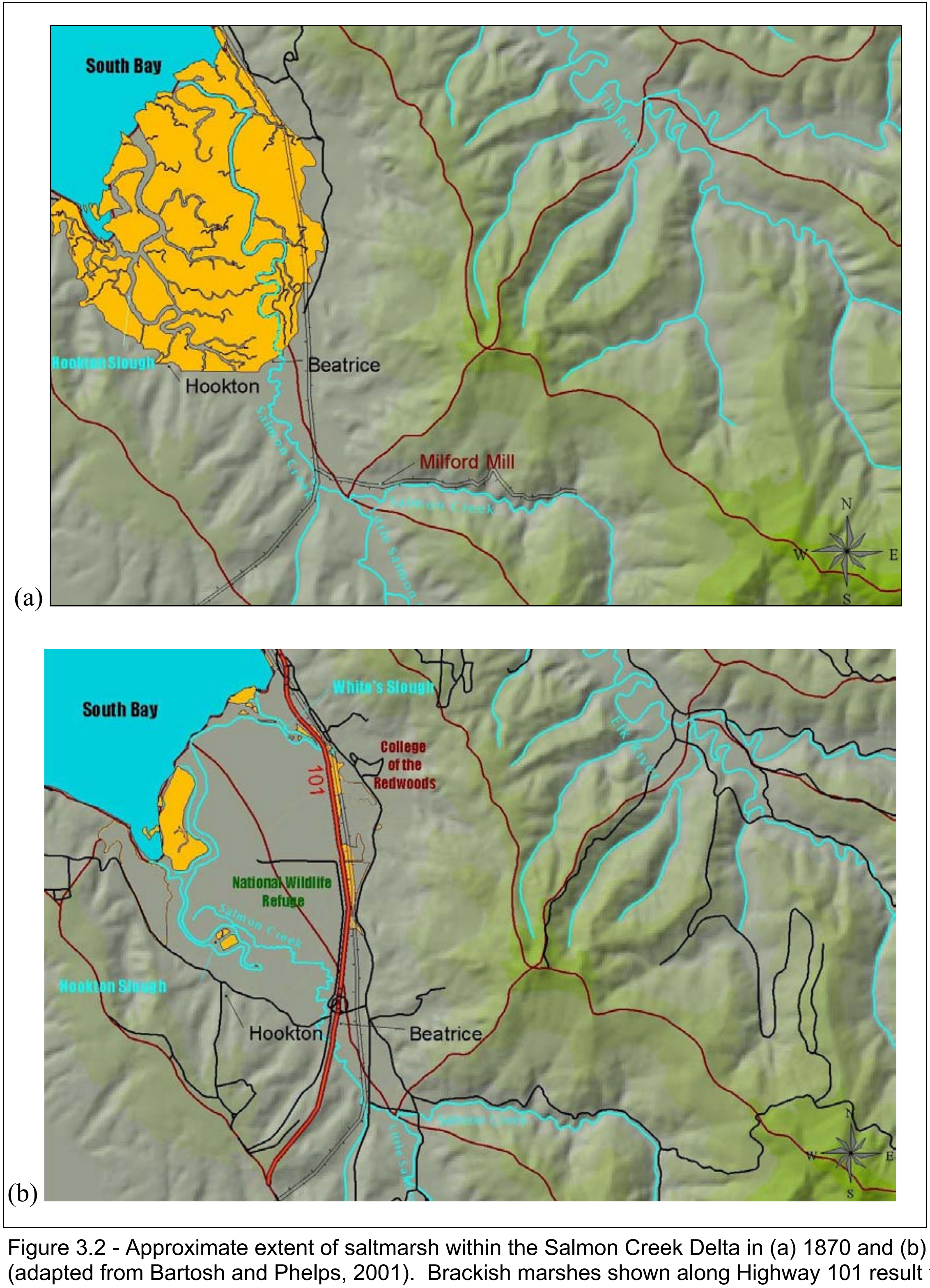

Figure 3.2 - Approximate extent of saltmarsh within the Salmon Creek Delta in (a) 1870 and (b) 1993 (adapted from Bartosh and Phelps, 2001). Brackish marshes shown along Highway 101 result from a leaky tidegate.

frequently closed due to flooding. During the winter of 2001-2002, which produced average rainfall amounts for the region, the stream inundated Hookton Road on at least four separate occasions. During December of 2002 flooding was extensive in both area of impact and duration. Even portions of Highway 101 were inundated for a short period.

Extended periods of no precipitation are common in summer and early fall. During dryer months of the year flows within Salmon Creek decline to less than one cubic feet per second.

3.4 Tidal Characteristics of Hookton Slough

Salmon Creek flows into Hookton Slough, located in the southeast corner of Humboldt Bay. The Hookton Slough tidal station (no. 9418723), located at the mouth of the slough near Long Pond, was operated from 1977 to 1979. The tidal station experienced an average daily tidal flux of 6.85 feet (MLLW to MHHW), and recorded the mean tide level at 3.69 feet above the MLLW.

3.5 Native Fisheries

As its name implies, Salmon Creek historically had large runs of chinook and coho salmon. In addition to salmon, anadromous steelhead and coastal cut-throat trout were historically found throughout the watershed. Although the stream continues to support populations of all four native anadromous salmonid species, their populations are believed to have dramatically declined over the past 150 years.

In an effort to gather some baseline information, an adult fish trap was operated within the Refuge periodically. An upstream adult migrant fish trap was placed in the stream channel during winter flows for five consecutive years. Results showed chinook, coho, and steelhead continue to use Salmon Creek and its tributaries (Table 3.1).

Table 3.1 - Results from upstream adult migrant trapping on lower Salmon Creek, within the HBNWR (Van Kirk, 1998).

	Coho	Chinook	Steelhead
Dec. 1990 – March 1991	23	17	41
Jan. 1992 – March 1992	1	1	17
Dec. 1992 – March 1993	15	1	17
Dec. 1993 – March 1994	6	1	19
Nov. 1994 – March 1995	11	5	20

3.6 Description of the HBNWR Salmon Creek Unit

3.6.1 Geology and Soils

The Salmon Creek Unit of the HBNWR is flanked on two sides by active faults. The Table Bluff Fault runs along the base of Tompkins Hill to the south. The geology within this region is part of the Hookton Formation. The Little Salmon Fault runs along the eastern side of the Refuge. The hills to the east are part of the Wildcat Group (Shapiro & Assoc., 1980).

The soils within the Refuge are composed of recent fluvial deposits. The southern portion of the Refuge consists predominately of sands and silts. Moving to the north the soils become more clay dominated.

3.6.2 Topography

The topography of the Refuge is relatively flat with many small features. Numerous historic tidal channels are still evident within the landscape of the Refuge. With exception of the levees, most of the Refuge lies below mean higher high-tide. Elevations range between 2-feet and 9-feet (NAVD88 datum), with lowest elevations found in the northwest corner of the Refuge and the highest elevations occurring to the south near the highway.

3.6.3 Infrastructure

Recently the Refuge constructed a new headquarters and visitor center. In addition to the new building, there also exist several outbuildings used for maintenance and equipment storage. The main access road along the east side of the Refuge is paved. The remaining maintained roads are gravel, with most located along the tops of levees. Most of the levees within the Refuge have been upgraded and improved in the 1980's. Tidegates are located in seven locations within the Refuge (Figure 3.3). The northern tidegate system adjacent to White Slough was reconstructed in 1993. U.S. Highway 101, Hookton Road and the private land with residences south of Hookton Slough are all infrastructures within the flood plain of Salmon Creek that were also considered in the development of habitat improvement options.

3.6.4 Recent Habitat Enhancement Projects

Since the creation of the Salmon Creek Unit of HBNWR, a number of habitat enhancement projects have been implemented. Each project has matched the Refuge's general management plan and objectives. They include:

- Construction of numerous seasonal freshwater ponds in the central portion of the Refuge,
- Construction of a 2,500-feet reach of meandering stream channel for Salmon Creek to improve stream habitat quality,
- Extensive tree planting within the riparian corridor of Salmon Creek and along Highway 101,
- Installation of a "fish door" on the Salmon Creek tidegate to improve access for salmon and steelhead.
- Completion of a Watershed Assessment for Salmon Creek in 1999 including prescriptions for the treatment of sediment sources with likely future delivery to stream channels.

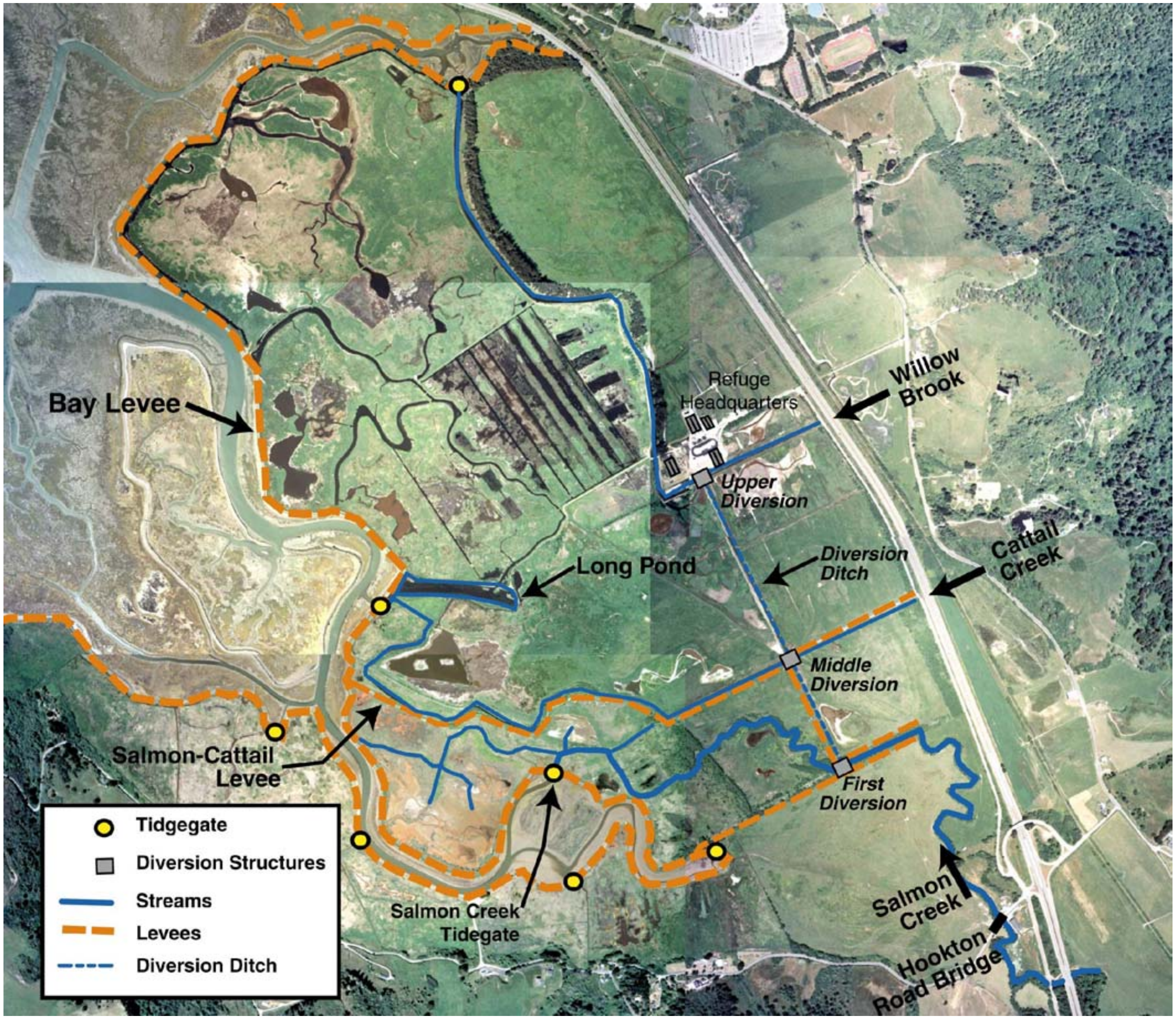

Figure 3.3 - Humboldt Bay National Wildlife Refuge Salmon Creek Unit site map.

Since the summer of 2000, three seasons of implementing prescribed erosion reduction treatments have been conducted through the removal or decommissioning of roads within the Headwaters Forest Reserve and on private timberlands in the Salmon Creek Watershed.

3.6.5 Current Water Management Operations

The HBNWR Salmon Creek Unit is composed of a complex arrangement of ponds, levees, diversion structures, drainage ditches, and tidegates. Each plays a role in creating a mixture of habitat types while providing drainage for storm runoff.

Three individual streams flow into the Refuge: Salmon Creek, Willow Brook, and Cattail Creek. The latter two are small intermittent streams. Willow Brook enters the Refuge after emerging from under Highway 101. A flashboard structure, which is located where the stream enters the Refuge, is used during dry periods to halt the inflow of saltwater that reaches Willow Brook through leaky tidegates located on adjacent property east of the highway. Willow Brook then flows through the Upper Diversion before exiting through a tidegate and into White's Slough at the northern end of the Refuge.

Like Willow Brook, Cattail Creek enters the Refuge after emerging from under Highway 101. It has a substantially smaller drainage area than Willow Brook and is reported to produce considerably less flow. After entering the Refuge it flows in a ditch through the Middle Diversion and then along the north side of the Salmon-Cattail Levee. After flowing through approximately 8,000 feet of ditch, waters from Cattail Creek eventually drain into Long Pond.

Long Pond, located along the Bay Levee, is a large brackish pond that serves as a collection and discharge basin for much of the waters draining from the Refuge. The pond receives flow from Cattail Creek and from several freshwater channels that drain wetlands to the north. The water surface elevation of the pond is managed through a set of tidegates equipped with flashboards.

Salmon Creek approaches the Refuge from the southeast, crossing under bridges located on Highway 101, Loleta Drive, and Hookton Road. Between Loleta Drive and the Refuge the stream flows in an entrenched channel, flanked by pastureland and a vacant dairy facility. Just as it enters the Refuge, the stream channel becomes linear, flowing in a straight, leveed channel. At the end of this reach the stream passes uninterrupted through the First Diversion, which is no longer actively operated. Downstream of the First Diversion the stream flows through a meandering channel that was constructed in 1993, eventually reaching the lower tidal estuary and the Salmon Creek tidegate.

Downstream of the First Diversion overbank flow in Salmon Creek is separated from the rest of the Refuge by the Salmon-Cattail Levee, which runs from the Middle Diversion to the Bay Levee. This levee separates Cattail Creek from the Salmon Creek system, directing Cattail Creek into Long Pond rather than flowing into Salmon Creek.

During high flow events, typically occurring several times each year, Salmon Creek overtops the First Diversion. These waters fill the diversion ditch that runs to both Cattail Creek and Willow Brook. As a result, high flow events in Salmon Creek provide a substantial amount of freshwater to the seasonal wetlands within other portions of the Refuge. The water provided by these overbank flows is relied upon as a critical part of Refuge operations; creating seasonal freshwater habitat for overwintering and migratory waterbirds.

Recently a deep well was drilled to provide freshwater to seasonal wetland ponds in early fall prior to the onset of rains.

3.7 Locations of Historic and Current Channels

The map produced in 1870 by the United States Coastal Survey provides a useful picture of the historic Salmon Creek Delta prior to its conversion to agricultural lands (Figure 3.4). From the map it is evident that the delta was a dynamic system composed of multiple channels. The main channel appeared to flow into the bay at the far northern end of the delta, commonly referred to as White Slough. There was also a smaller channel connecting Salmon Creek to the historic Hookton Slough. The multi-channel delta that was mapped in 1870 suggests that main channel of Salmon Creek was laterally unstable, shifted back and forth between White Slough and Hookton Slough.

Other interesting features of the historic delta are the number of small tributaries that flowed out of the hills and into Salmon Creek. Willow Brook was historically many smaller streams, each emerging from the hills to join the mulitchannel system within the delta. These small freshwater inputs may have provided productive estuarine habitat for foraging salmonids.

By overlaying the 1870's channels onto an existing aerial photo of the delta the extent of tidal influence becomes evident (Figure 3.5). The saltmarsh extended east of the existing highway and south to Hookton Road. In the southeast corner the saltmarsh appears to have extended to the existing Hookton Road highway overpass.

Further study of the historic channels helps explain the existing locations of ditches and ponds throughout the Refuge. Long Pond appears to have historically been the location of a large tidal channel. Also, the lower portions of Cattail Creek currently follow the path of historic tidal channels.

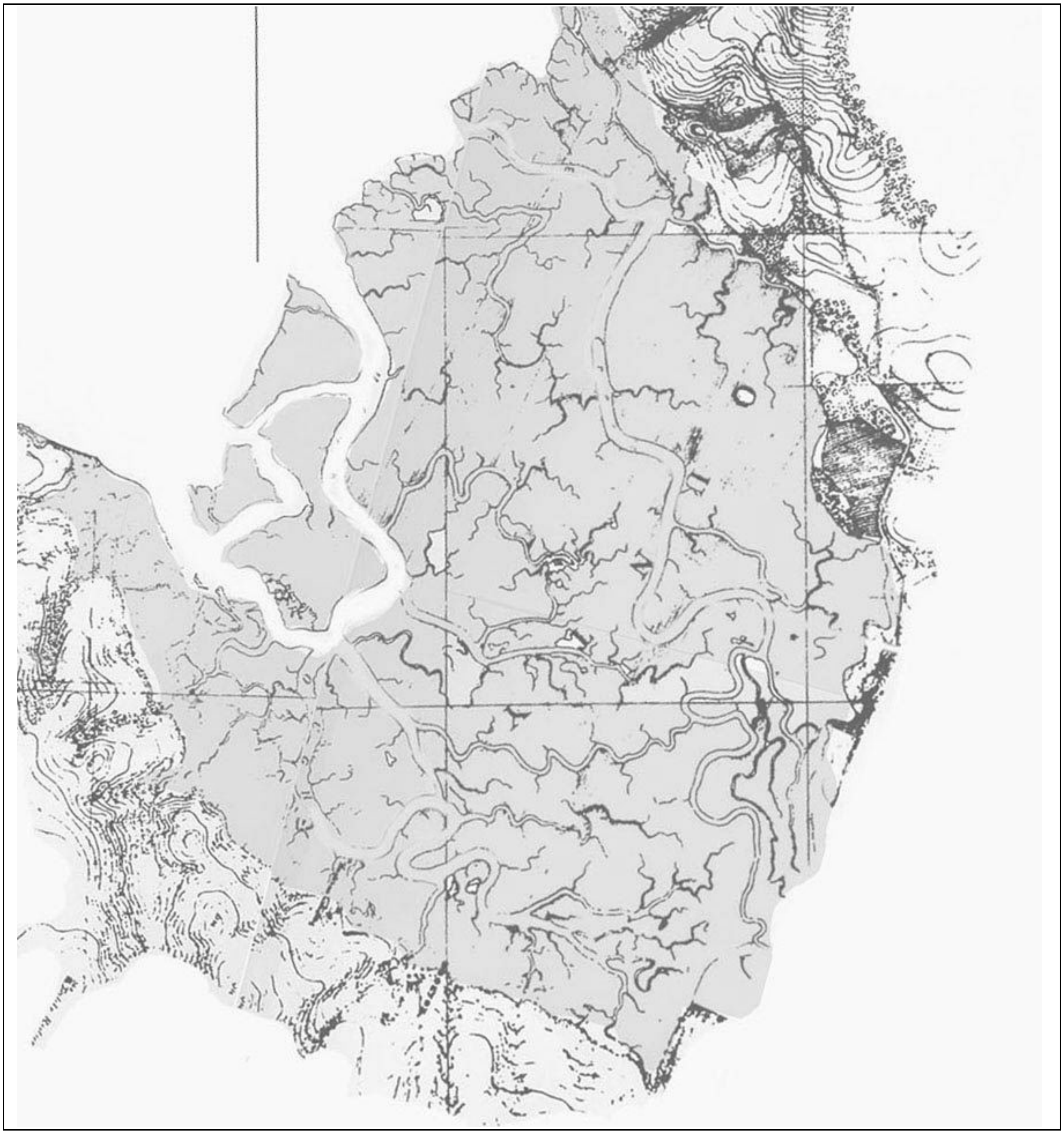

Figure 3.4 - Map of the Salmon Creek Delta in 1870 (adapted from USFWS, 2002). The darker shaded areas within the delta represent saltmarsh.

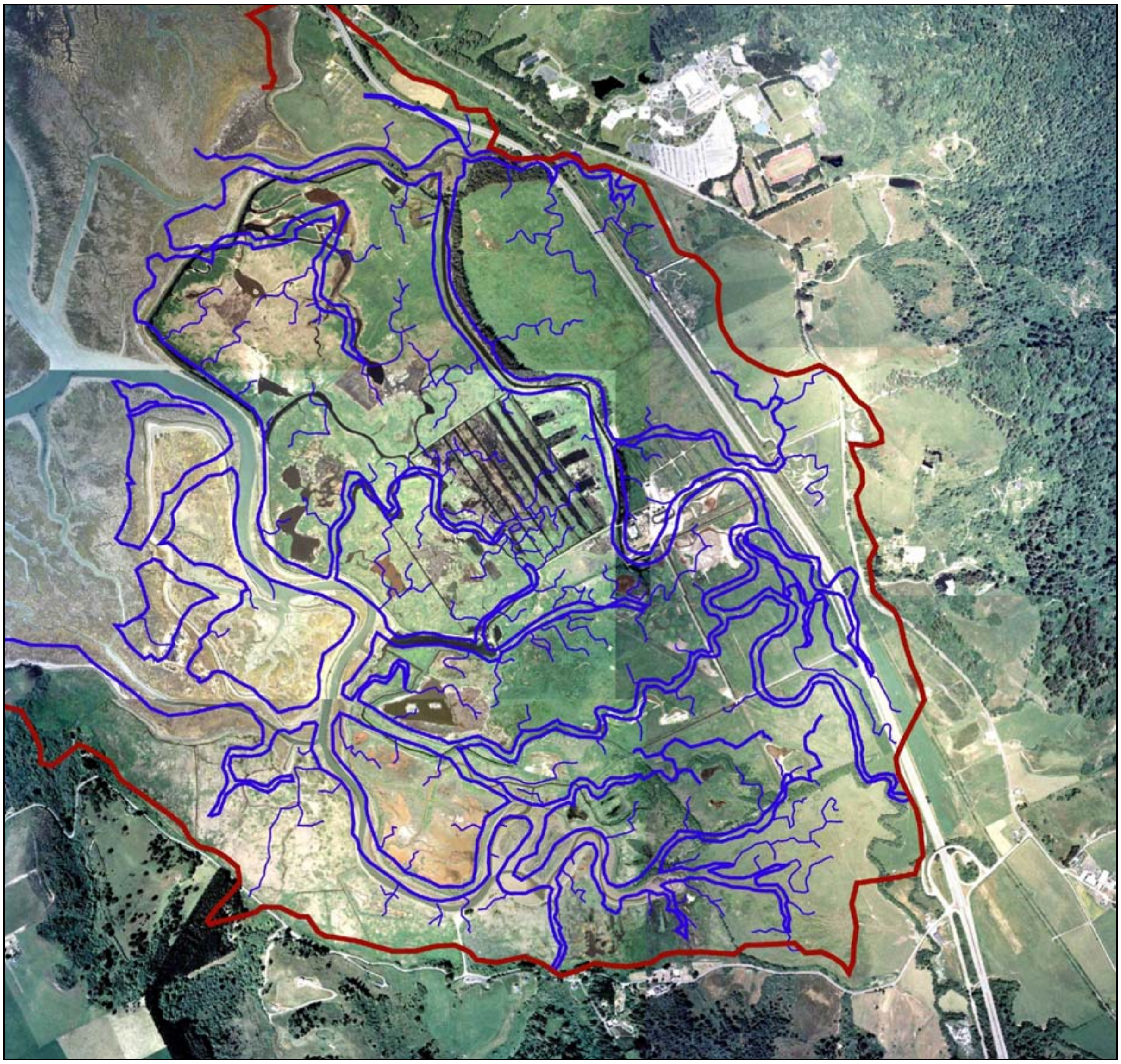

Figure 3.5 - The historic channels of the Salmon Creek Delta (blue), as mapped in 1870, overlain on aerial photos taken in spring of 2001. The outer line (red) indicates the extent of saltmarsh in 1870.

4 Project Activities and Findings

4.1 Mapping Existing Topography

4.1.1 Previous Mapping Efforts within the HBNWR

As part of an effort to construct additional seasonal freshwater ponds, HBNWR and California Waterfowl Association (CWA) retained the surveying services of Spencer Engineering to develop a topographic base-map. The resulting survey coverage extended from the northern edge of the Refuge to the Salmon-Cattail Levee. Completed in 2001, the final topographic map showed good detail, consisting of one-foot contour intervals. However, the vertical datum used in this survey appears to be assumed, and consists of a construction pin located near the Refuge buildings. The survey failed to include areas south of Cattail Creek, which is the principal focus area of this project.

4.1.2 Project Topographic Survey

The area between Cattail Creek and Hookton Slough was identified as needing a topographic survey prior to developing access and habitat enhancement options for Salmon Creek. Through cooperation with adjacent landowners, the survey also captured topography on two privately held parcels that lie adjacent to Salmon Creek, north of Hookton Road (Figure 4.1).

Prior to surveying, channel cross-section pins were set along the banks of Salmon Creek at various locations (approximately every 200 to 300 feet). The cross-sections were located within a 8,000-foot reach that extended from the lower estuary to the Hookton Road bridge. Staff plates and fence posts used for monitoring were also installed between the tidegate and the First Diversion.

A survey control network was established using Global Positioning System (GPS) survey equipment to provide horizontal and vertical control within the project area. The network was based on three tidal benchmarks and one HPGN benchmark maintained by the National Geodetic Survey. Final survey elevations used the North American Vertical Datum of 1988 (NAVD88) in feet, which is 0.70-feet above the MLLW tidal datum established in Hookton Slough. Horizontal coordinates used the North American Datum 1983 (NAD83) California State Plane, Zone 1, in feet.

Topographic mapping of the site used several types of survey techniques, depending on specific terrain conditions. Real-Time Kinematic GPS (RTK) was chosen where there was little or no overhead cover. In areas that were uniform and flat, such as levee tops and pastures, continuous RTK was used with a roving satellite receiver mounted on an ATV, automatically collecting points every 5 seconds. A Robotic Total Station was used in those areas where variable topography required greater detail or where 2 people were required to map through dense vegetation. Due to thick brush, dense canopy, and steep channel banks, most of the in-channel topography was collected with an auto-level and surveyors tape at the 28 cross-sections.

Insert

Figure 4.1 - Topographic Map of the HBNWR Salmon Creek Unit.

The following information was collected during the mapping phase, (1) survey data at established cross-sections along Salmon Creek, (2) benchmark references for manual and automated monitoring (fence posts and staff plates), and (3) topographic and bathymetry data of the project area

General ground topography was surveyed in the spring of 2002 using the total station and RTK surveying equipment. Points were surveyed in a rough grid fashion with actual point locations chosen by topographic breaks rather than a set distance apart. To accurately document topography , more points were collected in topographically complex areas. Beyond topographic grid points, significant slope breaks, water surface edges and elevations, and project boundaries were noted. The survey was conducted to be accurate within +/- 1-foot. Wet areas were mapped with RTK or total station by wading with extended rods, or by canoe where water was too deep for wading, such as in lower Salmon Creek and Hookton Slough.

All survey points were accumulated in Autocad LD3 software to build a digital terrain model (DTM) from which contour lines were generated. For the cross-sections, left and right bank endpins were surveyed with RTK or total station, and then the auto-level survey points were converted to 3-dimensional points based on the endpin coordinates. The final DTM was built from approximately 9000 points, 2200 of which were surveyed on the adjacent private parcel. Points along continuous slope breaks, such as tops and toes of levees, were connected with “breaklines” to assist the computer’s interpretation of the topography. The Salmon Creek in-channel topography upstream of the lowest cross-section was interpolated from the 28 cross-sections, and probably does not the represent 1-foot accuracy of the surrounding areas.

4.2 Monitoring Existing Channel Conditions

In late spring of 2002, automated water level recorders were installed in three locations within the project area. One recorder was placed at the upstream end of the First Diversion. Its placement allowed for monitoring water levels during in-channel and overbank flow events. The two other water level recorders were placed immediately upstream and downstream of the Salmon Creek tidegate, allowing for simultaneous monitoring of water levels within Hookton Slough and the Salmon Creek estuary, upstream of the tidegate. All recorders were set to collect water levels every 15-minutes, and data were downloaded on a regular basis.

A network of monitoring stations was established, each consisting of a benchmarked fence post placed within the channel to provide an elevational reference point. Fence post elevations were tied to NAVD88 datum during the topographic survey phase of the project area. The stations were installed to facilitate monitoring water levels and corresponding water quality parameters during various tidal and streamflow conditions. Six of these stations were placed within the main channel between the First Diversion and the tidegate. Two additional stations were placed within the tidal channels of the Salmon Creek estuary, located within the confines of the Bay and Salmon-Cattail Levees (Figure 4.2).

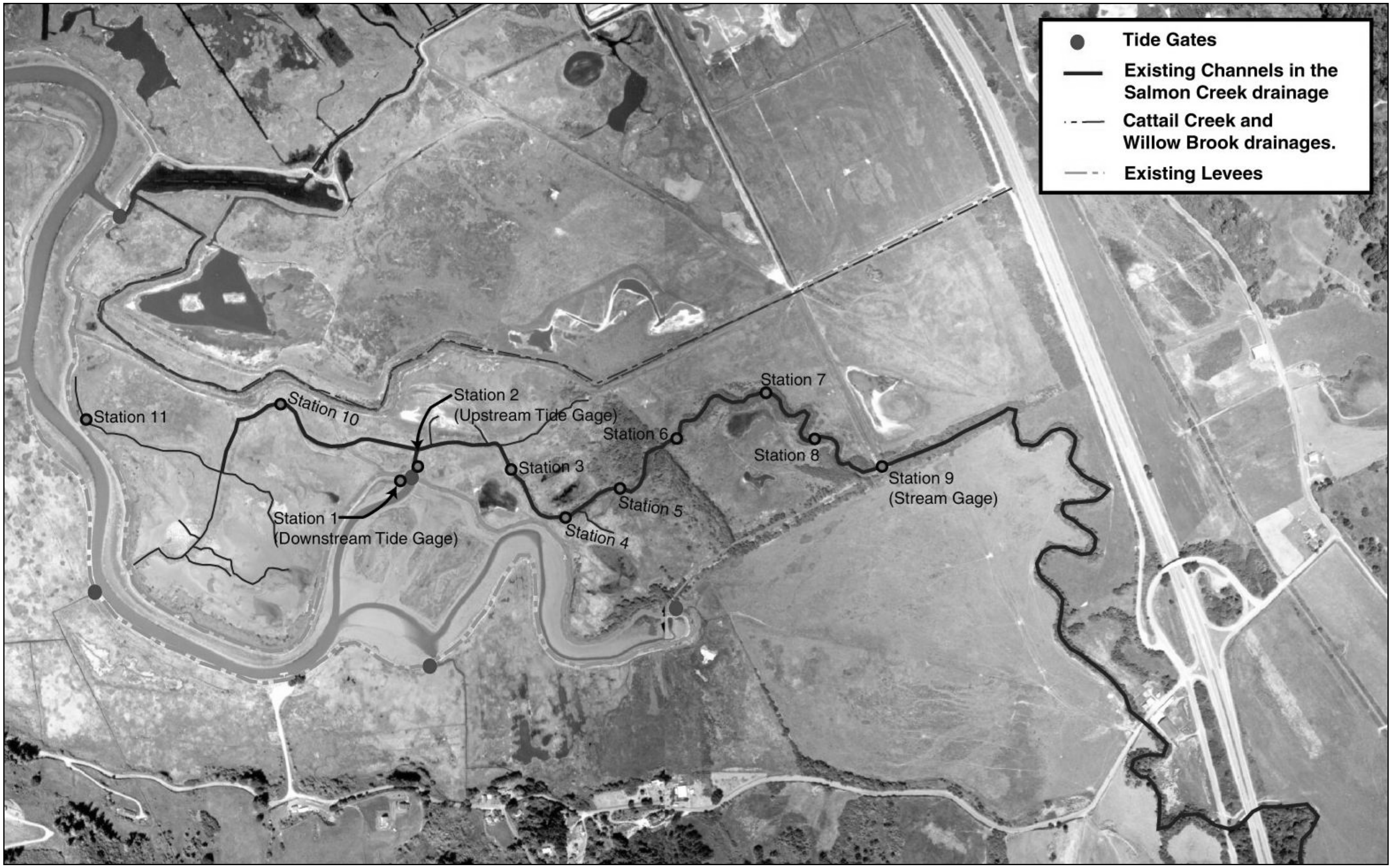

Figure 4.2 - Locations of monitoring stations. Stations 1, 2, and 9 consist of a water level recorder. The other eight stations consist of fence posts located within the channel to serve as elevational references.

On September 9, 2002 an effort was made to manually monitor water levels and water quality parameters at each of the eleven monitoring stations over a 10-hour period. From 800 to 1800 hours (PST), field staff rotated between stations, recording water levels and measuring various water quality parameters including temperature, specific conductivity, salinity, and dissolved oxygen. This effort provided valuable information regarding the extent of upstream tidal influence and associated salinity within Salmon Creek during low flow conditions. Measurements of water temperature and dissolved oxygen also assisted in assessing the feasibility of juvenile salmonid usage during seasonal low flow periods.

4.3 Existing Muted Tide cycle

The Salmon Creek tidegate consists of three rectangular concrete bays with wooden top-hinged flaps (Figure 4.3). One of the bays contains a “fish door”; a small rectangular opening located near the bottom of the flap intended to provide fish passage when the flaps are closed. Since the “fish door” is always open, even when the flaps are closed, there is continual exchange between the waters of Hookton Slough and Salmon Creek.

In addition to the “fish door”, Refuge staff suspects that near the bottom of one of the flaps an 8-inch wide board is either damaged or missing (Steve Lewis, per. com., 2002). The result has been an increase in the water exchange during periods when the flaps are closed. Plotting the recorded water levels from the two sides of the tidegate shows the tidal inflow into the Salmon Creek estuary during a specific period (Figure 4.4).

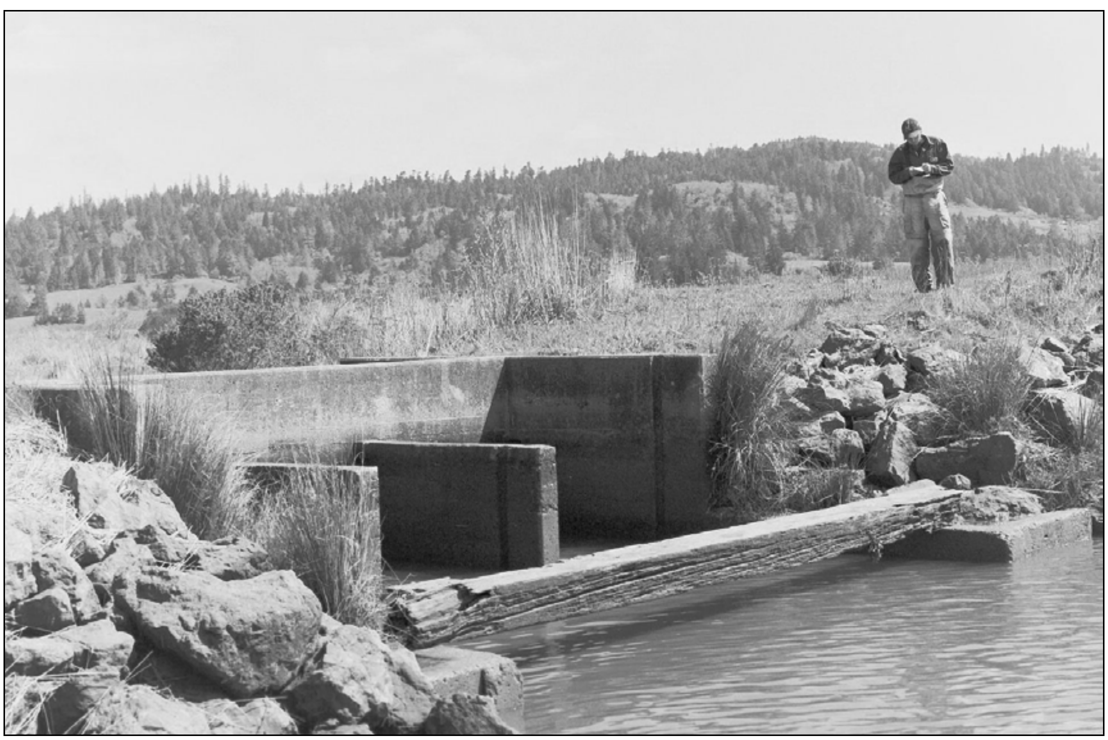

Figure 4.3 - Downstream side of Salmon Creek tidegate at Hookton Slough. Structure has three rectangular bays with top-hinged flaps. Far right bay contains a small opening to allow fish passage when flaps are closed.

The inflow of tidal water through both the "fish door" and the damaged tide flap creates a muted tide cycle upstream of the Salmon Creek tidgate. Shortly after low tide the tidegate flaps close. However, the volume of inflow remains adequate to maintain approximately the same water levels on both sides of the gate. At about elevation two-feet the inflow begins to overtop the tidal channels within the lower portion of the estuary. At this point the rate of inflow through the tidegate is not adequate to keep pace with the rising water levels in Hookton Slough. Consequently, a muted tide cycle within the estuary develops.

A curve was developed relating the duration various elevations are inundated by tidewater over the course of an average day (Figure 4.5). The curve was constructed from automated water level samples taken every 15-minutes. Water level data was selected that covered four complete lunar cycles during which low flow conditions persisted (from 6/17/02 - 9/9/02 and 11/11/02 – 12/9/02). Since low flow periods were selected the effects of inflow from Salmon Creek on water levels in the estuary were assumed negligible.

4.3.1 Muted Tide Cycle and Vegetation

Using the Humboldt Bay saltmarsh plant survey (Table 2.1) and the duration-elevation curve for Hookton Slough, we estimated the average daily duration various species can tolerate being inundated by seawater. Cordgrass (*Spartina densiflora*), an extremely aggressive invasive species, and native pickleweed (*Salicornia virginica*) are the most salt tolerant species within the bay, surviving at tidal elevations above 5.7-feet (MLLW). Using Figure 4.5, and adjusting Table 2.1 elevations from MLLW to NAVD88 within Hookton Slough by subtracting 0.7-feet, suggests that saltmarsh species can exist at locations that are inundated no more than 6.2 hours per day.

Using 6.2 hours of inundation per day as the upper extent any saltmarsh species can endure places the lower elevation saltmarsh upstream of the tidegate at approximately 3.2-feet (NAVD88). Surveys of the transition between mudflats and saltmarsh upstream of the tidgate verified little to no vegetation persist at elevations below 3.2-feet.

4.3.2 Muted Tide Cycle and Channel Morphology

During incoming tides water levels in the Salmon Creek estuary rise much slower than that experienced in Hookton Slough. Additionally, water levels continue to rise in the estuary even after the tide begins to recede in the slough. Not until water levels within the slough drop below that existing in the estuary do waters begin to recede upstream of the tidegate. Because of these unusual tidal dynamics the estuarine channels upstream of the tidegate experience much slower currents during the incoming tides then during outgoing tides. These swift outgoing currents promote efficient routing of sediment through the lower portion of the Salmon Creek estuary and into the bay.

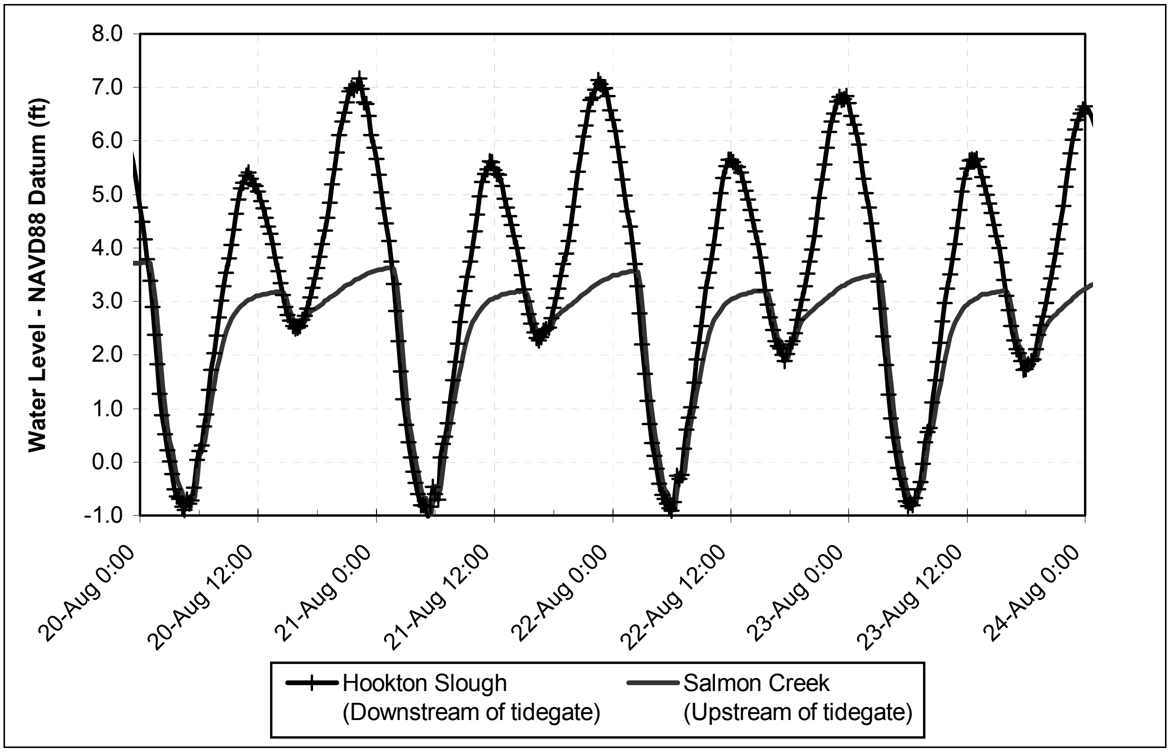

Figure 4.4 - The tide cycle upstream and downstream of the Salmon Creek tidegate. The fish door in the gate is responsible for the existing muted tide cycle in Salmon Creek

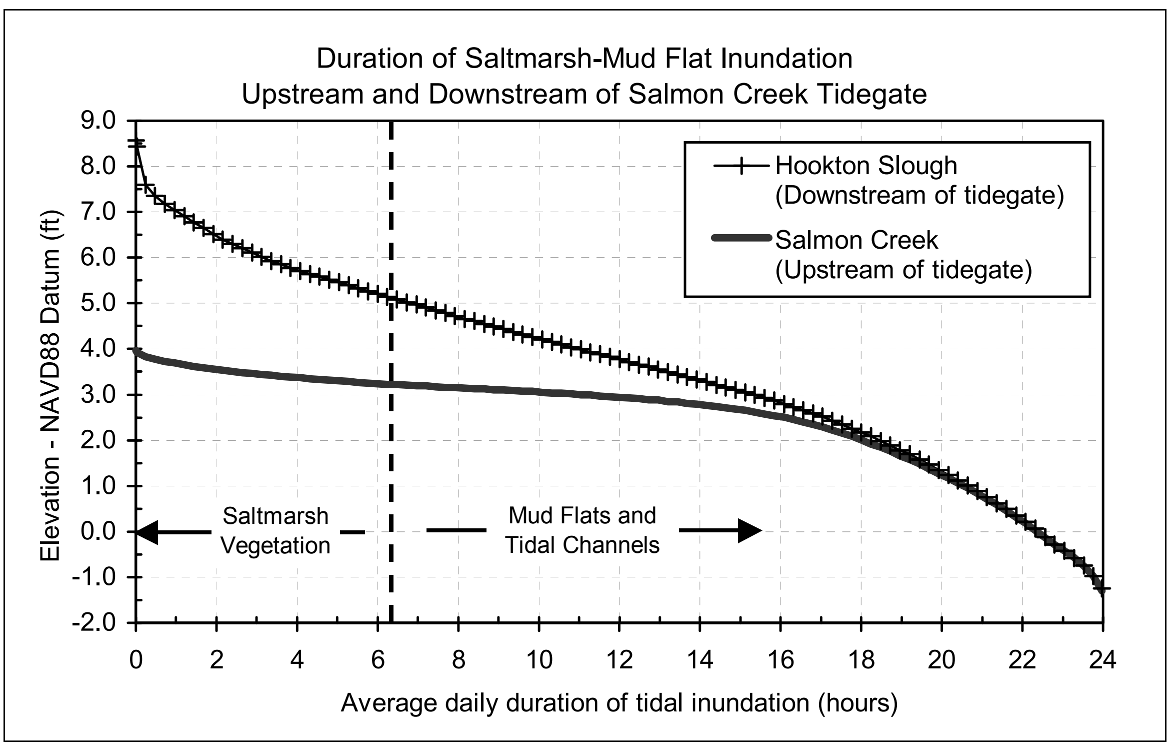

Figure 4.5 - The average daily duration various elevations upstream and downstream of the Salmon Creek tidegates are flooded by tidal waters.

Lower Salmon Creek Estuary

The lower portion of the Salmon Creek estuary contains a series of tidal side channels that drain adjacent mudflats and saltmarsh. Running eastward from the tidegate is the main channel of Salmon Creek, which carries all of the freshwater inputs from the stream. This channel is quite large and deep, with bottom elevations ranging from –0.8 to –3.0 feet (Figure 4.6). Top of banks throughout most of this reach are above 5-feet elevation and are out of tidal influence. The reach is approximately 2,000 feet in length and remains under tidal influence at all but the lowest of tides. Due to the constant tidal flux experienced within this reach, sediment appears to be efficiently routed downstream. Upstream of the lower estuary, the Salmon Creek channel experiences backwater effects only during higher tides.

Estuary Transition

Observations of the channel at different tidal elevations revealed a hard point in the channel which functions as a “knick point”, preventing headward channel erosion to proceed upstream. The knick point creates the transition between the lower and upper estuarine channel reaches. It is located approximately 2,000 feet upstream of the tidegate and appears to be composed predominately of clay. It is situated at the downstream end of a recently constructed channel that was connected to the lower preexisting channel. At high tide it becomes backwatered. However, during lower tides water can be seen cascading down this short, steep section, which is approximately 25-feet in length. At times the difference in water surface elevations upstream and downstream of the knick point can be as much as four feet.

Upper Salmon Creek Estuary

The upper estuarine channel reach extends from the knick point to approximately the First Diversion. During monitoring of the channel on September 9, 2002, field observations showed tidal backwater effect during low flow conditions extended to Station 8, which lies 3,800-feet upstream of the tidegate and 700-feet downstream of the First Diversion. During this event the high tide in Hookton Slough peaked at 7.0-feet and the tide upstream of the gate reached 3.4-feet. Since the muted high tide occasionally reaches 4.0-feet, it is likely that during certain tidal conditions the backwater effects could extend to the First Diversion.

The upper estuarine reach, from the knick point to the First Diversion, lies within a channel constructed in 1993 to restore the stream to a more natural form. Previously the stream flowed through a straight leveed channel. There exist no plans or as-built surveys of the reconstructed channel, making it difficult to assess the types of channel adjustments that have occurred since implementation. Anecdotal evidence from Refuge staff suggests that after the channel was relocated the streambed began to rapidly aggrade (Steve Lewis, 2002).

Currently, this section of the Salmon Creek channel appears to lack sufficient stream power to efficiently route sediment. The channel substrate throughout this reach is composed almost entirely of sands and silts. The reach has a high degree of sinuosity and within the inside bends of many of the meanders lie large sandbars that are colonized by young alders and willows. In addition, there are a number of locations where well established cattails grow in the middle of the channel; all evidence that even during large flows the stream lacks the power to scour the channel bed and banks.

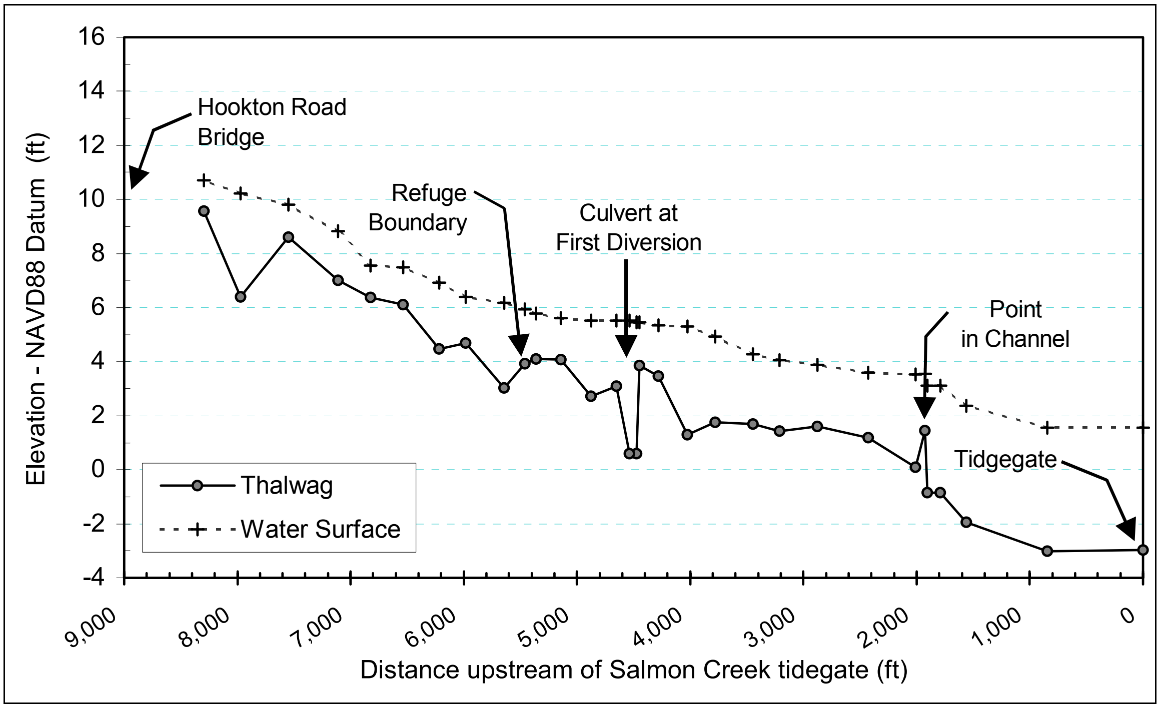

Figure 4.6 - Channel profile from tidegate to 600-feet downstream of the Hookton Road Bridge. Water surfaces were surveyed during low flow conditions on 5/8/02.

Overall, flows typically overtop the channel banks numerous times each year. Once overtopped, the water spreads out across the wide floodplain filling seasonal off-channel ponds and depositing large amounts of sand and silt onto the banks. Throughout much of the reach the height of the stream banks appear low relative to the channel size. Due to the broad flood plain that generally slopes away from the channel, once the banks are overtopped the water depth and velocity within the channel only slightly increases as flows increase.

The frequent deposition along the banks has begun to build natural levees. If left untouched, the stream banks will eventually build to a sufficient height that the channel will reach a dynamic equilibrium; overbank flow will become less frequent and in-channel water depths and velocities will increase leading to improved sediment routing. However, this will likely take many years, and any changes in the upstream channel configuration may interrupt this process.

4.4 Existing Flooding below Highway 101

4.4.1 Locations of Overbank Flow

Once Salmon Creek emerges from the coastal hills it flows through a low-lying valley consisting primarily of grazed grasslands before flowing under Highway 101 and then onto the Refuge. From the upper portions of the valley to its termination at South Bay, the stream channel is relatively unconfined and low gradient. The overall channel capacity is low and overbank flow both upstream and downstream of the highway is a regular occurrence.

Highway 101

Salmon Creek crosses under Highway 101 south of the Refuge at the foot of Tompkins Hill. The crossing consists of a wide-spanning bridge with little to no encroachment on the channel. A small ranch road also passes under the bridge providing access to pastures on both sides of the highway. Due to the overall slope of the topography, upstream floodwaters generally flow north, away from the channel. As a result, inundation of the highway, although infrequent, occurs near Cattail Creek instead of at the Salmon Creek crossing.

Loleta Drive and Hookton Road

Once below the highway, Salmon Creek crosses under Loleta Drive and then Hookton Road. Bridges at both crossings have relatively low bridge-decks. Streamflow typically overtops the channel banks within this short reach several times each year. Over a foot of water can cover the roadway and bridge-deck, with swift moving currents flowing down Loleta Drive and through the adjacent dairy before crossing Hookton Road (Figure 4.7).

Levee Breach below Hookton Road

A levee begins to run along the left bank of Salmon Creek immediately downstream of Hookton Road. In the late 1990's, the land owner breached a small portion of the levee in an effort to reduce upstream flooding. This has allowed floodwaters to exit the channel at the breach and flow across the adjacent field. The waters eventually reach the Refuge and the Hookton Slough levee. The volume is often so great that it overwhelms the first tidegate and then continues flowing along the southern levee to the next two tidegates. On several occasions floodwaters have been sufficient enough to damage the access road to the HBNWR boat launch.

Below the breach Salmon Creek forms the border between two separate private parcels before entering the Refuge. The levee breach and resulting loss of in-channel flow has reduced overtopping of the banks and levees throughout this reach.

Refuge Boundary to the First Diversion

Once Salmon Creek enters the Refuge the channel becomes straight with levees on both sides. This reach, which extends to the First Diversion, experiences only minor overtopping of the right bank levee during high water. Once overtopped, waters flow into the adjacent field and fill seasonal ponds. The left (south) levee top is higher and does not get overtopped.

The First Diversion

The diversion structure, known as the First Diversion, marks the transition between the channelized and the upper estuarine reaches of Salmon Creek. Flow is prevented from being diverted by flashboards blocking the entrance to the diversion ditch (Figure 4.8). Once water levels overtop the flashboards flow is diverted to other portions of the Refuge and does not reenter the Salmon Creek system. Typically flows become sufficient to overtop the flashboards several times each year and is relied upon for providing water to many of the Refuge's seasonal wetlands.

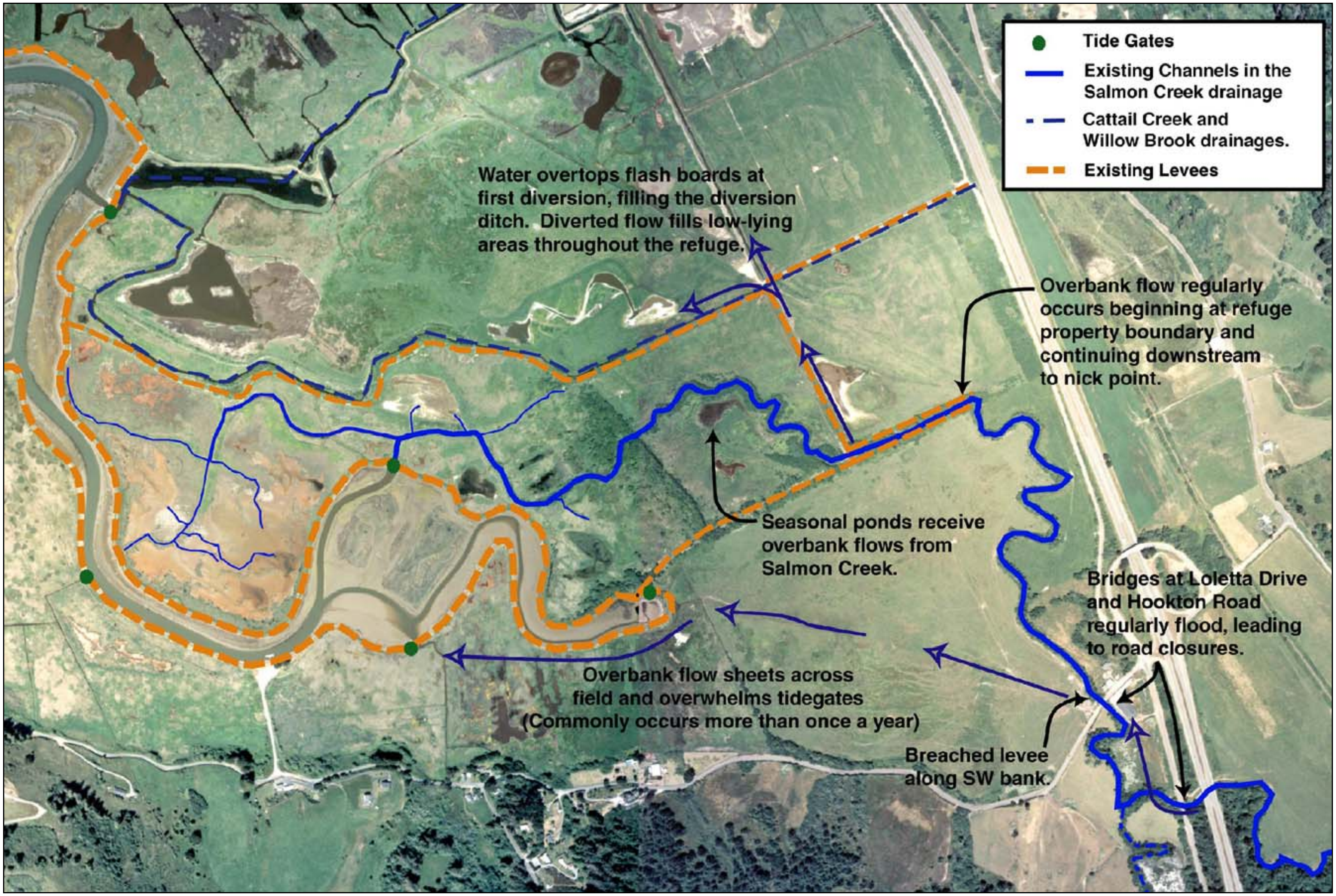

Figure 4.7 - Existing flow paths of Salmon Creek floodwaters within the Refuge and adjacent parcels.

Figure 4.8 - The First Diversion located on Salmon Creek. Once water levels overtop flashboards flow is routed to other portions of the Refuge.

The Upper Estuarine Channel

The upper estuarine channel, constructed in 1993, flows from the First Diversion to the channel knick point. This portion of the channel experiences regular overbank flows even though substantial portions of the flood flow exit the channel at the levee breach and at the First Diversion. Hydraulic analysis combined with visual observation of the channel from Hookton Road to the Knick Point indicated that this portion of the stream has the lowest overall hydraulic capacity. Overbank flow occurs within this reach prior to overtopping the flashboards or flowing through the breached levee. Overbank flow conveyance and water velocities appear to be low, as evident by the large volume of sediment deposition on the floodplain after each high water event. This frequent deposition of sediment has led to the formation of natural levees along the stream banks, causing a portion of the overbank flow to head away from the stream channel, filling adjacent seasonal wetlands.

4.4.2 Flood Frequency Estimates

Peak flows and their associated recurrence intervals were estimated using long term streamflow records from nearby drainages. A total of four gages with drainage areas less than 50 mi^2 and with at least 10-years of record were identified. Their annual peak flows were fitted to a Log Pearson Type III (LP3) distribution using the procedures outlined in Bulletin 17B (USGS, 1982). The ratio of drainage areas for the gaged stream and Salmon Creek was used to scale and transfer the peak flows between basins (Appendix A). For comparison, a set of commonly used flood estimation equations for Northwestern California was also used to estimate peak flow events in Salmon Creek

(Waananen & Crippen, 1977). Close agreement was found between the two methods (Table 4.1).

Table 4.1 - Recurrence intervals of peak flow events in Salmon Creek at Highway 101, extrapolated from nearby gaged streams and estimated using regional flood estimation equations.

Recurrence Interval	Average of Gages[1] (LP3)	Regional Flood Estimation Equations[2]
1.2-year	1,112 cfs	-
2-year	1,886 cfs	2,058 cfs
5-year	2,946 cfs	2,864 cfs
10-year	3,738 cfs	3,728 cfs
25-year	4,752 cfs	4,647 cfs
50-year	5,577 cfs	5,666 cfs
100-year	6,447 cfs	6,363 cfs

[1] Average area-adjusted peak flows for each recurrence using four gaging stations: Elk River, Jacoby Creek, North Fork Mad River, Little River

[2] Flow estimation equations for Northwestern California (Wannanen & Crippen, 1977).

4.4.3 Frequency and Magnitude of Overbank Flow

During the fall and winter of 2001-2002 substantial overbank flow was observed at Hookton Road below Highway 101 on four separate occasions. However, no discharge measurements were taken during these events. To estimate the magnitude and associated recurrence interval of overbank flow events we obtained instantaneous flow records for 2001-2002 from three nearby gaging stations and instantaneous flow measurements for two other stations (Table 4.2). Scaling all of the flows by drainage area and plotting the hydrograph revealed five distinct peak flow events (Appendix A). Assuming Salmon Creek and Elk River, which are adjoining drainages, react similarly to individual rainfall events, it appears channel banks become overtopped at the Hookton Road Bridge between 400 and 550 cfs. Based on these flow estimates and the frequency of flows shown in Table 4.1, it appears overbank flow events occur more than once a year.

4.5 Water Quality within Salmon Creek

Monitoring of salinity, water temperature, and dissolved oxygen during a rising tide on September 9, 2002, found tidewater had higher temperatures and higher levels of dissolved oxygen then that measured in the freshwater reaches immediately upstream. Tidewater in Hookton Slough had a fairly constant salinity of about 34.0 (S), based on the salinity scale. Water temperatures within the tidal channels of the lower estuary adjacent to the mud flats had the same salinity as in Hookton Slough. Within the tidal channels water temperatures reached 20^{o} C, and dissolved oxygen exceeded 68% saturated, with supersaturated conditions measured in the afternoon.

Table 4.2 - Streamflow records from water year 2002 used to estimate flows in Salmon Creek. Only instantaneous discharge measurements were available for the North and South Fork of Elk River.

Stream Name	Stream Gage Operator	Drainage Area	Distance from Salmon Creek at Highway 101
Little River	USGS	40.5 mi^2	24.5 mi NNE
Sullivan Gulch	Humboldt State University	2.1 mi^2	18.9 mi NE
Lower Elk River	Pacific Lumber Company	44.2 mi^2	3.5 mi NE
NF Elk River	Salmon Forever	22.7 mi^2	3.8 mi NE
SF Elk River	Salmon Forever	19.0 mi^2	3.7 mi NE

Salinity was monitored throughout the upper estuary as the tidewater moved upstream. The first rise in salinity was observed at Station 5, 120-feet downstream of the knick point. The tidewater rapidly moved upstream to Station 7, 1,260-feet below the First Diversion. At the peak of the high tide within the estuary a small backwater effect was observed at Station 8 but no accompanying rise in salinity was measured.

In the upper estuary above where the water became brackish, water temperatures stayed fairly constant throughout the day, ranging between 11^{o} C and 13^{o} C. However, dissolved oxygen levels were low, with most measurements falling between 30% and 45% of saturated. Water quality data is summarized in Appendix B.

5 Salmonid Access and Habitat Enhancement Goals Objectives, and Limitations and Constraints

5.1 Goals and Objectives

The general overall goal and objective of most restoration projects is the ultimate recovery of the natural form, function and composition of the disturbed or altered landform. However, the reality of project limitations, constraints and associated costs often limit the extent of realized restoration goals and objectives. The overall goals and objectives to be considered for the eventual completion of a salmonid access and habitat enhancement project for lower Salmon Creek are:

Goals

1) Improve salmonid access to lower Salmon Creek by providing facilities and/or operational procedures for salmonid migration between Salmon Creek and Humboldt Bay,

2) Improve salmonid holding and rearing habitat in lower Salmon Creek,

Objectives

3) Improve water quality conditions in lower Salmon Creek,

4) Restore and/or enhance estuary habitats within the project area,

5) Restore and/or enhance freshwater wetland habitat within the project area,

6) Restore and/or enhance the lower Salmon Creek channel,

7) Allow Salmon Creek and Humboldt Bay flows to interact with restored or enhanced site features, such as wetlands,

8) Reduce potential for salmonid stranding in lower Salmon Creek,

9) Reduce linear features of lower Salmon Creek,

10) Improve lower Salmon Creek channel/floodplain interactions,

11) Provide hydraulic conditions more favorable for sediment transport through the project area to Humboldt Bay to maintain and improve channel capacity for salmonid habitat and flood routing, and

12) Maximize, as much as possible, habitat benefits to other species besides salmonids.

These goals and objectives can be achieved by altering the existing topography, channels, and hydraulic structures within the project site. Section 6 describes in detail different design elements that can be implemented to achieve the stated goals and objectives.

5.2 Limitations and Constraints

A number of issues and concerns must be considered in planning modifications to existing conditions within the project area. Some concerns relate to water quantity/quality effects on adjacent properties; others center on public nuisance issues. Still others issues of concern relate to minimizing the need for future maintenance and employing a relatively simple operational scheme, or minimizing the impacts to existing Refuge facilities. The following limitations and constraints were developed based on discussions with Refuge personnel and from input received during the two advisory committee meetings. Briefly stated, the limitations and constraints are:

1) No worsening of flooding on adjacent properties,

2) No worsening of saltwater intrusion to adjacent properties,

3) Do not affect public/private utilities, such as roads,

4) Do not affect adjacent lands,

5) Propose economically feasible enhancement elements or alternatives,

6) Self-maintaining, as much as possible,

7) Future enhancement and restoration options to be kept viable,

8) Minimize impacts to cultural resources,

9) Do not substantially alter the Refuge's current water management regime for maintaining freshwater ponds and wetlands within the Refuge boundaries,

10) Any proposed action requiring Salmon Creek water must be within the Refuges current water right quantity and use,

11) Vector/Mosquito reduction,

12) Minimize levee construction, and

13) Do not negatively affect existing Refuge facility capital improvements, such as roads, buildings, facilities for Refuge management, and trails.

5.3 Lower Salmon Creek Project Area Delineation

The entire HBNWR encompasses a large area, and to better help define and focus efforts associated with this project, it was decided that defining a distinct project area within the Refuge was critical for the scope of this project. Based on discussions with Refuge personnel, consideration of the stated goals and objectives, and limitations and constraints, along with existing topography, levee configurations, hydraulic structures, and the location of the existing Salmon Creek channel, a distinct lower Salmon Creek project area was delineated (Figure 5.1). The project area encompasses approximately 197 acres. The majority of the background data collection efforts occurred within this project area. All of the salmonid access and habitat enhancement design elements and scoped conceptual alternatives for this project occurred within the project area.

5.4 Relationship of Project within Watershed

The Salmon Creek watershed is unique in the Humboldt Bay area, in that both a significant portion of the upper watershed and the land at its connection to the bay are in public ownership and are managed for natural resource protection. The vast majority of private lands within the watershed are either in an agricultural land use zoning designation by Humboldt County, or in the development restrictive Timber Production Zone classification. As a result, the Salmon Creek watershed hasn't undergone the rural residential development, as have the other major Humboldt Bay tributary watersheds. The relatively undeveloped flood-plane is especially important in providing the opportunity to achieve significant habitat improvements for native salmon populations in lower Salmon Creek.

This Salmon Creek Delta Salmonid Habitat Enhancement Opportunities document is an effort to address what are probably significant limiting factors to recovering salmon populations in Salmon Creek. The opportunities proposed here, if implemented over the next few years, will produce measurable improvements in access to more usable habitat in the Salmon Creek Delta. These improvements, in conjunction with efforts in the upper watershed, form a unique "tidewaters to headwaters" approach to salmon recovery.

Insert

Figure 5.1 – Lower Salmon Creek Project Area

6 Design Elements of Potential Salmonid Access and Habitat Enhancement Alternatives

This section describes the salmonid access and habitat enhancement design elements or components that were developed for lower Salmon Creek. These elements are based on the historical, hydrologic, salmonid habitat, and water quality analyses previously described and generally reflect information on the form, function, and compositional characteristics of low gradient stream and delta environments. Ultimately, the design elements can be combined in a variety of ways to develop various restoration alternatives for lower Salmon Creek. It should be noted that all of the design elements are proposed to occur within the previously defined project area only.

6.1 Additional Project Area Planning/Scoping Data and Information

To assist in the planning and scoping efforts for the various salmonid access and habitat enhancement design elements, specific data and information was required. Some of this information is discussed and provided in Section 4. This section describes the additional data and information developed for planning and scoping efforts as part of this project, and will be useful in later project phases (e.g. detailed design and analysis).

6.1.1 Detailed Project Area Topography

Figure 6.1 shows the detailed topography of the project area only. Based on the accuracy of the collected topographic data, the project area topographic map should be adequate for further detailed analysis, design, and construction purposes.

6.1.2 Project Area Inundation

One of the proposed design elements, which will be discussed in more detail later, is allowing a larger tidal prism to occur within the project area through tidegate modifications. An increased tidal prism will inundate a larger area, increasing the potential for tidal wetland enhancement. Figures 6.2, 6.3, 6.4, and 6.5 shows the approximate aerial extent of allowing the project area to be inundated to elevations 4, 5, 6, and 7 feet, respectively. Table 6.1 gives the approximate surface area at each inundation level. It should be noted that some inundated areas appear isolated from the main inundated body of water, indicating isolated, low depression areas in the topographic surface. For tidal waters to actually inundate these areas, it will be necessary to connect them to the Salmon Creek channel. For completeness, the inundated areas on the adjacent Vance parcel are also included in Figures 6.2 to 6.5, even though this property is isolated from the lower Salmon Creek project area by levees and would not be inundated unless connected. The surface areas in Table 1 are for the project area only, and do not include the adjacent Vance property. The muted tide cycle that currently exists within the project area allows tidal water to reach a maximum elevation of approximately 4-feet, and Figure 6.2 shows the upper areal extent of tidal inundation at that elevation.

Insert

Figure 6.1 - Topographic map of project area only.

Insert

Figure 6.2 - Tidal inundation at elevation 4.0-feet.

Insert

Figure 6.3 - Tidal inundation at elevation 5.0-feet.

Insert

Figure 6.4 - Tidal inundation at elevation 6.0-feet.

Insert

Figure 6.5 - Tidal inundation at elevation 7.0-feet.

Table 6.1 - Surface area inundated by tidewater within the project area at various elevations.

Tidal Elevation (ft - NAVD88)	Surface Area Inundated (acres)
4.0	53.1
5.0	73.4
6.0	90.1
7.0	111.4

6.1.3 Project Area Stage-Surface Area-Storage Relationship

Based on the topographic survey and developed digital terrain model, a stage-surface area (Figure 6.6) and a stage-storage volume (Figure 6.7) relationship for inundation of the project area was developed. The relationships were confined within existing levees and topographic high points surrounding the project area, and do not include the adjacent Vance parcel.

6.1.4 Project Area Features Table

Table 6.2 lists the length and/or surface area of various existing features within the project area, such as levee length, tidal wetland coverage, and channel length.

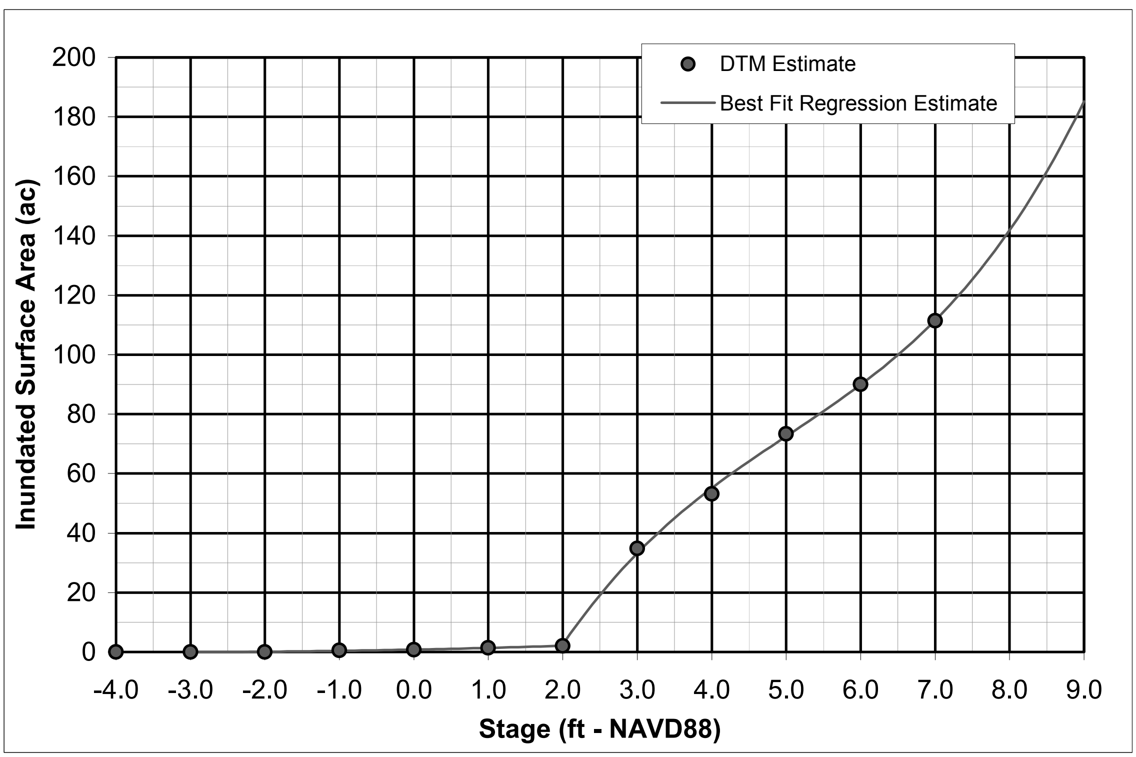

Figure 6.6 - Stage-surface area relationship for project area.

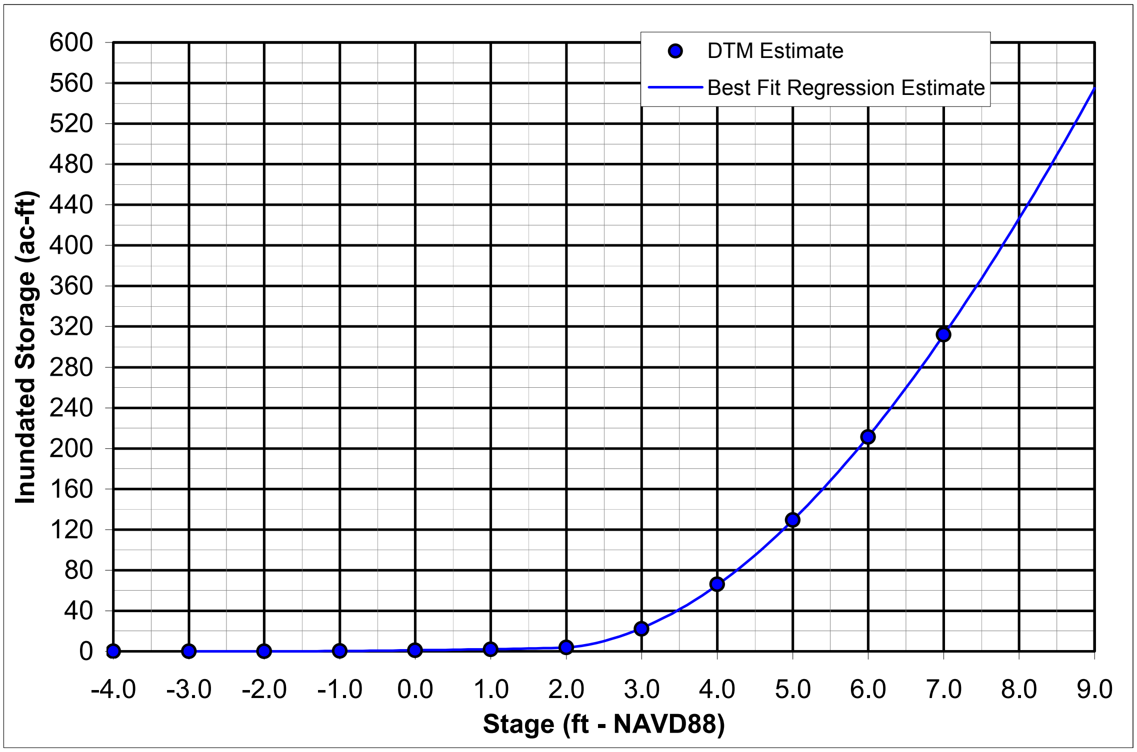

Figure 6.7 - Stage-volume relationship for project area.

Table 6.2- Extent of Project Area Features.

Project Area Feature	**Extent**
Length of Salmon Creek Channel[1] (ft)	7,066
Length of Salmon Creek Channel[2] (ft)	3,542
Length of Lower Estuary Channel[3] (ft)	1,881
Area of Tidal Wetland (ac)	57.2
Length of Slough Channels (ft)	4,355
Length of External Levees (ft)	15,617
Length of Internal Levees (ft)	1,837

[1] From Hookton Road Bridge to knick point.
[2] From Refuge north-east property corner to knick point.
[3] From knick point to tidegate.

6.2 Salmonid Access and Habitat Enhancement Design Elements

6.2.1 Improve Salmonid Access to Lower Salmon Creek

Description

This design element consists of replacing and/or upgrading the existing Salmon Creek tidegates which drains the project area and Salmon Creek to Humboldt Bay. The improvement can consist of an open breach in the existing levee, functionally different tidegates (fish friendly tidegates), constricted opening such as an open culvert(s) (muted tide cycle), or modifications to the existing tidegates. The breach or tidegate improvements can occur in the existing tidegate location, or they could be relocated to another location that could provide additional channel length to the lower Salmon Creek channel, and provide additional estuarine habitat.

Depending on the extent of the tidegate modifications, a larger tidal prism can also be provided to interact with the project area. This increased tidal prism can provide the necessary hydrology for increased tidal estuary enhancement, water quality improvements, sediment transport and routing improvements, and improved channel maintenance.

Opportunities/Benefits

- Improve salmonid access into Salmon Creek,
- Improve water quality and sediment transport conditions by providing a larger tidal prism exchange,
- Promote upstream head-cutting and deepening of Salmon Creek channel at current tidal transition zone,
- Promote channel and in-channel vegetation maintenance by lengthening the extent of the tidal prism within the Salmon Creek channel,
- Provide larger tidal prism for tidal wetland/estuary enhancement,
- Provide larger tidal prism for increased freshwater/saltwater interface,
- Potentially provide improved flood routing capability by steepening the energy gradient of flood discharges and site runoff into the bay.

Requirements

- Design, construction and capital costs of new tidegate or levee breach if one of these elements is considered,
- Costs of associated repairs and/or upgrades of existing tidegate if this structure is to remain,

- Additional design and analysis of modified tidegates or levee opening to demonstrate that improvements will not worsen upstream flood conditions, and
- Agency permits and approvals may be required for new tidegates and/or levee breach. However, it is possible that modifications and/or repairs to the existing tidegate can occur under the Refuges current operational permit.

6.2.2 Salmonid Habitat Enhancement

Description

Salmonid habitat improvement primarily focuses on providing or enhancing juvenile rearing habitat. Based on work by Miller and Sadro (2000), it was demonstrated that juvenile coho salmon in South Slough, Coos Bay, Oregon, benefited from the rearing habitat provided by tidal channels, restored salt marshes, and off-channel ponds. The proposed salmonid rearing habitats for lower Salmon Creek could consist of a wide range of habitat types, such as restored tidal estuary wetlands, channel fringe wetlands, woody vegetation cover, steep and overhanging channel banks, and side channel brackish wetlands. Under most conditions, it will be necessary to construct these new features, which would require earth moving, contouring and revegetation. However, isolated low depression areas currently exist within the project area that fill during extreme tidal events and/or overbank discharges. Most of these areas do not currently drain since they are isolated from the existing Salmon Creek channel. By constructing channels between the low depression areas and the Salmon Creek channel (similar to slough channels), it would be possible to create and provide access for salmonids to a limited number of off-channel wetland habitats with minimal construction requirements.

Opportunities/Benefits

- Improve habitat for juvenile and adult salmonids in lower Salmon Creek by providing tidal or slough channels and off-channel wetland habitat,
- Improve riparian and emergent vegetation, and
- Improved water quality conditions in and around proposed wetland improvements.

Requirements

- Design, construction and capital costs associated with construction of new salmonid wetland habitat improvements,
- Minimize or eliminate the potential for salmonid entrapment within newly constructed habitat improvements,
- Depending on the location, salmonid habitat improvements could require the construction of new or modification of existing levees, and

- Agency permits and approvals will likely be required for constructing new wetland habitats. However, it may be possible to connect existing low depression areas to the existing channel by excavating small channels under the Refuge's current operating permit.

6.2.3 Salmon Creek Channel Restoration

Description

A majority of the existing lower Salmon Creek channel has been straightened, leveed and channelized over the years. The proposed channel restoration elements focus on what we believe are the most viable elements for the project area. In the recent past, the Refuge restored a portion of the Salmon Creek channel immediately below the First Diversion. The channel restoration consisted of creating a lower gradient, less confined, and more sinuous channel. According to Refuge personnel, the channel restoration more-or-less followed several old remnant channel meanders that were apparent on the ground.

The proposed channel restoration elements consist of three different options, in which any combination of them could be constructed.

A. The first channel restoration option consists of deepening the existing channel from the knick point upstream to the First Diversion structure, creating a deeper low-gradient tidal channel similar to the channel downstream of the knick point. Since it is necessary for the concrete channel diversion to remain for current Refuge water management, the bottom of the diversion structure creates a grade control and a break between the deeper low-gradient channel and a shallower steeper-gradient channel. This would allow the entire channel between the tidegates and the diversion structure to be under tidal influence, allowing tidal flushing to efficiently route incoming sediment to the bay.

B. The second channel restoration option consists of creating/restoring a more natural meandering channel upstream of the First Diversion, replacing the straight leveed section of channel running north-south along the Refuge's north-east boundary. The restored channel would be entirely constructed on Refuge property, and ultimately join the existing channel near the north-east corner of the Refuge. An advantage of creating this restored channel is that it can be constructed on dry ground and vegetation can be allowed to become established before introducing Salmon Creek flow into the restored channel.

C. The third restoration option consists of creating a secondary slough channel that would reconnect with the main Salmon Creek channel upstream of the existing knick point. This secondary channel would be constructed in the old remnant channel apparent on aerial photos. This would create a multi-channel system within the upper estuarine portion of Salmon Creek, increasing tidal influence, creating area of larger fresh-saltwater mixing, and likely improve sediment routing.

Following construction of any of the channel options revegetation of riparian species would occur along the channel.

Opportunities/Benefits

- Improve habitat for juvenile and adult salmonids in restored Salmon Creek channel and/or secondary slough channels,
- Improve riparian and emergent vegetation along the restored channel,
- Improve water quality and sediment transport conditions by providing a larger tidal prism exchange with upstream reaches of Salmon Creek,
- Promote channel and in-channel vegetation maintenance by extending the extent of tidal prism in the Salmon Creek channel,
- Provide larger tidal prism for freshwater/saltwater interface,
- Potentially provide improved flood routing capability by steepening the energy gradient of flood discharges and site runoff into Humboldt Bay.

Requirements

- Design, construction and capital costs associated with construction of channel restoration elements,
- Potentially fill existing portions of Salmon Creek channel,
- Potential need for cut soil disposal, and
- Agency permits and approvals will likely be required for conducting any of the proposed channel restoration options.

6.2.4 Tidal Wetland/Estuary Enhancement

Description

This element consists of creating more tidal estuary areas within the project site. The tidal estuary would consist of salt marsh, mudflats, and tidal channels, depending on the depth and frequency of inundation associated with the increased tidal exchange from the improved salmonid access element (Section 6.2.1). It is currently proposed that much of the tidal wetland/estuary enhancement would likely occur in the lower portions of the project area (Figure 3.3). The tidal wetland/estuary enhancement can be done actively by recontouring large areas to create distinct mud flat, salt marsh, tidal channel and estuary zones. For this type of enhancement it will be necessary to accurately model the hydraulics and tidal inundation levels from the selected tidegate modifications discussed in Section 6.2.1 (e.g. a muted tide cycle or a large levee breach), as recontouring elevations will become critical. Another more passive approach to creating tidal wetland/estuary enhancement would be to conduct minimal or no recontouring work, and allow the tidal wetland/estuary areas to form naturally based on existing topography and increased hydrology from the proposed tidegate modifications. Over the years, this type of process has been occurring in the large south-westerly area that is currently inundated by the muted tide cycle created after the “fish door” was installed into one of the existing tidegates. The primary disadvantage of passive enhancement is that the mud flat, salt marsh, tidal channel and estuary areas to be created are dictated by existing topographic gradients and drainage may be poor. This could potentially lead to fish entrapment and/or vector (mosquito) production in areas that do not properly drain.

Opportunities/Benefits

- Improve habitat for juvenile and adult salmonids in restored salt marsh and expanded estuarine channel areas,
- Improve water quality conditions, assuming the saltmarsh and mudflats are well-draining, by providing a larger tidal prism exchange, and
- Provide larger tidal prism for freshwater/saltwater interface.

Requirements

- Design, construction and capital costs associated with active construction of mud flat, salt marsh, and tidal slough areas,
- Potential need for cut soil disposal, and
- Agency permits and approvals will likely be required for conducting active tidal wetland/estuary enhancement. However, if no construction activities are proposed, it unlikely that any permits would be required for passive tidal wetland/estuary enhancement, and it is likely that this action could be accomplished within the Refuges current operating permit.

6.2.5 Freshwater Wetland Enhancement

Description

Opportunities for creating year-round freshwater wetlands within the project area are limited due to the lack of sufficient Salmon Creek discharges during most of the year. However, the potential does exist for enhancing seasonal freshwater wetlands by excavating shallow depressions on the upland portions of the project area. These shallow depressions could be designed to capture and temporarily store precipitation and Salmon Creek overbank flows during storm events. Depending on the depth to summer groundwater levels, it may be possible to excavate portions of the wetlands into groundwater, thus creating smaller perennial freshwater wetland habitat. However, evaluating the feasibility of creating this type of wetland requires a detailed analysis of seasonal groundwater depths and site hydrology.

Opportunities/Benefits

- Potentially create freshwater wetland habitat for juvenile and adult salmonids, Requirements

- Design, construction and capital costs associated with active construction of freshwater wetlands,
- Potential need for cut soil disposal, and
- Minimize or eliminate the potential for salmonid entrapment within newly constructed habitat improvements,
- Agency permits and approvals will likely be required for creating freshwater wetlands within the project area.

6.3 Secondary or Ancillary Benefits

Secondary or ancillary benefits to other wildlife species and/or to natural processes can occur with restoration activities. As stated earlier, the primary goals and objectives of this project are access improvements and habitat enhancement for salmonids within lower Salmon Creek. The proposed access and habitat elements serve as means for obtaining these goals and objectives within the project area. However, the following ancillary benefits should also occur from the proposed design elements.

1) **Improved flood routing within the project area**. The tidegate modifications necessary for the improved salmonid access element (Section 6.2.1), either with an open culvert (muted tide cycle) or an open levee breach, could improve flood routing through the project area and help alleviate to some extent upstream flood problems. This ancillary benefit should occur even with the introduction of a larger tidal prism into the project area. To further improve flood routing through the project area additional culverts with tidegates could be installed at lower elevations along the levee to further increase outflow capacity and steepen the energy gradient of stormflows exiting the site at low tides.

2) **Bird, Waterfowl and Wildlife Habitat Improvement**. Conducting tidal wetland/estuary, channel, and wetland enhancement (Section 6.2.2, 6.2.3, 6.2.4, 6.2.5) within the Refuge will also provide additional riparian and wetland vegetation, which will indirectly improve fish and wildlife habitat.

3) **Weed Control**. Providing a larger tidal prism within the project area will help control invasive weeds and other problematic vegetation (e.g. cattails) growing within the Salmon Creek channel by allowing brackish water to extend further upstream.

3) **Vector Control**. Recently the Refuge has been experiencing mosquito problems. The mosquito in question is a species that breed in stagnant salt or brackish water. During extreme high tide events, the existing muted tide cycle fills low depression areas. Once the tide retreats, these areas cannot drain, and since they are only infrequently re-inundated, the ponds become stagnant mosquito breeding areas. By introducing a larger tidal prism within the project area and/or constructing channels

between the low areas and the existing channel, some of these low areas will become inundated one or more times daily, thus eliminating the stagnation, introducing mosquito predators (fish), and greatly reducing the mosquito breeding problem.

7 Conceptual Salmonid Access and Habitat Enhancement Alternatives

This section describes three conceptual salmonid access and habitat enhancement alternatives developed for the lower Salmon Creek project area. These alternatives were developed based upon collected background data, project goals and constraints, discussions with Refuge personnel, two advisory committee meetings, and prior experience with similar projects. The conceptual alternatives were created by combining the different design elements presented in Section 6. Three major factors assisted in creating each of the conceptual alternatives:

1) The first factor was the qualitative length of time required to implement an alternative and realize the associated benefits, and includes consideration of the time necessary for design, data collection and analysis, environmental document preparation, permitting, construction documents, and construction time. These were termed short-term, near-term, and long-term improvements.

2) The second factor was implementation requirements, such as construction requirements and difficulties.

3) The third and final factor was a qualitative consideration of the costs associated with implementing each alternative. With these being the major factors in developing alternatives, other factors were then applied, based upon salmonid access and the extent and location of salmonid habitat enhancement.

7.1 Conceptual Alternative Limitations and Refuge Concerns

A primary purpose of this feasibility scoping report is to assist the Refuge with limiting the full range of possible alternatives to those which are most feasible and practical for meeting the stated salmonid access and habitat enhancement goals and objectives. The conceptual alternatives, or any modification or alternative developed from the provided design elements could be considered to be in agreement with the goals and objectives. While this scoping study does not provide information of sufficient detail for developing enhancement designs and specifications, it does provide a basis for ultimately defining and selecting an alternative which meets the goals and objectives outlined earlier. Once an alternative has been selected by the Refuge, additional studies, analysis, design, and construction documents and specifications (as required) may be developed.

Refuge personnel felt that providing information and guidelines on specific design elements that could be implemented to improve salmonid access and habitat enhancement was most appropriate and useful. They would also like to assess and consider design elements that could be implemented immediately (short-term improvements) to improve access and habitat. To accommodate this need, we felt that providing three conceptual restoration alternatives based on the major factors outlined would be a useful exercise, and at a minimum provide the Refuge guidance regarding their ultimate selection of a salmonid access and habitat enhancement alternative for lower Salmon Creek.

7.2 Alternative A – Short-Term Improvement

7.2.1 Description and Design Elements

The intent of Alternative A is to demonstrate an alternative that could be implemented rather quickly and provide immediate (short-term) improvements to salmonid access and habitat enhancement to lower Salmon Creek. This alternative requires essentially no earth moving or recontouring of the project site, no new hydraulic structures, and would only require repairs and modifications to the existing tidegates. Figure 7.1 shows the requirements and locations of the various design elements associated with Alternative A.

Three design elements are proposed for Alternative A consisting of (1) improving salmonid access to lower Salmon Creek, (2) salmonid habitat enhancement, and (3) tidal estuary enhancement.

1. The first design element would be modifying the existing tidegate to allow better salmonid access and provide a larger tidal prism or larger muted tide cycle to enter the project area. This can be accomplished by either enlarging the "fish door" that currently exists in one of the tidegates, upgrading one of the tidegates to have an adjustable opening (sluice-gate) that allows adaptive management of the tidal prism, or completely removing or bracing open one of the tidegates allowing unimpeded flow in one of the channel bays. The increased tidal prism could promote the knick point to migrate upstream, thus deepening the upper portions of Salmon Creek. However, knick point migration would be passive and could take years to occur naturally.

2. The second element consists of providing better salmonid habitat, which would be done in a passive manner by providing a larger tidal prism in the project area. No earth moving or recontouring of the existing topography is proposed. The larger tidal prism should provide more tidal wetland area, and improve water quality conditions within the existing slough channels and estuary. Some of the low depression areas could also become more viable off-channel salmonid habitat due to the interaction with a larger tidal prism. However, since the low depression areas will not be connected to the main channel (e.g. with slough channels), the potential exists for fish stranding and increased vector production in these areas.

3. The third design element involves improving or enhancing the existing western portion of the estuary. As with the salmonid habitat enhancement element, no earthwork is proposed, and the enhancement would passively occur due to the introduction of a larger tidal prism into the area. For example, if the tidegate was modified so that the exiting tidal prism (muted tide cycle) was increased so that inundation occurred to an elevation of 5 feet, then Figure 6.5 shows the aerial extent that the tidal wetland and potential salmonid habitat could be increased.

7.2.2 Opportunities/Benefits Gained

Implementation of Alternative A should provide for the following goals and objectives and opportunities and benefits within lower Salmon Creek:

1. Improved salmonid access,
2. Improved salmonid rearing and holding habitat,
3. Improved water quality conditions,
4. Enhanced tidal wetland/estuary habitats,
5. Improved sediment transport conditions,
6. Improved tidal prism, which would extend further upstream than existing conditions thus providing more estuary habitat,
7. Improved channel and in-channel vegetation maintenance, and
8. Improved flood routing.

7.2.3 Construction Phasing

No phasing of Alternative A is required. Once the tidegates are modified, the other design elements would occur passively due to the larger tidal prism.

7.2.4 Additional Data, Analysis, and Design Requirements

Since no earthwork is proposed for Alternative A, additional data collection, analysis and design requirements should be minimal. The only design required would be the modification to the existing tidegate. It would be necessary to conduct additional hydrologic/hydraulic analysis of Alternative A to determine the impacts of the proposed tidegate modification, proposed tidal prism volumes and levels, and analyze the effects to upstream flood conditions. Based on the extent of the increased tidal prism, the potential for fish entrapment within the existing low depression areas would also need to be addressed.

Following implementation of Alternative A, it is proposed that the Refuge develop and implement an effectiveness monitoring plan that examines salmonid numbers and habitat usage, muted tide cycle extent, tidal wetland development and changes, channel modifications, and in-stream water quality.

7.2.5 Costs

The only major cost associated with implementation of Alternative A would be the costs of the required tidegate modification design, analysis, and construction associated with modifying the tidegate. Table 7.1 is a preliminary cost estimate to implement Alternative A by design elements. Since this cost estimate is preliminary, a 25% contingency and a 25% engineering, design, construction document preparation, and permitting fee was included. The preliminary cost to implement Alternative A was estimated to be $150,000.

Table 7.1 - Preliminary cost estimate for Alternative A by Design Element.

Design Element	Action	Approximate Quantity (unit)	Approximate Cost per Quantity ($/unit)	Cost ($)
Improved Salmonid Access	Tidegate Modification	Modification	Lump Sum	100,000
Salmonid Habitat Enhancement	Passive	No Cost	No Cost	0
Tidal Estuary Enhancement	Passive	No Cost	No Cost	0
			Subtotal	100,000
			Contingencies (25% of Subtotal)	25,000
			Engineering, Design, Construction Document Prep., Permits (25% of subtotal)	25,000
			Preliminary Cost for Alternative A	**150,000**

7.2.6 Tide Routing Analysis

The tidal routing model described in Section 2.3 was used to demonstrate the effects of one possible tidegate modification that could be used for an Alternative A concept. Required Alternative A input for the tide routing model included (1) rating surfaces for the proposed opening and tidegates, (2) stage/surface-area and stage/volume table for the proposed tidal wetland area, and (3) a Salmon Creek discharge hydrograph. For this analysis it was assumed that the existing tidegates where modified to allow a larger muted tide cycle to occur in the project area (Section 7.2.1). The tidegate modification consisted of providing an opening equivalent to one-half of one of the existing rectangular concrete bays, and retaining the remaining two and a half tidegated openings. This could essentially be accomplished by cutting one of the wooden top-hinged tidegate flaps in half. This proposed opening would be approximately 20 square foot(ft^2) in size, which is larger than the existing opening of approximately 2.3ft^2 in size (ignoring the existing broken boards on one of the gates). Since no excavation was proposed for Alternative A, the stage/surface-area and stage/volume relationships developed for existing conditions (Figures 6.6 and 6.7) were used in this analysis.

Two conditions were modeled for Alternative A. The first modeled condition demonstrates the extent of increased tidal inundation due to the larger tidal prism (larger muted tide cycle). At low creek flows, this would occur during flood tides introduced by the proposed tidegate modification (larger opening). This condition is shown in Figure 7.2 for an extended period covering a wide range of tidal boundary conditions in Humboldt Bay/Hookton Slough for existing conditions and Alternative A. Modeling indicates that the larger tidal prism of Alternative A would increase tidal inundation above existing conditions, thus providing the hydrology for increased tidal wetland/estuary habitat.

The second modeled condition demonstrates the effects that the proposed tidegate modifications of Alternative A would have on upstream conditions when Salmon Creek floods. For this analysis, a synthetic hydrograph was estimated for the Salmon Creek 2-year 24-hour flood (Q_2 flood). It was also assumed that the entire Q_2 flood hydrograph routes through the project area, which is a conservative assumption, since a large part of the Q_2 flood would flow into adjacent areas reducing the actual flood discharge into the project area. Consequently, the presented results for the Q_2 flood discharge should be considered hypothetical only, demonstrating the effects of a hypothetical flood hydrograph routed through the project area, and do not necessarily represent how the actual Q_2 flood would pass through the project area. Figure 7.3, shows the water surface elevations during the hypothetical Q_2 flood for existing conditions and Alternative A. Also shown on the figure is the hypothetical Q_2 flood hydrograph. Modeling results indicate that the proposed tidegate modifications and larger tidal prism do not significantly change existing flood conditions within the project area for the hypothetical Q_2 flood. Thus, preliminary modeling results indicate that implementing the Alternative A concept with tidegate modifications similar to those proposed should not have significant impacts on upstream flood conditions.

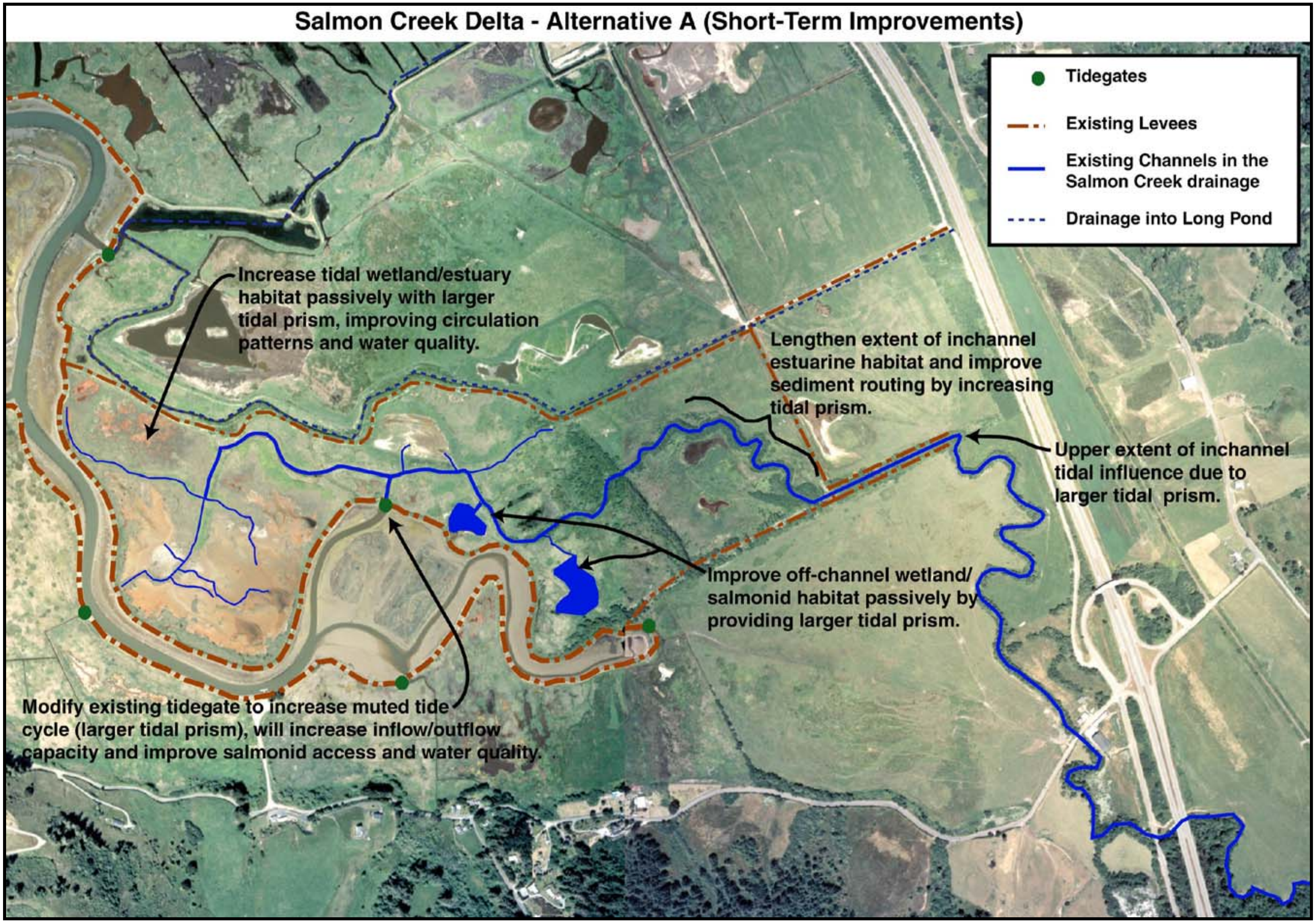

Figure 7.1 – Site map illustrating the Alternative A concept (Short-Term Improvements). With the exception of modifying the tidegates, all habitat improvements are achieved passively through an increase in the tidal prism.

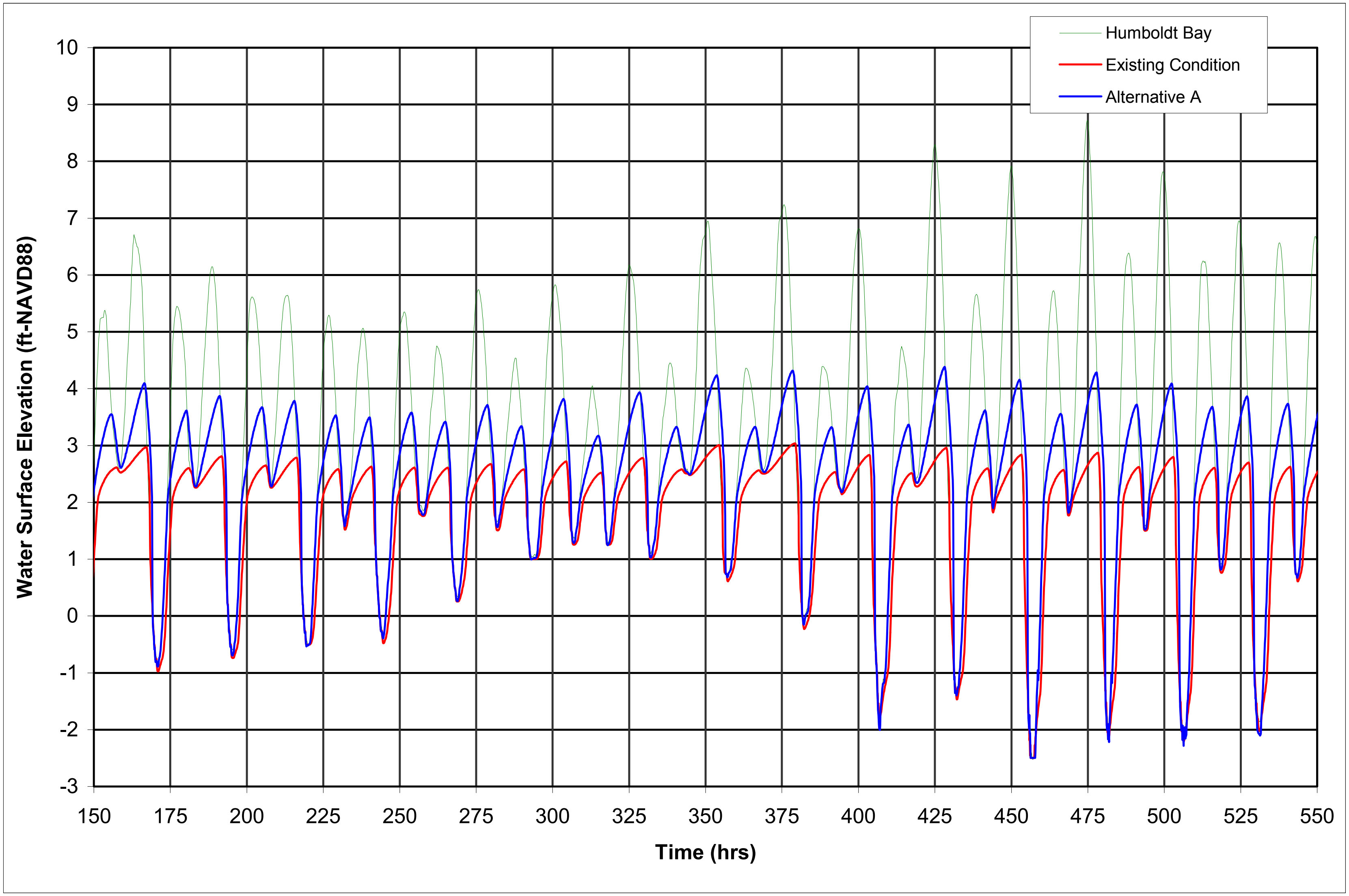

Figure 7.2 - Comparison of water surface elevations in Humboldt Bay/Hookton Slough and project area for existing conditions and Alternative A under low Salmon Creek flow conditions.

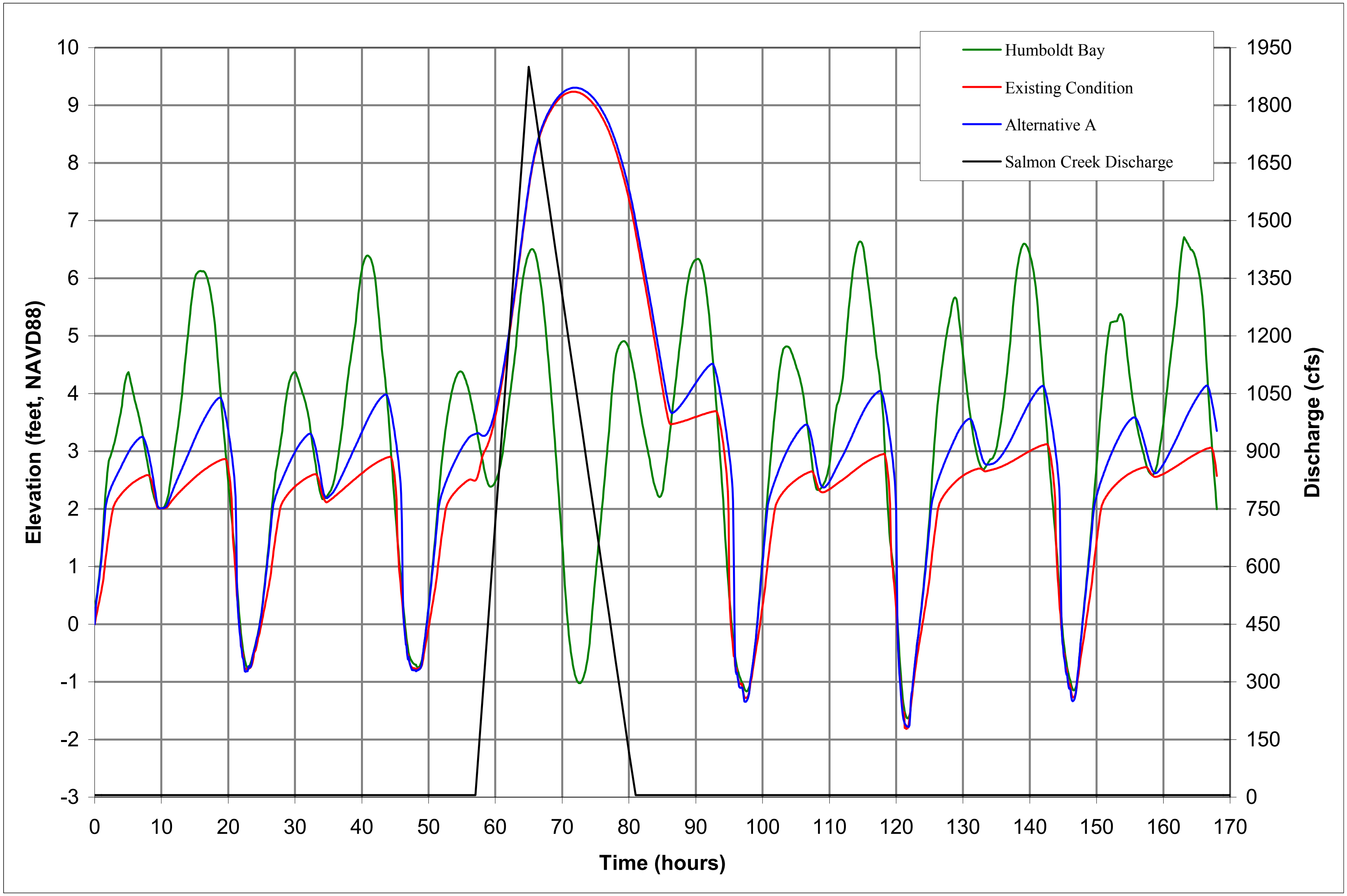

Figure 7.3 - Comparison of water surface elevations in Humboldt Bay/Hookton Slough and project area for existing conditions and Alternative A under hypothetical Q_2 flood discharge hydrograph.

7.3 Alternative B – Near-Term Improvement

7.3.1 Description and Design Elements

Alternative B requires a moderate amount of construction activity, and moderate design, permitting and environmental requirements. Due to the likely time requirements necessary to implement Alternative B, this alternative is considered a near-term improvement. The advantage with this alternative is that it incorporates more design elements, thus providing more opportunities for salmonid access and habitat enhancement than Alternative A. Figure 7.4 shows the requirements and locations of the various design elements associated with Alternative B.

Four of the design elements would be incorporated in Alternative B, and include (1) improving salmonid access to lower Salmon Creek, (2) in-channel estuarine habitat enhancement, (3) main channel restoration, relocation and enhancement, and (4) tidal wetland/estuary enhancement.

1. The first design element consists of installing a new tidegate structure at the location indicated in Figure 7.4. This new tidegate structure would have an opening designed to allow a larger tidal prism (muted tide cycle) than currently exists. New tidegated openings would also be included in the new structure to improve ebb tide or outflow discharge capabilities. The existing tidegates would be repaired and used to increase the floodwater discharge capability.

2. The second element consists of providing increased salmonid habitat within both the lower and upper estuary by constructing and enlarging slough channels in the lower estuary to connect low depressions to the main channel. Like Alternative A, the first action would, for the most part, rely on the increased tidal prism to passively enlarge existing slough channels. Earth moving would be limited to constructing or enlarging several small slough like channels to connect the low depression areas to the Salmon Creek channel. Construction of these channels would significantly improve the off-channel wetland habitat values in the low depression areas for foraging salmonids. The channels would also help to reduce potential fish stranding, and help to eliminate vector (mosquito) production.

3. The third element consists of three distinct actions: (1) creating a new Salmon Creek channel that connects downstream of the First Diversion (2) removing the knick point and deepening the channel mechanically if needed, and (3) creating secondary slough channels.

   The first action, the upstream channel restoration, would consist of creating a new meandering channel around and to the west of the first diversion, thus removing the straight channelized section of Salmon Creek running along the Refuges north-east property boundary. Restoring the channel in this location is simplified since the construction can be carried out on dry ground, allowing Salmon Creek to remain in its current channel. Only after the new portion of restored channel has been stabilized and revegetated would Salmon Creek flow be diverted into the new channel. The first diversion structure would remain and the upstream end of the existing channel would be plugged. The existing straight channel would remain as side-channel or backwater habitat. To provide access to the easterly levee, a new bridged crossing would need to be constructed over the new Salmon Creek channel. The mid-diversion would also have to be modified to handle flood flows from Salmon Creek.

The second action consists of deepening the existing Salmon Creek channel downstream of the connection with newly created channel, which would create a deeper low-gradient tidal channel similar to the channel downstream of the knick point. This would lengthen the estuary habitat running from the new tidegate structure upstream to the newly created channel, improving sediment routing, and increasing the channel capacity. It may be possible to limit earth moving to mechanically removing the knick point. With the increased tidal prism and the knick point removed, the channel could quickly incise to the desired depth. This should be implemented prior to constructing a new upstream channel to ensure a stable channel form and promote efficient sediment routing.

The third action consists of extending an existing tidally influenced channel and connecting it to the main channel upstream of the existing knick point. This secondary channel would increase the area of the fresh-saltwater interface, which serves as a valuable salmonid habitat type. It would also increase the overall channel capacity within the lower portions of Salmon Creek, decreasing the frequency of overbank flows. The hydrology for this secondary channel would be tidal exchange from the larger tidal prism as well as a portion of the freshwater inputs from Salmon Creek.

4. The fourth and final design element is improving or enhancing the existing western tidal estuary area. As with Alternative A, no earthwork is proposed, and the enhancement would passively occur due to the introduction of a larger tidal prism into the area. However, by relocating the tidegate structure in its proposed location, the tidal exchange in this tidal estuary area should significantly increase, allowing for faster enhancement of the tidal estuary area. Water quality conditions in the area should also improve do to increased circulation.

7.3.2 Opportunities/Benefits Gained

Implementation of Alternative B should provide for the following goals and objectives and opportunities and benefits within lower Salmon Creek:

1. Improved salmonid access,
2. Improved salmonid rearing and holding habitat,
3. Improved water quality conditions,
4. Enhanced tidal estuary habitats,

5. Enhanced/restored lower Salmon Creek channel,
6. Improved sediment transport conditions,
7. Improved channel and in-channel vegetation maintenance, and
8. Improved flood routing.

7.3.3 Construction Phasing

Some construction phasing of Alternative B would be required. The first phase would include repair of the existing tidegate, removal of the knick point, construction of all proposed channel creation and restoration work, modification to the mid-diversion structure, and construction of the new bridge crossing. Phase two construction would include redirecting the Salmon Creek flow into the created channel, and plugging the end of the old channel. Construction of the new tidegate structure would also occur in phase two, but the new opening would be blocked until the final phase. The third and final phase of construction is essentially unblocking the new opening, introducing the larger tidal prism (muted tide cycle) to the project area.

7.3.4 Additional Data, Analysis, and Design Requirements

Based on the proposed improvements for Alternative B, additional data collection, analysis, and design studies would be required. Design and construction documents would be necessary for all of the channel restoration elements, and the new tidegate structure. It would also be necessary to conduct additional hydrologic/hydraulic analysis of Alternative B to determine the impacts of the proposed tidegate modification, proposed tidal prism volumes and levels, and analyze the potential effects to upstream flood conditions.

Prior to implementation of Alternative B, it is proposed that the Refuge develop and implement a monitoring plan aimed at collecting both pre and post project physical and biological data. The monitoring should focus on assessing salmonid numbers and habitat usage, muted tide cycle extent, tidal wetland development and changes, channel modifications, and in-stream water quality.

7.3.5 Costs

The costs of Alternative B would be substantially higher than the cost of Alternative A. Costs include the additional design, analysis, and construction document preparation for the various Alternative B design elements. Construction costs include earthwork requirements, construction of the new tidegates, and repair of the existing tidegates. Table 7.2 is a preliminary cost estimate to implement Alternative B by design elements. Since this cost estimate is preliminary, a 25% contingency and a 25% engineering, design, construction document preparation, and permitting fee was included. The preliminary cost to implement Alternative B was estimated to be $1,800,000.

Table 7.2- Preliminary cost estimate for Alternative B by Design Element.

Design Element	Action	Approximate Quantity (unit)	Approximate Cost per Quantity ($/unit)	Cost ($)
Improved Salmonid Access	Existing Tidegate	Modification	Lump Sum	50,000
Improved Salmonid Access	New Tidgate Structure	New Tidgate	Lump Sum	350,000
Salmonid Habitat Enhancement	Construct/Enlarge Slough Channels	5,000 yd^3	$20/$yd^3$	100,000
Salmon Creek Channel Restoration	Construct New Channel	25,000 yd^3	$20/$yd^3$	500,000
Salmon Creek Channel Restoration	Deepen Existing Channel	10,000 yd^3	$20/$yd^3$	200,000
Tidal Estuary Enhancement	Passive	No Cost	No Cost	0
			Subtotal	1,200,000
			Contingencies (25% of Subtotal)	300,000
			Engineering, Design, Construction Document Prep., Permits (25% of subtotal)	300,000
			Preliminary Cost for Alternative B	**$1,800,000**

7.3.6 Tide Routing Analysis

The tidal routing model described in Section 2.3 was used to demonstrate the effects of one possible tidegate modification that could be used for an Alternative B concept. The same stage/surface-area and stage/volume relationship used for the Alternative A analysis was used in this analysis since minimal earthwork is proposed for Alternative B. Also, the same hypothetical Q_2 flood hydrograph and assumptions used in for Alternative A were used in this analysis. The tidegate modifications proposed for the Alternative B concept consisted of installing a new tidegate and using the existing tidegates for outflow discharge only (Section 7.3.1). To model this condition it was assumed that the new tidegates would be similar to the existing tidegates, and that one concrete bay would be left completely open (no tidegate), and the remaining five bays would have tidegates. The proposed opening would be approximately 40ft^2 in size, much larger than the existing 2.3ft^2 opening.

Figure 7.5 shows the increased tidal inundation in the project area due to the larger muted tide cycle (increased tidal prism) under low Salmon Creek flow conditions for Alternative B. Modeling results indicate that the larger tidal prism of Alternative B would increase tidal inundation to an approximate maximum elevation of 5.3 feet, which is higher than the existing condition inundation of approximately 3 feet. Reference to Figure 6.3 shows the approximate areal extent of a 5 foot tidal inundation within the project area, which will provide the hydrology for increased tidal wetland/estuary habitat.

Figure 7.6 shows the effects on project area flooding from the proposed tidegate modifications for Alternative B due to the hypothetical Q_2 flood discharge. Modeling results indicate that significant improvements in both the reduction of flood elevations and flood duration within the project area occurs for the proposed tidegate modifications under Alternative B. These reductions could also improve upstream flood conditions, as flood waters should route through the project area faster, causing upstream flood levels to recede quicker.

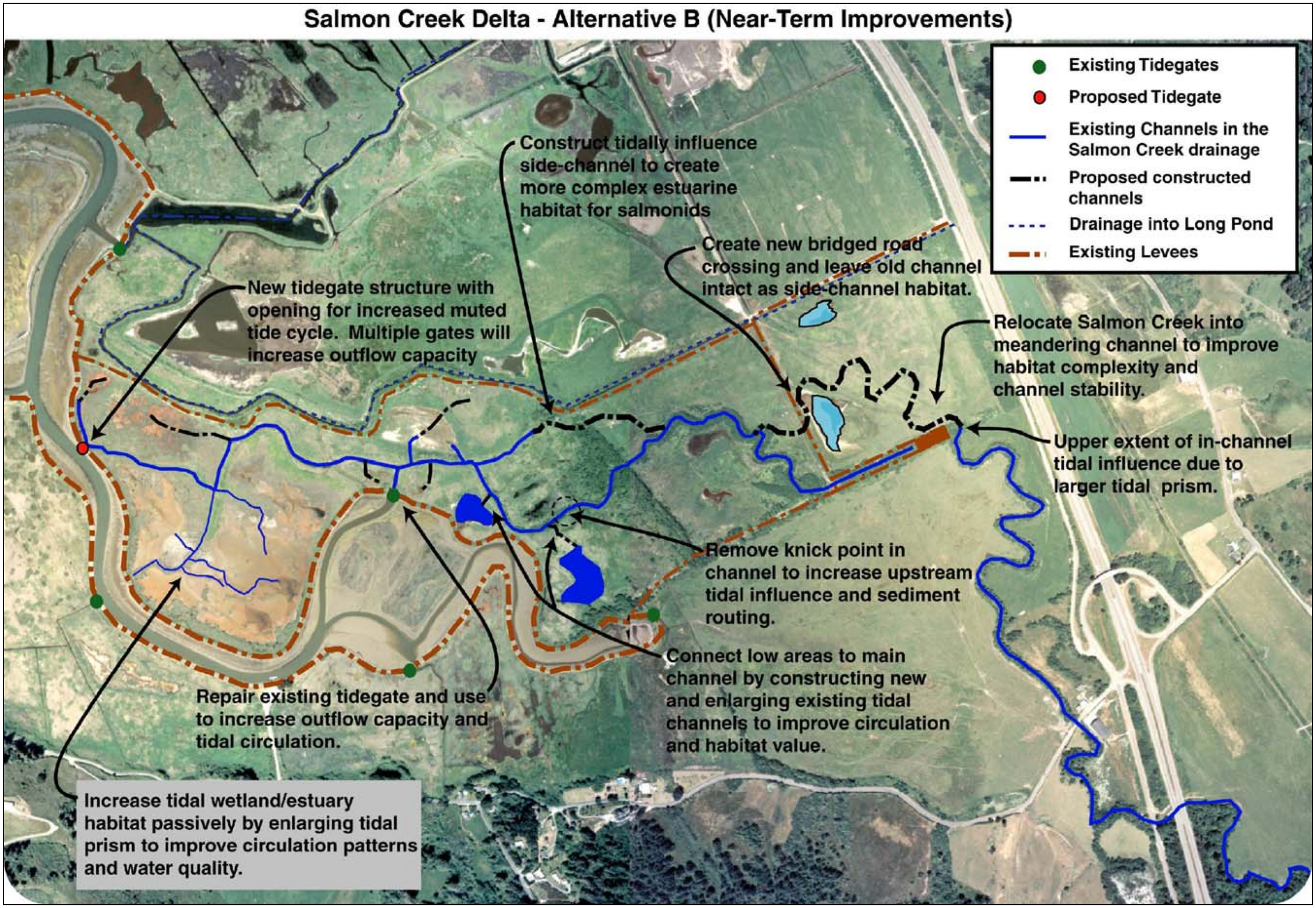

Figure 7.4 – Site map illustrating the Alternative B concept (Near-Term Improvements).

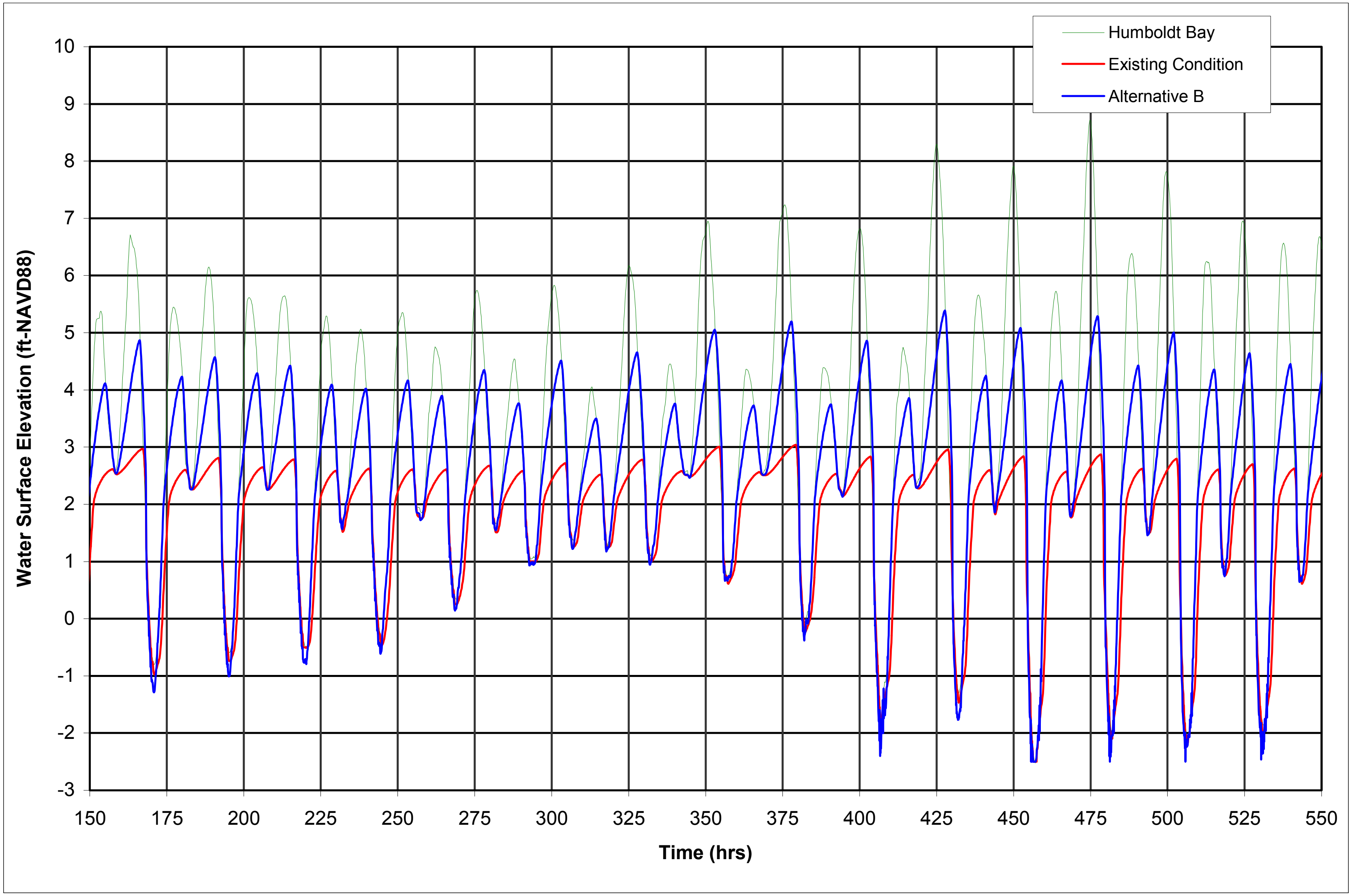

Figure 7.5 - Comparison of water surface elevations in Humboldt Bay/Hookton Slough and project area for existing conditions and Alternative B under low Salmon Creek flow conditions.

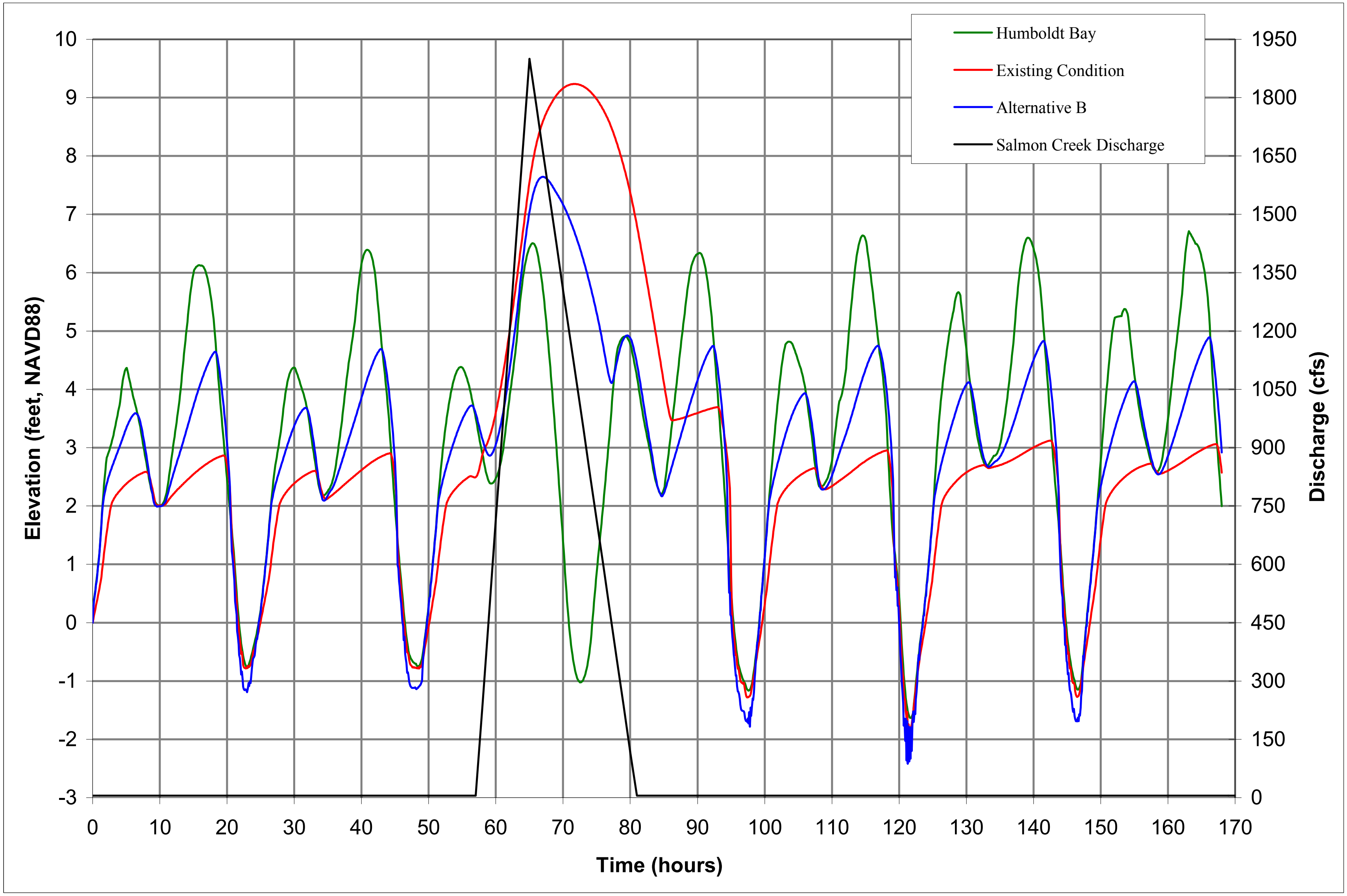

Figure 7.6 - Comparison of water surface elevations in Humboldt Bay/Hookton Slough and project area for existing conditions and Alternative B under hypothetical Q2 flood discharge hydrograph.

7.4 Alternative C – Long term Improvement

7.4.1 Description and Design Elements

Alternative C demonstrates a complex alternative that aims to restore lower Salmon Creek estuary as close to its historic form, function, and compositional characteristics as possible within the project area. Historic form, function and compositional characteristics would be based on historic photos, mapping, and surveys of existing, unaltered (as much as possible) features surrounding Humboldt Bay. One of the primary design elements of Alternative C is a levee breach that would allow unimpeded tidal exchange within the project area, and provide optimal salmonid access. However, to obtain salmonid habitat enhancement for Alternative C, it will be necessary to conduct extensive earthwork, recontouring, and excavation and filling within large existing wetland and riparian areas to accommodate the larger tidal prism due to the levee breach. This alternative is considered a long term option due to the time and expenditures required for implementation. Figure 7.7 shows the concept and locations of the various design elements for Alternative C.

At some level, all five of the design elements would be utilized with Alternative C, and include (1) improving salmonid access to lower Salmon Creek, (2) salmonid habitat enhancement, (3) Salmon Creek channel restoration, (4) tidal wetland/estuary enhancement, and (5) freshwater wetland enhancement.

1. For Alternative C, an engineered levee breach is proposed as the first design element, and would be located as shown in Figure 7.7. This levee breach would be large enough to allow full or approximately full Humboldt Bay tidal inundation of the project area, along with unimpeded salmonid access. The existing tidegate would be removed and the opening filled to surrounding levee elevations. Depending on the existing interior levee and ground elevations, it may be necessary to raise existing levees or construct new levees to protect adjacent property, roads, and Refuge lands not in the project area from tidal inundation.

2. Excavation and extensive recontouring of existing areas would be required to provide optimal salmonid habitat enhancement (Design Element 2) to offset the increased tidal inundation depths resulting from the levee breach. Excavation, filling and recontouring would be done to maximize the amount of restored salt marsh, slough channels, and off-channel wetland, thus providing the largest and most complex salmonid habitat possible within the project area. At some level, earthwork would be required over most of the project area.

3. For the third design element, most of the existing lower Salmon Creek channel would be abandoned and filled, and a new meandering channel would be created that would resemble historic lower Salmon Creek channel characteristics, although not in its most recent historic location. In addition, off-channel slough and secondary channels would be created providing complex flow paths, more resembling historic conditions

(Figures 3.4 and 3.5). Removal of the First Diversion would occur with Alternative C, and it would be necessary to provide new water management facilities to other parts of the Refuge which rely on First Diversion water.

4. The fourth design element would focus on creating and enhancing tidal wetland/estuary habitat within in the project area. The maximum amount of tidal wetland/estuary habitat feasible would be created within the project area. Also, consideration would be given to developing tidal wetland/estuary habitat that provides the most optimal salmonid habitat (Design Element 2). Maximizing optimal tidal wetland/estuary and salmonid habitat could require extensive filling, excavation and recontouring of the project area.

5. The fifth design element proposed for Alternative C is freshwater wetland enhancement. Due to the potential extent of tidal inundation caused by the levee breach, the freshwater wetland would need to be created in the northern portion of the project area, outside the extent of tidal flooding. The freshwater wetland could be a seasonal wetland that only captures precipitation and overbank discharges. Another option would be to divert all or a portion of Cattail Creek into the created wetland providing a additional freshwater inputs to the wetlands. It would be important during the design phase to ensure that the channel connecting the wetland to the Salmon Creek channel is high enough to limit saltwater from entering the freshwater wetland.

7.4.2 Opportunities/Benefits Gained

Implementation of Alternative C should provide for the following goals and objectives and opportunities and benefits within Lower Salmon Creek:

1. Improved salmonid access,
2. Improved salmonid rearing and holding habitat,
3. Improved water quality conditions,
4. Enhanced tidal wetland/estuary habitats,
5. Enhanced/restored lower Salmon Creek channel,
6. Enhanced freshwater wetland habitat,
7. Improved sediment transport conditions,
8. Improved channel and in-channel vegetation maintenance, and
9. Improved flood routing.

7.4.3 Construction Phasing

Construction of Alternative C would be complicated, requiring phasing, and likely spanning three or more construction seasons. To provide some insight on construction difficulties, the following demonstrates one possible construction phasing scenario. The first construction phase (year 1) would require blocking the channel that feeds the south-westerly tidal wetland area, allowing this area to dry. This could be done by extending the internal levee along the easterly boundary of the tidal wetland. If the first phase was conducted in the spring, the tidal wetland area could be dry enough to allow earthmoving activities to occur in the summer and fall construction period. The second phase (year 1), which would likely require an entire construction season, would consist of recontouring large portions of the site to create the tidal wetland and freshwater wetland habitats. During this time, segments of the new Salmon Creek channel and slough channels could be constructed, but would remain closed and isolated from the existing Salmon Creek channel. The third construction phase (year 2) would consist of finishing the new Salmon Creek channel, and excavating all of the remaining slough, secondary and connector channels. The Salmon Creek flow would then be diverted into the new channel, and the existing channel filled and recontoured. Revegetation of the upland, riparian and freshwater wetland areas would then occur. The final construction phase (year 3) would be to revegetate the tidal wetland areas, and remove the internal levee constructed during the first construction phase. The tidal breach would then be constructed in the levee, thus opening the entire project site to Humboldt Bay. The final step would be removing the old tidegate and filling the remaining portion of the old channel.

7.4.4 Additional Data, Analysis, and Design Requirements

Based on the proposed improvements for Alternative C, additional data collection, analysis, and design studies would be required. Design and construction documents would be necessary for the entire restoration project. Alternative C would require detailed hydrologic/hydraulic modeling and analysis to accurately predict water levels from the breached levee, and assess impacts to upstream flooding.

Following implementation of Alternative C, it is proposed that the Refuge develop and implement a monitoring plan that monitors salmonid numbers and habitat usage, muted tide cycle extent, tidal wetland development and changes, channel modifications, and in-stream water quality.

7.4.5 Costs

The cost of Alternative C would be substantially higher than the cost of Alternative A or B. Higher costs would be associated with the design, analysis, and construction document requirements. Due to the extensive earthmoving, and construction requirements for certain design elements, construction costs for Alternative C would be significantly higher than the other alternatives. Due to the complexities involved and the large quantities of earth work necessary to construct Alternative C, no preliminary cost breakdown was done. It is believed that a cost to implement Alternative C would range from approximately $5,000,000 to $10,000,000.

7.4.6 Tide Routing Analysis

The tidal routing model described in Section 2.3 was used to demonstrate the effects of one possible levee breach scenario for an Alternative C concept. The same hypothetical Q_2 flood hydrograph and assumptions used in Alternatives A and B were also used in this analysis. Even though significant earthwork is proposed for Alternative C (Section 7.4.1) which would alter the existing condition stage/surface-area and stage/volume relationship (Figures 6.6 and 6.7), the same stage/surface-area and stage/volume relationship used for the other alternatives were used in this analysis. For Alternative C, a 200ft^2 levee breach is proposed that will provide more-or-less unimpeded flow. For preliminary modeling purposes, it was assumed that the levee breach was equivalent to five of the existing open concrete bays without tidegates. No tidegated openings were provided in the Alternative C tidal routing analysis.

Figure 7.8 shows the increased tidal inundation in the project area due to the levee breach and larger tidal prism for Alternative C. Modeling results indicate that the levee breach does not provide complete unimpeded tidal inundation, and some muted effects are evident in both high and low water surface elevations. The larger tidal prism of Alternative C would significantly increase tidal inundation over existing conditions, and Figure 7.8 shows that maximum tidal inundation levels approach 8 feet. Reference to Figure 6.5 shows the approximate areal extent of a 7 foot tidal inundation within the project area, and the proposed levee breach for Alternative C would inundate a larger area than this under maximum inundation levels, providing the hydrology for maximum tidal wetland/estuary habitat.

Figure 7.9 shows the rather surprising results on project area flooding due to the proposed levee breach for the hypothetical Q_2 flood discharge. Modeling results indicate that the proposed levee breach provides improvements to both project area flood levels and duration of flooding. Even though these flood improvements are less than Alternative B conditions, they are significantly improved over existing conditions. Preliminary modeling results indicate that a proposed levee breach under the Alternative C concept, could improve project area and upstream flood conditions.

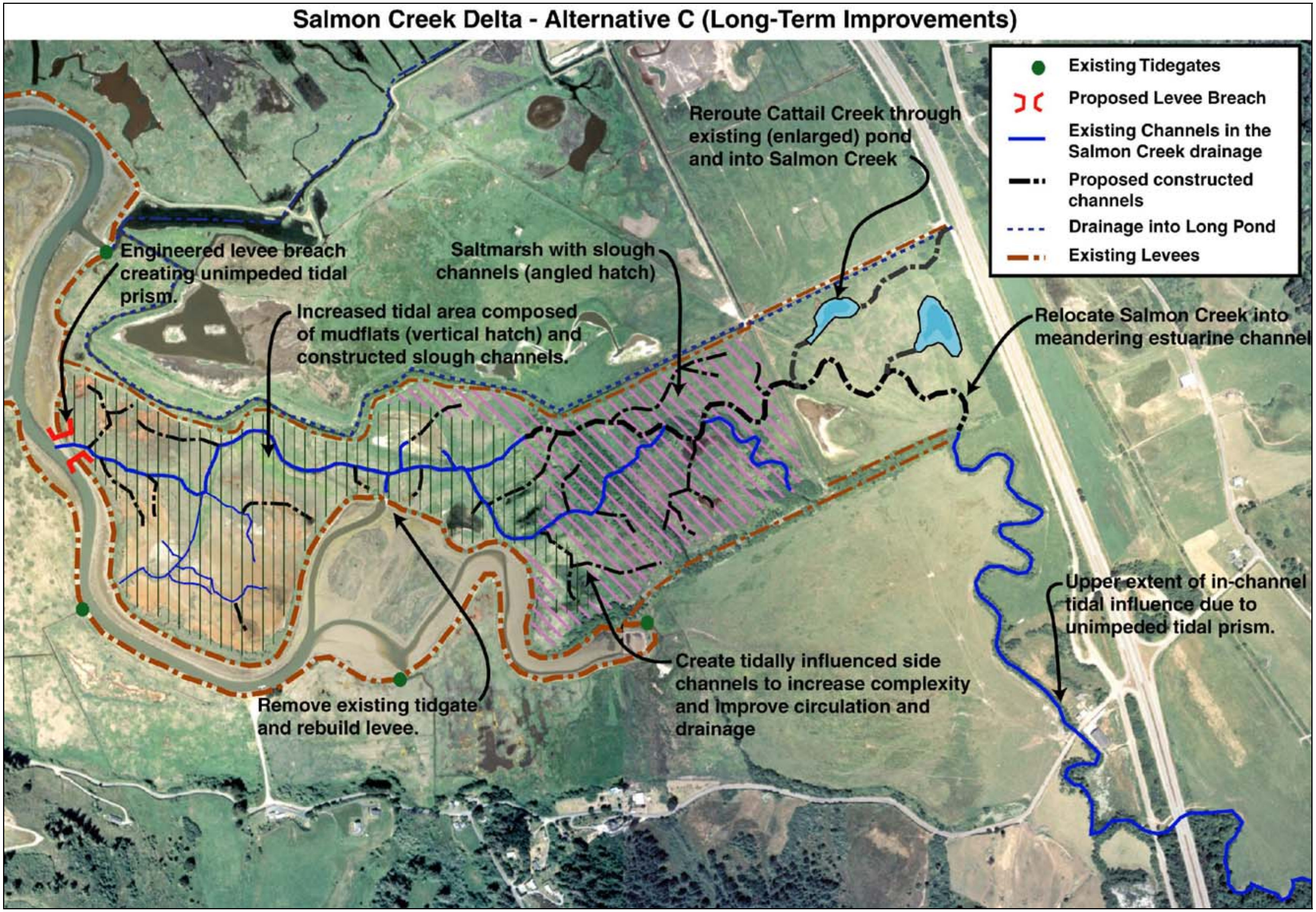

Figure 7.7 - Site map illustrating the Alternative C concept (Long-Term Improvements).

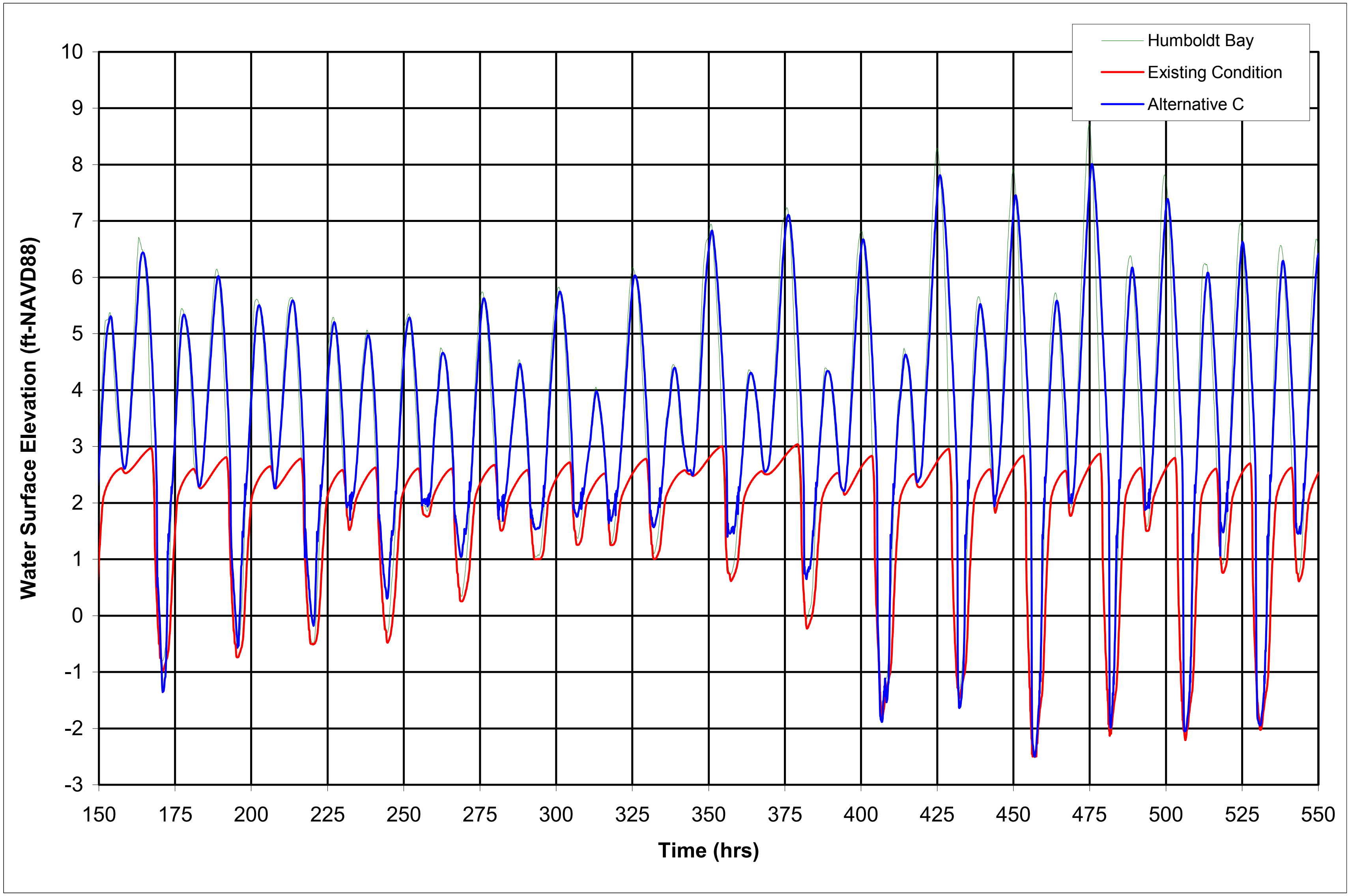

Figure 7.8 - Comparison of water surface elevations in Humboldt Bay/Hookton Slough and project area for existing conditions and Alternative C under low Salmon Creek flow conditions.

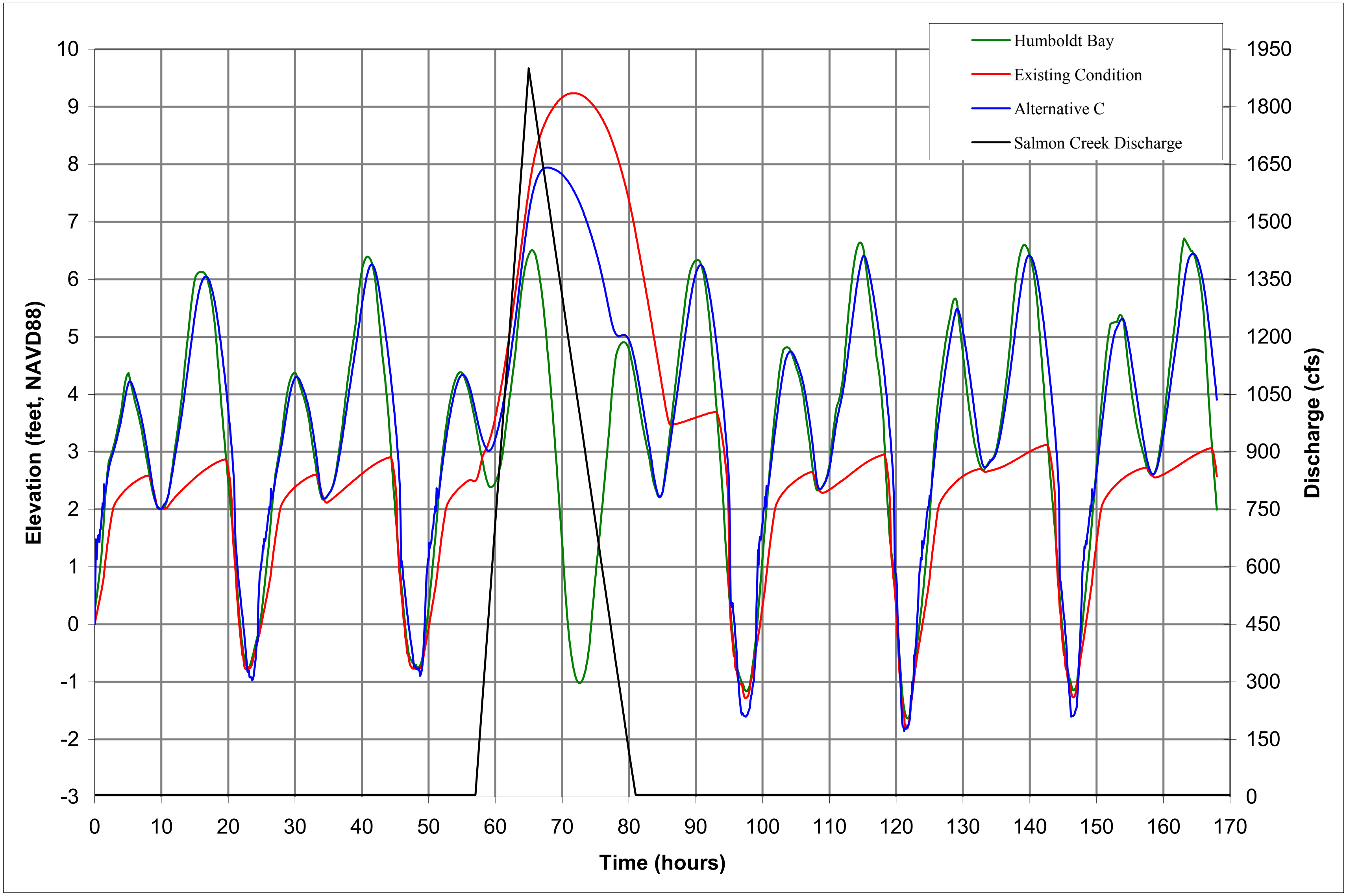

Figure 7.9 - Comparison of water surface elevations in Humboldt Bay/Hookton Slough and project area for existing conditions and Alternative C under hypothetical Q2 flood discharge hydrograph.

8 Summary and Recommendations

Based on this feasibility scoping report, we believe that improving salmonid access and habitat enhancement in lower Salmon Creek to be a viable restoration project. Further, the project could be compatible with other Refuge goals and objectives and would provide ancillary benefits, such as improved channel maintenance and sediment routing in lower Salmon Creek, improved and/or reduced upstream flood conditions, and provide additional habitat for other wildlife species.

The intent of the concept alternatives developed in Section 7 was to demonstrate how the various design elements could be integrated to provide a wide range of alternatives for restoring salmonid access and habitat in lower Salmon Creek. Each of the three concept alternatives was different in terms of complexity and the goals and opportunities provided. Likewise, implementation issues, requirements, limitations and costs associated with each alternative increased with the complexity of each alternative. As mentioned earlier, this feasibility report is preliminary, meant only to scope potentially viable restoration concepts for salmonid access and habitat enhancement to lower Salmon Creek. When Refuge and/or stakeholder agreement is reached regarding a restoration alternative and the design elements presented in this report, the next step would be to conduct more detailed, data-intensive analysis and studies which will ultimately lead to project design and specifications, and permitting.

8.1 Alternative Development and Selection

Ultimately, it will be up to the Refuge to choose a salmonid access and habitat enhancement alternative for implementation. The alternative could be one of the conceptual alternatives developed in the study, a variation of one of the concept alternatives, or a completely new alternative based on Refuge perception and needs. However, we feel that the alternative ultimately chosen for implementation should include as many of the proposed design elements as feasible to ensure the best opportunities for improved salmonid access and habitat enhancement of lower Salmon Creek. To assist the Refuge in alternative selection, some type of alternative evaluation methodology could be utilized, such as alternative ranking. Besides considering the criteria outlined for each concept alternative in Section 7, the associated risk and phasing requirements should also be considered in selecting a restoration alternative.

8.2 Risks

Certain risks are associated with any environmental restoration effort. At a minimum, the following risks should be considered with implementation of an alternative or design element:

- Ecological Risks,
- Cultural Resource Risks,
- External Risks to areas outside of Refuge, and
- Hydrologic Risks.

8.3 Phasing Between Alternatives

The alternatives, or even phases of alternatives, can be considered horizons in reaching a long term restoration goal for lower Salmon Creek. Since it will not be possible to consider all combinations of design elements, consideration should be given to how some alternatives (or elements of alternatives) could be coupled or phased with a minimum of lost costs. For example, it may be possible to implement the Alternative A concept in the short term, with the Alternative B concept being the long term restoration goal. However, it will be important to consider if implementing a short term alternative or design element would limit the future possibility of implementing a more complex alternative or design element. For example, if an Alternative C concept is the ultimate restoration goal, then implementing Alternative A or B, or some design elements, could result in lost costs, and/or impede the ultimate implementation of Alternative C.

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