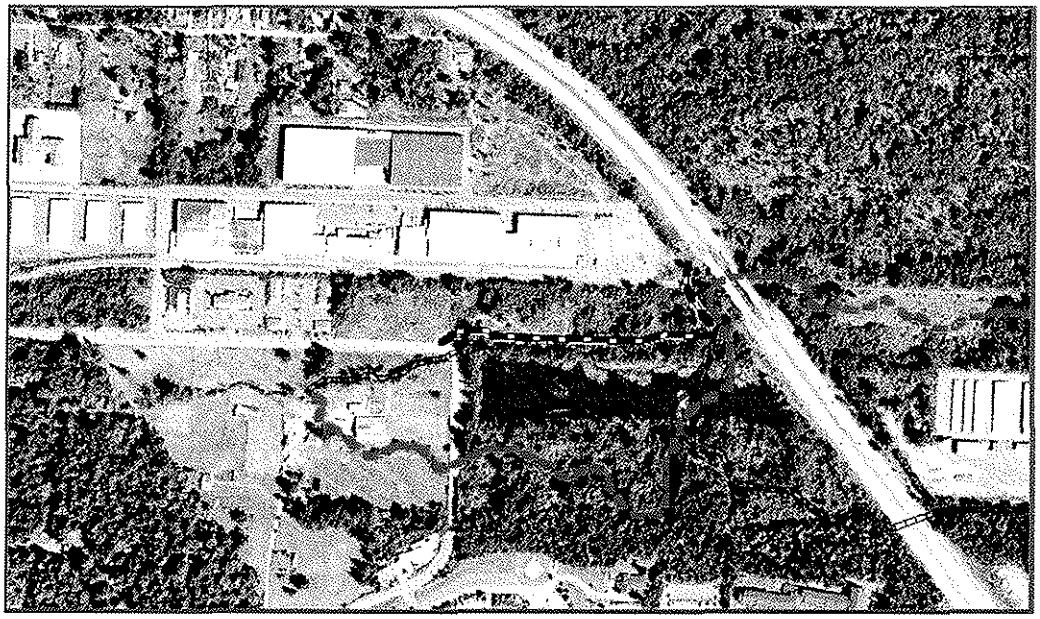
SQUALICUM CREEK RE-ROUTE FEASIBILITY STUDY
BUG LAKE AND SUNSET POND

Final Report



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Prepared for

Nooksack Salmon Enhancement Association

August 22, 2002

GeoEngineers

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August 22, 2002

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RE: Squalicum Creek Re-Route Feasibility Study

GeoEngineers is pleased to submit this final report entitled "Squalicum Creek Re-Route Feasibility Study". This evaluation was conducted using the best available information at the time of this assessment. Conditions within the subject reach may change both spatially and with time, and additional scientific data may become available. Significant changes in site conditions or the available information may require reevaluation. This report is prepared in accordance with GeoEngineers, Inc. Services Agreement #9461-001-00, dated January 24, 2002. This report is for use by the Nooksack Salmon Enhancement Association.

We appreciate the opportunity to provide these services to the Nooksack Salmon Enhancement Association. If you need any additional information or have any questions regarding this report please call Tracy Drury at 360-647-1510.

Sincerely,

GeoEngineers, Inc.

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SQUALICUM CREEK RE-ROUTE FEASIBILITY STUDY

INTRODUCTION

Historical accounts indicate that large numbers of salmonids used Squalicum Creek for adult spawning and juvenile rearing. Currently returns to Squalicum Creek are small and much of the available habitat is underutilized. Major alterations to Squalicum Creek occurred in the 1960s and 1970s in conjunction with the construction of Interstate 5 (I-5). Two large gravel excavations were dug to acquire construction materials for the freeway. These excavations have since become Bug Lake and Sunset Pond and the creek currently flows through these waterbodies. Non-native warm-water fish currently reside in the lake and pond interacting with native fish species. In addition, the creek channel has been heavily modified during the installation of transportation routes and industrial construction within the floodplain and is currently routed through several culverts. The intensity and magnitude of these creek modifications has led to questions regarding their implications on the dramatic decline in salmonid stocks within Squalicum Creek.

STUDY AREA GOALS AND OBJECTIVES

The goal of this study is to determine if channel improvements or rerouting of Squalicum Creek through the study area (Figure 1) will provide cost effective ecological benefits to salmonids through all life history stages. Of particular interest are issues related to passage for adults and predation of juveniles by non-native fish species.

In general, the objective of this study is to evaluate actions that can be taken to achieve the project goals and are cost effective, low maintenance, self sustaining, and allow natural processes to improve and maintain habitat conditions over time.

BASIN DESCRIPTION

Squalicum Creek drains approximately 15,800 acres of a relatively low-elevation basin with a maximum elevation of just over 1,500 feet on Squalicum Mountain. The land cover in the upper portion of the drainage area is comprised by deciduous forest, mixed deciduous/coniferous forest, cropland, and pastureland. Lower in the drainage basin, residential, commercial, and light industrial land uses increase. For the purposes of this report, we have defined the study area as: an approximate two mile reach from Hannegan Road down to the Deets property (Figures 2a and 2b). The City of Bellingham (COB) boundary crosses the creek just upstream of Hannegan Road, and the entire study reach lies within the city limits.

Through the study area the creek runs through a shallow, east-west trending valley, with a width of less than ¼ mile in most places. The upland areas surrounding the valley and the valley walls are composed of unsorted, unstratified glacial drift (USGS, 1976). The valley walls rise roughly sixty feet from the valley floor with the south wall being much steeper than the gradual slope of the north wall. The geology of the valley floor consists of outwash sands and gravel from post-glacial meltwater channels (USGS, 1976). These deposits are younger than the older valley wall and upland sediments surrounding them. According to the 1976 USGS map, the surface materials of the valley are relatively fine-grained, former outwash plain deposits

underlain by a coarser layer of gravels. A noticeable clay layer (at least 2 feet thick, at a depth of approximately 1 and 1/2 feet) is exposed in the banks of the stream through most of the reach. During the construction of I-5, two gravel pits were excavated that now comprise Sunset Pond and Bug Lake. Hence, we assume that extensive gravel deposits exist to some depth under the site.

Estimation of peak flows for various recurrence intervals is difficult in the ungaged Squalicum Creek watershed. In 1980, the USDA Soil Conservation Service (SCS) performed a hydrologic analysis of the Squalicum Creek watershed to calculate peak flow values for certain recurrence intervals. These data were subsequently evaluated in preparation for a 2-dimensional hydraulic model undertaken as a portion of the Squalicum Creek Floodplain Management Plan (SCFMP, 1994). The results of this evaluation were such that the value for the 100-year flow event predicted by the SCS (1,310 cubic feet per second [cfs]) may be as much as 30 percent too high (SCFMP, 1994). However when modeling for future conditions, the SCFMP used 1,400 cfs as the 100-year peak flow. The COB has since developed a watershed management plan in which they adopted the following discharge quantities at a location just below the study area for various flow recurrences: 2-year return interval: 318 cfs; 25-year return interval: 883 cfs; 100-year return interval: 1,125 cfs (B. Reilly, pers. comm.).

HISTORICAL IMPACTS

Squalicum Creek has changed markedly through the study reach since the time of first Euro-American occupation. Nearly all of the native forest has been cut, either for timber or cleared for agriculture and grazing. Two railroad lines were routed through the Squalicum Creek valley suggesting that this valley was among the first in the area to be severely impacted. Initial timber harvest in the watershed was concurrent with settlement and railroad construction, and the close proximity to the railroads likely led to extensive harvest and subsequent impacts to Squalicum Creek.

In the 1960s and 1970s, the valley was impacted by the construction of I-5. The elevated road fill for I-5 rises to the same height as the valley walls and runs across the entire valley, save for the culvert crossings and railroad overpass. Bug Lake and Sunset Pond were excavated for materials associated with the construction of I-5. It is unclear whether the creek was routed through these excavations at that time, or moved into them sometime later. These ponds are now impeding natural sediment transport and channel evolution processes. Non-native piscivorous fish species now inhabit these ponds, and feed on native salmonid populations. More recently urbanization, industrialization, and floodplain encroachment has continually increased in the basin.

FISHERIES RESOURCES

Historically, coho and chum salmon (Oncorhynchus kisutch and O. keta) utilized Squalicum Creek for spawning and rearing (Downen 1999, Downen and Mueller 1999). Since the 1930s, Squalicum Creek had been stocked with sea run cutthroat (O. clarkii) and steelhead (O. mykiss). In the headwaters of the creek, upstream of the study area, Toad Lake has been stocked with rainbow trout (O. mykiss) and kokanee (O. nerka) and Squalicum Lake is stocked with rainbow trout. As recently as 1998, chum, coho, and fall-run chinook salmon fry have been released in Squalicum Creek. Steelhead and sea-run cutthroat trout stocking was discontinued in 1988 because the stocked fish may compete against the native trout in the system. Other native fish that utilize Squalicum creek include three-spine stickle back (Gasterosteus aculeatus), prickly sculpin (Cottus asper), western brook lamprey (Lamptera richardsoni), and Pacific lamprey (Lamptera tridentata).

A variety of warm-water fish have been introduced into Bug Lake and Sunset Pond and because of suitable conditions a sustained community has thrived. These fish include: largemouth bass (Micropterus salmoides), yellow perch (Perca flavescens), bluegill (Lepomis macrochirus), brown bullhead (Ameiurus nebulosus), and yellow bullhead (Ameiurus natalus).

Brown trout (Salmo trutta) have been identified in the stream system. Brown trout have a competitive advantage over other salmonids. They are more aggressive, can withstand warmer water, and can survive with lower dissolved oxygen. Brown trout are piscivorous and will prey on fish smaller than themselves (Wydoski and Whitney 1979). Brown trout are fall spawners and migrate from pools and lakes to riffle areas to spawn (Sigler and Sigler 1996) where they may compete for spawning and rearing habitat with native salmon.

These introduced fish may compete with and prey on juvenile salmonids in Bug Lake, Sunset Pond, and the creek itself.

REACH DELINEATION AND DESCRIPTION

Within the study area, the creek was broken into shorter reaches to facilitate easier discussion of various portions of the stream (Figures 2a and 2b). The reaches delineated are roughly similar to those utilized in the SCFMP, although some new reaches were created to facilitate our evaluation. Reach endpoints are generally based on infrastructure within the valley, but were also associated with changes in the character of the stream, floodplain, or land use. The reaches are defined as follows:

Reach 1: Hannegan Road to Burlington Northern Railroad (BNRR) grade
Reach 2: BNRR grade to the Chicago Milwaukee and St. Paul Railroad (CMSPRR) grade
Reach 3: CMSPRR grade to Sunset Pond
Reach 4: Sunset Pond inlet to James Street
Reach 5: James Street to I-5
Reach 6: I-5 to Squalicum Parkway
Reach 7: Squalicum Parkway to Deets property

REACH 1: HANNEGAN ROAD TO BNRR GRADE

Squalicum Creek enters the study reach through a three-span concrete box culvert under Hannegan Road and flows along the southern edge of a meadow area. The creek then turns north through the meadow where the reach ends at the BNRR grade. The channel is relatively narrow and channelized and the floodplain areas show signs of extensive grazing. Some large wood exists in this reach, providing habitat complexity and promoting sediment deposition. Beaver sign is abundant in the lower end of this reach.

The abandoned BNRR grade crosses the creek in the middle of the valley. There are several old, wood pilings in the channel likely the remnants of a bridge. A remnant beaver dam is evident among the pilings and has impounded sediment upstream of the grade. Impounded flow and sediment has redirected flow and promoted erosion of the BNRR grade, however only one break in the railroad grade was identified. Therefore, the railroad (RR) grade forms a topographic barrier across the valley, and a beaver pond has formed in the impounded area between RR grade and the south valley wall.

REACH 2: BNRR GRADE TO THE CMSPRR GRADE

In Reach 2, Squalicum Creek runs through a relatively natural channel from the remnant beaver dam to the CMSPRR grade. The channel makes several broad turns before reaching the railroad grade where it turns sharply to the west. The channel is wider than Reach 1, and has significantly more cover from large trees, including several mature conifers. Vegetation on the left bank is extensive and appears more mature than that of the right. We observed several large trees that have recently toppled into the stream naturally, along with at least one active beaver dam and extensive evidence of their habitation. The natural state of the vegetation, width of the channel, and presence of meander bends in this reach indicate that this reach is largely natural and has been less impacted than others within the study reach.

REACH 3: CMSPRR GRADE TO SUNSET POND

For purposes of description, this reach has been broken into two sections: the mainstem of Squalicum Creek and two secondary channels, Tributaries V and W that run along either side of the CMSPRR grade through the entire study reach. The tributary names have been adopted from the Beck report, which notes that this nomenclature has been used in previous flood studies.

Squalicum Creek

The mainstem of Squalicum Creek flows along the south side of the CMSPRR grade, eventually turning to the south and entering Sunset Pond. Through the upper portion of this reach, the channel runs along the southern side of the CMSPRR grade and is straight, relatively narrow, and appears to have either captured this section of channel from Tributary V or been routed through it. Near the end of this straight section of channel, the stream makes an abrupt turn to the south and flows into Sunset Pond. At the point where the creek takes a 90-degree turn, it is evident that significant flows have continued down Tributary V in the past. This point is described in the SCFMP as an area where a beaver dam blocked flow and dispersed it into several channels. Some of these channels flowed across the floodplain into Sunset Pond and are still

visible today. At least one channel continued straight down Tributary V, however the Tributary V channel is currently blocked with large rock and various fill materials at this location preventing normal flows from continuing along the RR grade. The channel that currently leads to Sunset Pond was excavated to facilitate flow into the pond (B. Reilly, pers. comm.) and is wider than the upper reaches. Some large trees have toppled into the creek in this area resulting in relatively good channel complexity, and a sizeable delta has formed at the pond inlet where bedload sediments are being deposited.

In the upper portion of the reach, a maturing riparian forest is present along the left bank. The right bank runs along the toe of the railroad grade, and is steep and some areas are covered in bushy vegetation and young trees. Evidence of erosion and subsequent maintenance (riprap) was observed along the RR grade. There are several small beaver dams in this reach including one that impounds water for at least several hundred feet.

Our field surveys confirm the existence of a historic channel in the southern portion of the valley through this reach. This channel is very distinct and observable in the downstream portion of the reach, and slowly grades upstream to become not at all apparent in the upper portion of the reach. There are several stands of mid-seral stage conifers adjacent to and near the former channel, particularly in the lower portion of the reach. As a consequence, canopy cover and shade are excellent on several portions of this former channel. Several old-growth conifer stumps are evident, the only ones we observed during our surveys.

Tributaries V and W

Tributaries V and W run parallel to the CMSPRR grade with Tributary V to the south and Tributary W to the north. The tributary channels may be the consequence of excavation and construction of the CMSPRR railroad and may have initially been borrow pits. Through the study reach the grade acts as a levee, separating the tributaries under most flow conditions. In fact, Tributary W can be thought of as a separate watershed with flows being divided under all but extreme events. Tributary W conveys surface and groundwater flow from the northern section of the valley and is a year-round stream. The floodplain to the north of Tributary W is a flat wet meadow with patchy mixed deciduous forest. The upstream portion of this meadow has been cleared, apparently in preparation for development. As previously mentioned, in the upper portions of Reach 3, Squalicum Creek is currently occupying Tributary V. This occupation has dramatically changed the characteristics of Tributary V since it is an overflow channel throughout the rest of the study area, conveying flow only during high flow events.

REACH 4: SUNSET POND INFLOW TO JAMES STREET

This reach description is also broken into two sections: the mainstem through Sunset Pond and Tributaries V and W.

Squalicum Creek

In Reach 4, Squalicum Creek flows through Sunset Pond and outlets along the southern valley wall just upstream of James Street. Sunset Pond is not a natural feature in the valley as it was excavated to obtain aggregate and/or fill material for the construction of I-5. Based on sediment deposition observed at the pond's inlet delta, the level of the pond can fluctuate approximately 2 feet. With a surface area of approximately 10 acres, the pond may be capable of providing 20 acre/feet of flood storage. During most flows the creek outlets the pond at the southwest corner, where it flows through a short channel section and under James Street through a 16-foot plate arch culvert.

Our evaluation of historical maps and aerial photographs indicates that prior to excavation of the pond, the creek traveled along the southern margin of the valley through this reach. The 1947 aerial photograph depicts the Sunset Pond area as a cleared pasture with the creek channel running along the southern side of the pasture bordered by a thin strip of riparian vegetation. Sunset Pond is visible in the 1976 aerial photographs and it appears that a channel to the south of the pond may still be present, although it appears straightened and connectivity on the upstream end is not clearly visible. In comparing the 1947 and 1976 aerial photographs, it seems that the channel straightening associated with the pond excavation could be the consequence of actions to confine the creek to the south of the valley with a berm, enabling excavation without the creek flowing into the gravel pit. During our site investigation of the southern side of the pond, we identified a low area separated from the pond by a berm roughly 4 feet high. It is unclear whether this depression was the stream channel before the pond was dug, a temporary channel during pond excavation, or merely a low, wet area that has developed in the lee of the berm. At its upstream end, this depression connects with the old creek channel just east of Sunset Pond that we identified in Reach 3.

Tributaries V and W

Tributaries V and W continue along the railroad grade through this reach, flowing under a pair of bridges at James Street. These are old, wooden structures with limited conveyance capacities. Both of the stream channels upstream of the bridges are filled with vegetation, indicating that discharges capable of channel alteration have not come through these channels for a considerable amount of time.

REACH 5: JAMES STREET TO INTERSTATE 5

This reach description is broken into two sections: the mainstem of Squalicum Creek and Tributaries V and W.

Squalicum Creek

The mainstem of Squalicum Creek through Reach 5 is relatively short, running through a straightened channel between James Street and I-5. The mainstem channel has been cleared along the right bank and straightened to provide room for industrial development. Riparian vegetation had recently been planted on the toe of this embankment likely as mitigation for filling a building pad. The stream is channelized between the building pad and the toe of the south valley wall and little opportunity for channel migration or alternate flow paths exists.

The roadfill for I-5 creates a nearly complete barrier across the valley, rising over 40 feet. The embankment starts on the south valley wall and continues north until it reaches the CMSPRR. The creek is conveyed under I-5 through two 225-foot corrugated metal pipes approximately 8 feet in diameter. The 1947 aerial photograph depicts the mainstem of Squalicum Creek in this reach flowing further to the north, through the portion of floodplain currently occupied by warehouses, storage facilities, and I-5. The channel was likely placed in its current location during I-5 construction. Evidence of any historical channels in this area has been buried under I-5 and the industrial area on the right bank.

Tributaries V and W

On the northern side of the valley, Tributaries V and W continue to run along the railroad grade downstream of James Street. Wetland forest lies to the north of the railroad grade in the Tributary W watershed. Forest and wet meadow cover the land between the RR grade and the industrial development to the south. At the downstream end, I-5 is carried over the railroad grade and the tributaries by a reinforced concrete overpass. This structure is a relatively wide span (over 250 feet of elevated roadway) and provides the only significant opening across the valley. Both stream channels are narrow and fairly deep (over 4 feet) through the upper portion of the reach. Tributary W is entrenched and narrow and seems to function more as drainage for the associated wetland area than as a component of the ecosystem. An end-of-track bumper appears on the railroad grade several hundred feet downstream of James Street, but active travel on the line appears restricted to the area downstream of I-5 near the industrial and warehouse facilities north of the tracks.

Tributary V shallows and widens considerably just upstream of I-5 and disperses into a relatively flat, wet meadow area. This area is between the railroad grade and what appears to be an old road prism just north of the industrial development to the south. This prism may have been a haul road enabling transport of materials for I-5 from Sunset Pond through this wetland area to the construction area. This wetland area is drained by a small channel, referred to in the SCFMP as the North Fork of Squalicum Creek. This "north fork" channel is conveyed under I-5 through a 24-inch diameter concrete culvert with limited conveyance capacity and flows directly into Bug Lake less than 100 feet downstream of I-5. According to Bill Reilly (pers. comm.) once the culvert under I-5 is exceeded water then travels in shallow sheet flow to the north around the I-5 elevated roadway through the gap provided by the railroad grade. It is unclear what proportion of the water leaving this wetland area flows through the North Fork or travels down

Tributary V for a given discharge. What is clear is that the North Fork has limited discharge capacity through I-5 such that higher flows are mainly conveyed through the gap provided by the railroad grade.

REACH 6: INTERSTATE 5 TO SQUALICUM PARKWAY

This reach description is broken into two sections: the mainstem of Squalicum Creek and Tributaries V and W.

Squalicum Creek

Exiting the I-5 culverts, the mainstem of Squalicum Creek flows through a meandering channel to its confluence with Bug Lake. The creek continues through Bug Lake, and outlets at the corner of Squalicum Parkway and Birchwood through three culverts. The creek channel enters Bug Lake through a low spot in a berm that separates the lake from the southern floodplain. Bug Lake was also excavated during the construction of I-5 and the berm is likely composed of spoil material sidecast during the excavation. It is unclear if the creek was purposely routed into the lake or avulsed into it during a high flow event, but the base level change between the lake and the former channel has triggered headcut development (from 3 to 6 feet) that has propagated upstream to within 100 feet of the I-5 culvert outlet. The floodplain along this section of channel is well vegetated with deciduous trees, shrubs, and a few conifers.

Prior to routing through Bug Lake it appears that the creek flowed through the floodplain area south of the lake. This area is flat and swampy with vegetation consisting of deciduous trees and riparian shrubs. The Washington Department of Fish and Wildlife (WDFW) has collected topographic survey data for this area, indicating that topographic relief across the floodplain is minimal, with maximum values approximately two to three feet. Under Squalicum Parkway, a 6.25-foot corrugated metal pipe arch culvert currently conveys intercepted groundwater, local runoff, and overflow from the mainstem of the creek under high flow conditions. An additional 12-inch diameter plastic pipe conveys flow under Squalicum Parkway near the toe of the southern valley wall. There is no defined channel upstream of the pipe, though downstream there is a line of vegetation indicating that a channel may have been present prior to construction of the road.

Tributaries V and W

Tributaries V and W continue to flow down the valley adjacent to the tracks, eventually joining Squalicum Creek downstream of the study reach. The railroad grade downstream of I-5 still shows signs of active use as a spur track. Tributary W is nearly devoid of vegetation through this reach, as it is bordered by a warehouse facility on the right bank, and the railroad tracks on its left bank. On the downstream side of the I-5 roadway fill and adjacent to Tributary W, Cascade Natural Gas maintains a pipeline regulator facility. A 10-inch high-pressure line and the 4-inch plastic line that run east along the railroad grade begin here. Additionally a 12-inch high-pressure natural gas line (buried 4 feet deep) and a 4-inch plastic gas line (buried 3 feet deep) run to the west along the south side of the railroad grade. Further discussion of these gas lines is included in infrastructure sections within this report. Tributary V is less defined in the reach and it appears

that flow travels south into the lake. Vegetation exists along Tributary V's left bank until the commercial businesses on Birchwood Avenue downstream of Squalicum Parkway. The right bank of the channel is clear of vegetation along the railroad grade.

To address flooding problems in the commercial and light industrial areas between Birchwood Avenue and Orchard Drive, the COB has proposed the construction of a low berm structure to divert flood flows from Tributaries V and W into Bug Lake. This structure will key into the northern I-5 roadway fill and tie into the existing RR grade. A culvert will be installed in the berm to allow flow in Tributary W, but Tributary V would be blocked. The berm would then head southeast, running approximately 150 feet from the toe of the I-5 road fill. It then turns sharply west and connects to Birchwood Avenue, staying 75 to 100 feet to the north of the lake. The Bug Lake outfall is to be kept on the upstream side of this berm.

REACH #7: SQUALICUM PARKWAY TO DEETS PROPERTY

Downstream of Squalicum Parkway three stream channels exist. The northern channel contains the current mainstem of Squalicum Creek as it outlets from Bug Lake. An additional channel leads through a meadow area from the 6.25-foot pipe arch culvert and is likely the "pre lake" channel. A third channel is present leading from the 12-inch pipe on the south side of the valley. This small channel feature has likely survived by intercepting surface and groundwater from the south valley wall.

Though some riparian area is present in this reach, extensive riparian vegetation is lacking. The northern channel has several beaver dams on it that periodically back water into the culverts and raise the level of the lake. These affects are transient in that the beaver dams are often affected by higher flows. NSEA has implemented revegetation activities in portions of this reach which should lead toward long-term recovery.

EVALUATION CRITERIA

Based on our field investigations and discussions with NSEA and related stakeholders, the following criteria were developed to evaluate the suite of alternative solutions developed through this study. While linked, independent consideration was given to physical and biological criteria.

BIOLOGICAL EVALUATION CRITERIA

Four criteria with biological basis have been selection for evaluation of alternatives identified in this feasibility study. These four criteria have been identified as factors that likely limit the natural production of coho salmon, steelhead and cutthroat trout in the Squalicum Creek system.

- Predation by introduced warm-water fish in Bug Lake and Sunset Pond
- Upstream passage for returning adult coho salmon
- Quantity and quality of rearing and spawning habitat
- Water quality

Predation

Warm-water fish have been introduced into Sunset Pond and Bug Lake and some of these species prey on salmonid fry. Each alternative was judged by whether it reduced the interaction of salmon fry with the introduced warm-water fish. Since the degree of predation has not been assessed at this time, it is not possible to quantify the degree of predation with each alternative. We assume that bypassing Sunset Pond or Bug Lake will reduce the interaction of salmon fry with the introduced warm-water fish.

Passage

Within the Study Area, we have identified a number of impediments to upstream passage for returning adult salmonids. Each impediment by itself is not a complete barrier but reduces the window of opportunity for a fish to pass upstream. Coho salmon, steelhead trout and sea-run cutthroat trout can pass through the study area but the number of fish reaching habitat upstream of Sunset Pond is likely substantially reduced by each impediment. We compared each alternative by how it would improve upstream passage of returning adult salmonids.

Fish Habitat

For the purpose of this feasibility study, the following assumptions are used to compare habitat quality and quantity of rearing for each alternative. Spawning habitat is very limited in the study area and although the proposed alternatives may improve spawning habitat, the extent of improvement could not be quantified.

- Created stream channels will provide rearing habitat of equal quality to the existing habitat observed in Reaches 1 and 2.
- Habitat quantity (area) of stream reaches can be compared based on the average bankfull width and reach length. Since channel slope is relatively consistent through the study area, it is assumed that average bankfull width is a conservative indicator of habitat quantity at various flows.
- The area of habitat in the created stream channels can be estimated using the channel length and the average bankfull width measured in the existing Reaches 1 and 2.
- The area of suitable habitat for juvenile rearing is within a 10-foot band around the perimeter in Bug Lake and a 6-foot band around the perimeter of Sunset Pond. These widths are based on the WDFW depth suitability index for coho salmon and the slopes of the ponds.

Water Quality

Water quality in Squalicum Creek is generally good but during late summer the low flow conditions combined with solar radiation cause the surface water of Sunset Pond and Bug Lake to warm to the lethal range for salmon and trout (Downen, 1999). The creek flows through these ponds and the pond outlets discharge only surface water so there is potential for increased water temperatures and warm water generally correlates with low dissolved oxygen levels. The impact of each alternative to water quality was judged based on whether the alternative increased the riparian vegetation cover and thereby reducing solar radiation and reducing the potential for increasing water temperature. We assume that the increase of shade will reduce the potential of the stream water to exceed the water quality standard of 18°C during the late summer period. Water temperatures may exceed this standard due to conditions upstream of the study area and although shading may allow stream water to cool, this was not a consideration of this feasibility study.

PHYSICAL EVALUATION CRITERIA

Physical evaluation included assessing the complex site conditions and requirements and logistics of alternative implementation as well as the physical affects each respective alternative will induce. The specific physical characteristics evaluated are discussed below.

Infrastructure

Local infrastructure affecting the existing channel route including roads and highways, culverts, gas lines, storm and wastewater distribution networks, and flood routing structures were identified in the evaluation of existing conditions section of this report. In the evaluation of alternatives section, the modifications to existing infrastructure or new infrastructure required for the implementation of a given alternative are discussed.

High flow conveyance

High flow conveyance through the study area is very complex, occupies several flow paths, and has implications on numerous public and private properties. Lack of conveyance is an issue where flooding adversely affects these properties, but floodplain inundation is not considered damaging if no structure or infrastructure are at risk.

Multiple flow paths and flood inundation areas are summarized in the existing condition section. The affect of alternative implementation on the routing of flow and flood inundation area was evaluated with respect to each alternative.

Low Flows

Low flow issues were assessed as they relate to fish passage including the possibility of subsurface flow in some sections of the creek and passage at culverts. Existing problematic low flow conditions were documented, and the affect of alternative implementation discussed. The primary consideration was whether an alternative successfully treats low flow issues.

Natural Stream Processes

Preservation and enhancement of natural stream processes are an important component of a successful and sustainable stream rehabilitation project, and project alternatives were evaluated based on their potential to enhance and maintain these processes. The processes evaluated included the natural transport and distribution of sediment and stream channel migration through wooded floodplain areas creating dynamic and complex channel forms. Mature riparian vegetation was also considered beneficial because of the leaf litter, large woody debris (LWD), and shade it provides to the stream.

EVALUATION OF EXISTING CONDITIONS

PREDATION

Downen (1999) determined that juvenile largemouth bass prey on coho salmon fry in Sunset Pond, Bug Lake and in stream reaches below these ponds. Stomach contents of captured largemouth bass contained coho fry. Though stomach contents of yellow perch were not collected in this study, it is very likely that this species also consume salmon fry. This study documented the predation of warm-water fish on salmonids but could not quantify the degree of species interaction. A number of variables such as temporal overlap of species, water temperature and metabolic activity are involved in the species interaction but have not been thoroughly studied in the Squalicum Creek system. Predation on juvenile salmon by introduced warm-water fish is certainly a factor that limits natural production of salmon in the Squalicum Creek system. Removal of the introduced fish may not be practical. The source of these species is unknown and may be upstream private ponds, Toad Lake, or Squalicum Lake where populations of warm-water fish and brown trout could be seed populations for down stream reaches (M. Downen pers. comm). Rerouting Squalicum Creek around Sunset Pond and Bug Lake could enhance the survival of salmon fry and smolts by minimizing the interaction of juvenile salmon with the introduced predatory fish. However, the ponds will act as seed populations to downstream ponded and backwater habitat. That is, bypassing Bug Lake may reduce the predator/prey interaction for a short period of time but ponded water down stream of Sunset Pond may become populated by warm-water species possibly in as little as one or two years.

In addition to predation by the introduced fish, Mueller and Downen (1999) suggested that water quality, pathogens, sport fishing, birds, otters and native fish species also contribute to the mortality of juvenile salmon in Squalicum Creek.

PASSAGE

The Whatcom County map folio (1994) indicates that salmonids utilize Squalicum Creek upstream of Sunset Pond, however the quantity of returning adult salmonids has not been reported. WDFW has conducted visual spawner surveys of spawning adult salmon, spawned-out salmon carcasses, and redds created by spawning salmon. From 1976 through 1984 only two coho salmon were observed spawning in Squalicum Creek. In 1985, 21 chum salmon were observed spawning and in 1997, 156 chum salmon and 31 coho salmon were observed spawning. Although observations were made upstream of Sunset Pond, all but one coho salmon were observed spawning in the creek downstream of Sunset Pond and most were downstream of Bug Lake. Table 1 lists the results of the spawner surveys conducted in Squalicum Creek from 1976 through 1999.

Table 1: Spawner survey data for Squalicum Creek.

DATE	STREAM MILE		COHO	CHUM	CHINOOK	COMMENTS
	START	END				
11/30/76	0.0	2.5	2	0	0	Down stream of Sunset Pond [1]
12/08/76	0.0	2.5	0	0	0	
12/16/76	0.0	2.5	0	0	0	
12/21/76	0.0	2.5	0	0	0	
1978	7.1	0.0	0	0	0	12/01 and 12/06
12/22/78	2.0	0.0	0	0	0	
12/13/79	6.6	7.1	0	0	0	Upstream of Sunset Pond [1]
10/04/80	6.3	7.1	0	0	0	Upstream of Sunset Pond [1]
11/08/82	0.5	1.2	0	0	0	
11/08/82	5.9	6.1	0	0	0	Upstream of Sunset Pond [1]
12/22/83	0.5	0.7	0	0	0	
12/04/84	2.0	2.2	0	0	0	
12/27/85	6.3	6.5	0	0	0	
12/30/85	0.4	1.5	0	21	0	Downstream of Bug Lake [2]
01/23/88	0.0	2.7	0	0	0	
11/28/94	0.7	0.0	0	2	0	
10/21/97	0.1	2.0	2	0	1	Downstream of Bug Lake [2]
10/27/97	0.1	2.0	10	0	0	Downstream of Bug Lake [2]
11/03/97	0.1	2.0	0	7	0	Downstream of Bug Lake [2]
11/11/97	0.1	2.0	1	20	0	Downstream of Bug Lake [2]
11/11/97	2.0	3.5	1	0	0	Location uncertain
11/17/97	0.1	2.1	0	44	0	Downstream of Bug Lake [2]
11/17/97	3.0	5.0	0	0	0	Upstream of Sunset Pond [1]
11/18/97	0.0	0.5	0	0	0	
11/24/97	0.1	2.0	7	42	0	Downstream of Bug Lake [2]
12/02/97	0.1	2.0	8	43	0	Downstream of Bug Lake [2]
12/02/97	3.0	4.0	0	0	0	Upstream of Sunset Pond [1]
11/23/98	6.9	7.5	0	0	0	Upstream of Sunset Pond [1]
01/05/99	6.7	7.5	0	0	0	Upstream of Sunset Pond [1]

[1]Sunset Pond Stream Mile 2.5 (3.0 on WRIA map)
[2]Bug Lake Stream Mile 2.2 (2.5 on WRIA map)

Though these surveys are qualitative in nature, they do provide information on where salmon spawning is occurring. It is likely that some salmon pass through Bug Lake, the I-5 culvert and Sunset Pond but it appears that much of coho and chum salmon spawning occurs downstream of Bug Lake. Coho and chum salmon spawning has also been observed in Baker Creek, a tributary to Squalicum Creek with its confluence downstream of Meridian Street at stream mile 1.8. But spawning was not observed in Toad Creek, a tributary above Sunset Pond at stream mile 5.8 in 1979, 1980, or 1999. Barriers to upstream passage have not been determined in Squalicum Creek by WDFW (1975) but each culvert, cascade, and chute presents an impediment to passage and the interaction of these impediments appears to prevent salmon from utilizing habitat upstream of Sunset Pond. Table 2 contains a list of potential barriers to upstream passage in the study area.

Table 2: Potential upstream passage barriers in the study area.

BARRIER	OCCURANCE	CONDITION	PASSAGE
Culvert at Bug Lake outlet	Low flows	Subsurface flow	Impassable
Stream channel upstream of Bug Lake	All flows	High velocity in chute formed in clay outcrop	Passable
I-5 culvert ; 225 feet long	Mid and higher flow	High velocity	Impassable
Stream channel upstream of I-5 culvert	High flow	Velocity and no resting stations after I-5 culvert	Passable
Sunset outlet	Low flow	Subsurface flow	Impassable

The culvert at the outlet of Bug Lake under Squalicum Parkway apparently was placed on top of large, porous fill material. Consequently at low discharges, water discharges subsurface under the culvert and upstream passage is blocked (R. Deryckx, pers. comm.).

A short section of the stream channel upstream of Bug Lake has cut a chute through the consolidated clay sediment. At low flows the water flows through a narrow chute at high velocities and at mid to high flow the water spreads out over top of a clay bench and forms a shallow sheet flow. This section is likely passable but would require considerable energy for a fish to pass upstream.

Water is conveyed under I-5 in two culverts that are 225 feet long with slopes of 0.25%. The culverts are set at the same elevation and the stream discharge is split evenly into each culvert. If the inlets are clear of debris, each culvert should convey half of the discharge. WDFW (1999) recommends that maximum water velocities in culverts 200 feet and greater should not exceed 2.0 feet per second (fps) for adult trout and 3.0 fps for adult coho, chinook, sockeye and steelhead to provide for the upstream passage. GeoEngineers used HEC-RAS (version 3.0) to estimate the water velocities in the I-5 culvert over a variety of flows. Table 3 lists the estimated water velocities for discharges in Squalicum Creek. Shaded areas indicate water velocities where upstream passage is in excess of WDFW recommendations.

Table 3: Modeled velocities in the I-5 culverts.

Squalicum Creek Discharge (cfs)	Discharge in each Culvert (cfs)	Velocity at Inlet (fps)	Velocity at Outlet (fps)
5.0	2.5	1.37	1.66
10.0	5.0	1.67	2.26
15.0	7.5	1.92	2.73
20.0	10.0	2.10	3.22
25.0	12.5	2.26	3.76
30.0	15.0	2.39	4.21
35.0	17.5	2.52	4.54
50.0	25.0	2.83	5.04
70.0	37.5	3.23	5.37
100.0	50.0	3.55	5.68

It is clear that the I-5 culverts become a barrier to upstream passage for adult trout and salmon at relatively low discharge. If passage were available, salmon and trout could access habitat upstream of Sunset Pond and the natural production of fish would be enhanced.

NSEA measured stream discharges in Cornwall Park down stream of Bug Lake during the fall of 2001 and winter of 2002 when salmon were migrating upstream for spawning. Table 4 lists the discharges calculated from these measurements. From comparison of these data with those in Table 3, it is apparent that passage through the culverts is not available for much of the time. Since Squalicum Creek watershed is a rain-dominated system the stream flow will be flashy which is apparent in Table 4. Long-term stream gaging data is not available for Squalicum Creek so it is not possible to calculate a hydrograph or to determine a period of time when passage through the culverts is possible.

Table 4: Discharge data collected by NSEA.

DATE	DISCHARGE (cfs)
11/01/2001	15.38
11/06/2001	16.75
11/11/2001	1.89
11/16/2001	34.09
01/31/2002	66.99
02/07/2002	40.26
02/21/2002	67.06
02/28/2002	25.49

The stream channel directly upstream of the I-5 culverts has been modified and straightened and there are no boulders or large woody debris in the channel for a length of 560 feet to the James Street culvert. The stream channel is a straight run with no channel complexity to provide pools or backwater areas for fish resting stations. Fish that pass through the I-5 culverts need to swim at least an additional 560 feet to locate a resting station. Though this stream reach is passable, with the interaction of the I-5 culvert passage to James Street passage is difficult.

Above James Street the stream channel has large woody debris that provide pools and riffles. Quarry spalls used as armor over a storm sewer pipe control the outlet of Sunset Pond. This material is very porous and at low discharges the stream flows subsurface though the rocks (R. Deryckx, pers. comm.) and upstream passage is not possible.

Though each of these impediments to upstream passage may be passable at certain flows, the interaction of all impediments has essentially created a barrier to upstream migration of adult salmon and trout. The I-5 culverts are impassable during mid to high flows and the inlets to Bug Lake and Sunset Pond are barriers at low flows. Some fish are able to pass but the numbers must be very low which explains the observations that the rearing habitat above Sunset Pond is underutilized (Jim Johnston, WDFW, as cited in the SCFMP, 1994). During a field visit for the present study, though the habitat was judged to be good for rearing only one salmonid fry and one juvenile eel were observed between Hannegan Road and Sunset Pond. An additional issue that has been raised by Mark Downen, WDFW (pers. comm.) is that Washington State manages the coho fishery in Bellingham Bay as a terminal fishery and there is no escapement goal for Nooksack River. The Department treats coho salmon in Bellingham Bay as hatchery produced fish and essentially allows all returning fish to be harvested. This contributes to the low numbers of coho salmon observed in the Squalicum Creek system.

HABITAT QUALITY AND QUANTITY

The existing fish habitat in the study reach is limited due to historic channel modification. Where the condition of the channel is somewhat natural (Reach 1 and 2) the habitat is good for rearing with a few limited pockets of gravel appropriate for spawning. Where the channel has been straightened and instream structures removed (Reaches 3, 4, 5 and 6) the rearing habitat is fair to poor with very few areas with appropriate spawning habitat.

Spawning Habitat

Spawning habitat consists of appropriately sized gravel that is clear of fine sediment with appropriate hydraulic conditions to keep the gravel clean and salmon eggs aerated (Cedarholm et al., 2000) Ideal conditions are often found in the gravel at a pool tail out and often found below beaver dams. Within the study area, locations with appropriate spawning gravel are severely limited, because sediment supply, storage and transportation has been altered by land use practices. Gravel bars were observed upstream of the beaver dams in Reach 2 but gravel was absent in Reach 3 where the stream channel is parallel to the CMSPRR grade. Spawning habitat in the Study Area may be improved where appropriate sized gravel is retained and where

hydraulic conditions are adequate to keep the sediment clean. The availability of spawning habitat above Hannegan Road is unknown and should be assessed.

Rearing Habitat

Rearing habitat is good in Reach 1 and 2, fair in Reach 3 and fair in the margin of Sunset Pond and Bug Lake. Few salmon fry were observed during the field reconnaissance and as observed in the SCFMP (1994), rearing habitat is underutilized. Increasing upstream passage through the study area will increase natural production and provide more fry to use rearing habitat.

WATER QUANTITY AND WATER QUALITY

Water quality of Squalicum Creek is generally good in the study area though low dissolved oxygen was observed during low flow conditions and high fecal coliforms were observed during storm flow conditions (SCFMP). The SCFMP suggests that Bug Lake and Sunset Pond provide positive water quality function by decreasing turbidity, total phosphorus, and fecal coliform concentrations during storm flow and primary production in the ponds contribute dissolved oxygen to Squalicum Creek during low flow. The ponds become stratified in summer months with water temperatures near the lethal levels to salmon in the late summer (Downen, 1999). Since the outflow of the ponds are from surface water, the ponds contribute warm water to Squalicum Creek. In addition, to avoid the warm water, juvenile salmon may move to cooler-deeper water in the ponds and may become more exposed to predation.

Rerouting Squalicum Creek through areas with good riparian cover with more shade may provide for lower water temperature, higher dissolved oxygen levels and some aeration of water at beaver dam outlets.

INFRASTRUCTURE

Infrastructure affecting the existing creek configuration is primarily composed of the railroad grade that parallels the creek and several roadway grades that cross the valley floor perpendicularly. The floodplain is also confined in the lower section of the study reach by private residences and industrial development. The BNRR grade separates Reach 1 and 2 and the current creek location is a former bridge site for the railroad. The grade confines the creek crossing, but the crossing is not currently maintained so future channel migration is possible. Through Reach 3, Squalicum Creek travels along the CMSPRR grade. The grade constrains the creek from migrating to the north, is actively being maintained, and forms the northern boundary of the creek's meander zone through much of Reach 3. A sewer line runs along the south bank of Sunset Pond and crosses under the creek near the outlet of the pond. Coarse rock material was used as fill at this crossing, and consequently the creek goes sub-surface during low flow conditions. James Street constrains flow to three locations. The main channel, the outlet channel from Sunset Pond on the southern edge of the valley, conveys all flow under most flow conditions. Tributary V conveys overbank flow that spills out of Sunset Pond to the north and Tributary W conveys basin runoff that originates north of the CMSPRR grade. Flows from these

tributaries are conveyed beneath James Street directly north and south of the railroad grade under an existing bridge. The I-5 also confines flows to specific locations. The main channel runs along the southern edge of the valley and under I-5 through two 8-foot culverts. Tributaries V and W continue to run along the railroad grade and pass beneath I-5 under a large overpass. A small culvert through the embankment passes a limited amount of additional flow, the North Fork of Squalicum Creek. In Reach 6, plans to construct a large berm north of Bug Lake would route all future flow in Tributary V into Bug Lake. A culvert in the berm would allow flow to remain in Tributary W, but the berm would form the northern boundary of flood flows from the mainstem of Squalicum Creek. Flow is conveyed beneath Squalicum Parkway through several culverts. The main flow exits Bug Lake and is conveyed through three large culverts. Higher flows are conveyed through a large culvert located south of Bug Lake and a small culvert along the southern edge of the valley. Private property borders the creek and its floodplain throughout much of Reach 7.

As previously discussed, Cascade Natural Gas maintains a pipeline regulator facility near the north embankment of the I-5 RR grade overpass. From there, a 10-inch high-pressure line and 4-inch plastic line run east along the RR grade. These lines run east under James Street and continue through the study area. In addition a 12-inch high-pressure natural gas line (buried 4 feet deep) and a 4-inch plastic gas line (buried 3 feet deep) run to the west along the south side of the RR grade.

HIGH FLOW CONVEYANCE

The SCFMP indicates that the entire valley through the study reach is inundated during a 100-year flow event. This is foreseeable in that the creek valley through the study area is broad, low-gradient, with little cross valley relief. The SCFMP notes that flood inundation and distribution are related to floodplain encroachment and roadway construction. As discussed in the previous section, transportation routes across the valley limit flow locations. Conveyance capacities at these locations are also limited such that high flows are backwatered behind the roadways and flow over James Street and Squalicum Parkway during extreme events. Under these extreme conditions, flow also inundates the railroad grade separating Tributaries V and W. Because extreme flows are infrequent and flow paths, magnitudes, and contributing areas are uncertain, we discuss high flow conveyance under conditions where the railroad grade separates flow and Tributary W is essentially a separate watershed.

High flow conveyance is an issue where the lack of conveyance results in flooding conditions that adversely affect public and private property and infrastructure. Floodplain inundation is not considered damaging if no infrastructure is at risk. In Reaches 1, 2, and 3, channel capacities may not be sufficient to contain high flows, but ample unimproved floodplain area exists such that inundation would not affect any structures or put property at risk. At the upper end of Reach 4, the creek is routed into Sunset Pond. We estimated that the pond provides approximately 20 acre-feet of flood storage thereby attenuating downstream flooding. As described in SCFMP, the main channel conveys low to moderate flows until Sunset Pond is overtopped and flow traverses the floodplain to the north into Tributary V. It is thought that

under high flow conditions as much as half the discharge of Squalicum Creek spills out of Sunset Pond and flows down Tributary V (B. Reilly, pers. comm). In Reach 5, the main channel is confined through the reach and ultimately flow travels into two 8-foot culverts. Conveyance through these culverts is limited and backwatering occurs under high flow conditions. Little floodplain area exists in this location such that water is backed up all the way into Sunset Pond. Hence the backwatering of the culverts at the southern edge of the valley controls the water surface elevation in Sunset Pond and ultimately flow traveling down Tributary V in Reach 5. Ample area for flood attenuation does exist in the northern section of Reach 5, although this area is not fully utilized.

Squalicum Creek is routed through Bug Lake in Reach 6 with the culverts beneath Squalicum Parkway hydraulically controlling the level of the lake. We estimate that Bug Lake provides approximately 9 acre-feet of flood storage. High flows spill over into the floodplain to the south and are conveyed beneath Squalicum Parkway primarily through a single culvert. Flow also traverses the floodplain to the north, but the proposed COB berm would contain floods forcing them to flow through the existing culverts or over Squalicum Parkway. Through Reach 7, the creek flows through private property with little topographic relief. High flows typically inundate much of this area.

LOW FLOWS

Under existing conditions, low flow concerns occur at the following locations within the study area:

- The outlet of Sunset Pond
- The outlet of the two culverts below I-5
- The current headcut location
- The outlet of Bug Lake through the three culverts beneath Squalicum Parkway

Just below the outlet of Sunset Pond, porous backfill materials were placed over a sewer line installation resulting in periods of sub surface flow at the outlet. This occurs during dry periods in late summer (R. Deryckx, pers. comm). The outfall of the existing culverts under I-5 may also pose a passage problem under low flow conditions, although it was difficult to assess under flow condition during our site visits. It is clear that continued headcutting by Squalicum Creek toward the culverts will result in a significant barrier at the culvert outlet in the future. The upper extent of the headcut may also presently comprise a passage difficulty because of confined, high velocities and shallow flow. The culverts beneath Squalicum Parkway were placed on top of porous backfill materials such that Squalicum Creek flows subsurface beneath the culverts during low flow periods. Beaver dams below the culverts currently backwater the culvert area temporarily alleviating this problem, but, as beaver dams are transient features, this effect is not likely permanent.

NATURAL STREAM PROCESSES

Channel migration through forested riparian areas is a key element in the natural formation of instream salmonid habitat. LWD recruited through this process provides structural complexity and creates zones of hydraulic variability ideal for juvenile rearing. Sediment routed through the system from upstream distributes spawning gravels and incubation areas for salmonids and macro-invertebrates.

Channel migration rates in the study area are small because of the mild gradient and limited stream power of the system. This limits the likelihood of LWD recruitment and inhibits recovery rates for impacted stream segments. In turn, the importance of a mature, connected riparian zone is accentuated since the stream is less likely to move and less stream movement is required to recruit debris. Shade and leaf-litter associated with good riparian zones are also important ecological components.

Sediment production primarily occurs in the upper watershed and sediments are routed into the study area. Some recruitment of sediments from within the study area occurs, but cobble sized materials are limited and recruitment through channel migration is minor.

In the upper reaches of the study area (Reaches 1, 2, and 3), cobbles and small gravels are abundant and available in the channel and sediments are being stored in association with current and former beaver dams. These sediments provide suitable spawning gravels and ideal habitat for benthic invertebrates. In Reach 4, these sediments are being routed into Sunset Pond where an extensive delta has formed. Sunset Pond is essentially a sediment sink and its presence prohibits the routing of sediments from the upper watershed through the remainder of the system. As one would expect, the volume of suitable spawning gravels in Squalicum Creek decreases downstream of Sunset Pond. Bug Lake acts similarly as a sediment sink absorbing gravels that are recruited between the pond and the lake, and little cobble materials are found below Bug Lake.

Channel migration is relatively uninhibited through Reaches 1 and 2. The riparian zone in Reach 1 is thin in width and sparse in density, but riparian conditions in Reach 2 are near ideal. Both banks are thickly vegetated and overhanging trees provide ample leaf litter to the creek. Recruitment potential in Reach 2 is high relative to the remainder of the study area. Through Reach 3, the creek is primarily conveyed along the RR grade such that the right bank riparian zone is sparse. However the left bank riparian zone is a maturing mixed deciduous forest that provides good stream shading and recruitment potential. The problematic consideration for Reach 3 is that ongoing maintenance will prevent improvement of existing conditions. Maintenance of the grade will prevent the growth of a riparian zone and riprap was identified in the creek channel indicating that the channel configuration is maintained. Therefore it is likely that LWD that may fall into the creek will be removed preventing longterm improvement of instream habitat conditions. In Reach 4, the creek travels through Sunset Pond with little opportunity for habitat improvement through natural process. Reach 5 is confined and maintained. While the left bank riparian is a maturing, mixed deciduous forest that provides ample shade and recruitment potential, recent evidence of instream channel clearing suggests that future maintenance activities will limit the benefits of natural processes through the reach. In the

upper segment of Reach 6, the creek meanders through a maturing, mixed deciduous forest before its inlet into Bug Lake. This section provides ample stream shading and recruitment potential. Several areas have LWD accumulations both from natural treefall and beaver activities. Habitat conditions should continue to improve through time since no channel clearing or other maintenance activities are expected to occur in this area. However, the base level difference between Bug Lake and the former channel area has resulted in channel headcutting that extends to within 100 feet of the culverts beneath I-5. The resultant incision is on the order of 3 to 6 feet below the "pre lake" stream elevation. Where active headcutting is occurring, a steep "chute" in a clay layer may currently pose a passage problem, but continued headcutting will eventually reach the culvert area undoubtedly rendering the culverts impassable. Where the creek enters Bug Lake, a small delta has developed indicating that the lake is a sediment trap, similar to Sunset Pond. Below the lake, Reach 7, the creek travels through private property in which NSEA has initiated extensive riparian rehabilitation efforts. Riparian conditions through this area should improve through time.

In summary, natural sediment transport is interrupted by Sunset Pond and Squalicum Creek is sediment starved for the remainder of the study area. Substrates upstream of Sunset Pond provide the best spawning opportunities in the study area as well as ideal incubation for fry and benthic invertebrates. Future creation and maintenance of habitat through natural channel migration and LWD recruitment is also greatest in the upstream reaches. Maintenance of channel positions and instream debris limits much of the study area and the pond and lake provide no opportunity for long term evolutionary benefits.

ALTERNATIVES EVALUATION

ALTERNATIVE 1: NO ACTION

The natural production of salmonids and trout will continue to be impaired due to existing conditions in the Squalicum Creek system as discussed above.

ALTERNATIVE 2: ENHANCE FISH PASSAGE THROUGH THE STUDY AREA

Description

Alternative 2 would enhance fish passage through the study area by treating three low flow areas of concern described in the low flow section of the existing conditions evaluation and treating the culvert beneath I-5 that presents a barrier at moderate to high flows (Figure 3). Porous fill materials near the Sunset Pond outlet will be removed and grade control structures will be placed in conjunction with less porous materials to treat subsurface flow conditions. Baffles will be fit into the culverts under I-5 to reduce velocity within the culverts. Grade control structures will also be placed below the I-5 culverts to treat the current headcut area as well as prevent the headcutting from reaching the culvert outlet area. This will provide passage from Bug Lake to the I-5 culverts. Under Squalicum Parkway, one of the existing culverts would be removed and the coarse fill material below it would be removed. The culvert would then be replaced at a lower elevation. This would reduce the likelihood that flow will go subsurface under the existing culverts.

Predation

This alternative does not prevent predation on juvenile salmon and trout by introduced warm-water fish in Sunset Pond and Bug Lake.

Passage

Providing for the upstream passage of returning adult coho salmon, steelhead and sea-run cutthroat trout will dramatically increase the natural production of these fish. The available rearing habitat upstream of Sunset Pond is underutilized (SCFMP, 1994). If spawning habitat is accessible to returning salmonids natural production will likely increase and rearing habitat will be further utilized.

Habitat Quality and Quantity

This alternative does not substantially affect rearing habitat in the study area but by improving upstream passage for returning adult salmonids, natural production will provide fry to utilize the existing rearing habitat.

Water Quality and Quantity

This alternative does not affect the detrimental water quality issues in Sunset Pond and Bug Lake.

Infrastructure

Alternative 2 seeks to work within the existing infrastructure network to improve salmonid passage. The affected infrastructure includes the I-5 culverts and the 3 culverts beneath Squalicum Parkway. The I-5 culverts will be fit with baffles to reduce velocities. At Squalicum Parkway, subsurface flows will be treated by removing one of the culverts and replacing it at a lower elevation once porous fill materials have been removed. Grade control structures will also need to be placed at the outlet of Sunset Pond and just downstream of the I-5 culverts.

High Flow Conveyance

Installing baffles in the I-5 culverts will reduce their conveyance capacity and redistribute medium-high flows. As described previously the I-5 culverts regulate the water surface elevation in Sunset Pond in turn regulating overflow out of the pond, into Tributary V, and down the north side of the valley. Therefore, the threshold discharge that would result in overflow would be lowered and the magnitude of overflow for a given discharge would increase. This may result in more frequent high magnitude flooding in the vicinity of Tributary V from Sunset Pond to Bug Lake, and hence deserves additional modeling were this alternative to be undertaken. Lowering the elevation of one of the culverts under Squalicum Parkway will not appreciably affect high flow conveyance.

Low Flows

Implementing the strategies described for Alternative 2 will seek to address the current salmonid passage issues related to low flows within the study area. Hence, successful project implementation in problematic areas would alleviate these concerns and ease the migration route to the upper watershed.

Natural Stream Process

The primary affect that this alternative would have on natural processes is that it would halt the headcut activity below the I-5 culverts. This would alleviate current passage issues related to this activity and prevent future adverse passage conditions (that would be much worse) from developing once headcutting reached the I-5 culvert outlet area. Over the longterm, some sediment retention would also be realized enhancing ecological conditions within the creek.

ALTERNATIVE 3: REROUTE SQUALICUM CREEK AROUND BUG LAKE

Description

Alternative 3 would bypass Bug Lake and route Squalicum Creek through the floodplain to the south into what appears to be a historic (pre-lake) channel (Figure 4). Squalicum Creek would be blocked from entering Bug Lake during most flow conditions and some minor excavation would be required to route flow back into the former channel. An overflow connection to Bug Lake would remain under high flow conditions and the creek would remain connected downstream by way of its current outlet channel. The current creek channel would be blocked using a composite LWD weir structure that would be backfilled with native soils. This structure would be designed to allow high flows into Bug Lake.

Predation

The interaction of salmon fry with introduced warm-water fish would be reduced. However, ponded water and back water may be seeded with young-of-the-year warm-water fish from Sunset Pond that are capable of consuming salmon fry. Predation benefits may be short lived, hence the reduction in predation and benefit to salmon cannot be quantified.

Passage

This alternative will provide passage for returning adult salmon around Bug Lake during the low flow conditions where the Bug Lake culverts would be dry. Passage near the head-cut barrier, I-5 culvert, and Sunset Pond would remain problematic.

Habitat Quality and Quantity

Based on the assumption for quantifying habitat, Bug Lake provides 31,000 square feet of rearing habitat and the created bypass channel would provide about 33,800 square feet with an additional 1,250 square feet of habitat improvement upstream of Bug Lake. This represents an increase of about two percent of the rearing habitat for juvenile salmon in the entire study area.

Water Quality and Quantity

The proposed location for the bypass channel has mature deciduous trees and shrubs that would provide shade for the created channel. These conditions would be an improvement in comparison to the open canopy around Bug Lake and may reduce the potential of excessive water temperatures.

Infrastructure

Infrastructure affected by this alternative primarily consists of the existing culvert beneath Squalicum Parkway in the south floodplain area. The ability of this culvert to convey Squalicum Creek's flow was evaluated. The "full pipe" conveyance of this 6.25 foot, pipe arch culvert is approximately 325 cfs, approximately equal to a two-year recurrence flow for Squalicum Creek. However when the water level in the culvert reaches approximately 5 feet, Squalicum Creek would be spilling over the floodplain into Bug Lake near its current confluence. Therefore, this culvert would be working in conjunction with the three culverts at the Bug Lake outlet to convey high flows through this reach. In fact, the elevation of the weir structure, where the current channel is to be diverted, would be determined such that flow would begin to move into Bug Lake at a desired water surface elevation.

High Flow Conveyance

High flow conveyance would not appreciably be altered under higher flow conditions since flow would be routed into Bug Lake and conveyed through the three existing culverts near the lake outlet. Hence downstream flooding under higher flow conditions would be unaltered. However the distribution of flooding during moderately high flows may be altered. These are flows that reach an elevation near the threshold for flow moving into Bug Lake. Under these conditions, flooding may occur downstream in areas where it would only occur during extreme events under existing conditions.

Low Flows

Alternative 3 may alleviate passage concerns related to the current headcut activity depending upon the design height of the channel blocking weir. In addition, passage concerns related to the three culverts near the Bug Lake outlet may be alleviated because it would no longer be desirable to have upstream passage into Bug Lake. However, this alternative does not address all salmonid passage issues related to low flows within the study area.

Natural Stream Process

Alternative 3 would create approximately 1,000 feet of natural stream channel. The riparian habitat in this area is a dense, mixed deciduous that will provide ample shading and leaf-litter, as well as LWD recruitment potential. This area is broad and flat with little relief across the valley.

Noting the abundance of beaver activity in the surrounding area, it is likely that beaver would move into this area and create a series of ponds. Since this will likely be a low energy environment, channel migration activity will likely be low, but retention of LWD that does enter the system will be high. While this floodplain area will not likely provide large inputs of suitable spawning gravels through erosion, sediments that are recruited as well as sediments that are currently routed into Bug Lake will remain in the system and improve habitat conditions. In summary, the habitat quality in the recovered stream channel will initially be high, will be self sustainable, and will continue to improve over time.

ALTERNATIVE 4: REROUTE SQUALICUM CREEK AROUND BUG LAKE AND IMPROVE CREEK CHANNEL FROM I-5 TO DEETS PROPERTY

Description

Alternative 4 expands upon Alternative 3 by treating the stream segments directly upstream and downstream of the reroute area and installing baffles in the I-5 culverts (Figure 5). The infrastructure described in Alternative 3 would be installed as well as grade control structures to treat headcut activities downstream of the I-5 culverts and riparian plantings downstream of Squalicum Parkway.

Predation

As discussed above in Alternative 3, the interaction of salmon fry with introduced warm-water fish would be reduced with the bypass of Bug Lake. However, ponded water and back water may be seeded with young-of-the-year warm-water fish from Sunset Pond that are capable of consuming coho fry. Predation benefits may be short lived, hence the reduction in predation and benefit to salmon cannot be quantified.

Passage

This alternative will provide passage for returning adult salmon upstream through the I-5 culvert. This improves the passage difficulties and will potentially increase natural production however, the 560 feet long run above the I-5 culvert and the outlet of Sunset Pond is not addressed.

Habitat Quality and Quantity

This alternative improves rearing habitat as discussed above in Alternative 3.

Water Quality and Quantity

As discussed above in Alternative 3, the proposed location for the bypass channel has mature deciduous trees and shrubs that would provide shade for the created channel. In addition, plantings along the stream banks below Squalicum Parkway will enhance the riparian zone. These conditions would be an improvement in comparison to the open canopy around Bug Lake and may reduce the potential of excessive water temperatures.

High Flow Conveyance

The conveyance of extreme flows will not appreciably be altered by this alternative with the exception of the James Street crossing. The addition of a new bridge or culvert will add to the conveyance capacity under James Street such that it may no longer act as a weir during extreme events. What will be altered is the distribution of flooding during moderate to high flows.

The LWD weir installed to divert the creek from Sunset Pond will be designed to allow high flows into Sunset Pond by way of the existing channel. This weir will be sized such that the pond provides flood protection. However, design criteria for the weir will seek to fully utilize the floodplain area north of the pond for flood attenuation prior to allowing flow into the pond. Hence the creek/floodplain system in this area will function independently from the pond to the extent possible, ie. under most flow conditions. When water surface elevations exceed a predetermined level, flow will spill into Sunset Pond. In Reach 5, the new creek would be routed through a wet meadow area that will also provide flood attenuation. It is desirable for this area to absorb flood flows as well, prior to routing into the pond. The new creek channel will travel beneath the I-5 overpass, turn to the south, in inlet into the east end of Bug Lake. This section of the lake will be isolated from the western section by installing a berm across the lake. This berm would be attached to the COB's proposed berm north of the lake and the southern bank of the lake on the south. The berm would have a weir installed within it to allow high flows into the west section of the lake. The isolated eastern portion of the lake would become part of the creek system with the creek outleting this area through its current inlet area. The creek would then be routed as described in Alternative 3 with the culvert under Squalicum Parkway being a hydraulic control for the local area. Similar to the Sunset Pond area, the Bug Lake area will be designed such that the creek and its associated floodplain function independently from Bug Lake under most flow conditions.

Low Flows

Alternative 5 bypasses all the areas of concern with respect to adult salmonid passage and low flows. With creek discharge isolated from the lake and pond, we expect that water surface elevations within the water bodies will decrease during dry periods. Couple this with current passage issues, and it is likely that the surface water connection between the lake and pond and the creek will be severed for most of the year. However the outlet connections will remain intact allowing flows from the lake back into the creek during floods.

Natural Stream Process

Isolating Sunset Pond and Bug Lake from the creek system removes these sediment sinks from the system and allows for the reestablishment of sediment transport through the study area. As noted previously, sediment production within the study area is minor and the flat gradient results in slow rates of sediment transport. Hence, sediments that are being routed through the system are vital to the ecological conditions within the creek, and natural recovery of "pre pond/lake" sediment conditions will likely take many years.

The rerouting of the creek moves the creek from areas that are currently maintained for access, conveyance, etc. to areas where such maintenance is not required. These maintenance practices prevent long term ecological revitalization of the creek. New channel locations are in areas where current conditions are beneficial, but the opportunity for natural evolution to recreate ideal conditions is high. In addition, the ecological vitality of the creek system would be self sustaining, requiring little if any maintenance activity.

Floodplain riparian areas in most of the reroute locations are maturing mixed deciduous that will provide ample shading, leaf litter, and opportunity for LWD recruitment. These conditions will essentially jump start the natural recovery processes of the creek resulting in good initial conditions, while providing for ideal near future conditions.

Table 5: Summary of ecological considerations.

	Alternative 1: No Action	Alternative 2: Enhanced Fish Passage	Alternative 3: Reroute around Bug Lake	Alternative 4: Reroute and enhance channel	Alternative 5: Large scale rehabilitation
Passage	•Does not treat identified passage barriers within the study area	•Treats all identified passage barriers within the study area	•Alters creek/ Squalicum Parkway culverts •Does not treat remaining barriers	•Alters creek/ Squalicum Parkway culverts •Treats all remaining passage barriers within the study area	•Treats or renders insignificant all identified passage barriers within the study area
Predation	• Does not affect salmon/ warm-water fish interaction	• Does not affect salmon/ warm-water fish interaction	• Reduces salmon/ warm-water fish interaction in Bug Lake	• Reduces salmon/ warm-water fish interaction in Bug Lake	• Reduces salmon/ warm-water fish interaction throughout the study area
Juvenile Rearing Habitat	•Does not affect rearing habitat	•Enhances natural fish production to utilize existing habitat	•Enhances rearing habitat by about 2%	•Enhances natural fish production to utilize existing habitat	• Enhances rearing habitat by about 20% • Enhances natural fish production
Adult Spawning Habitat	•Does not affect spawning habitat	• Enhances natural fish production •Does not affect spawning habitat	•Does not affect spawning habitat	• Enhances natural fish production •Does not affect spawning habitat	• Enhances natural fish production •Does not affect spawning habitat
Riparian Habitat Conditions	•Does not affect riparian conditions	•Does not affect riparian conditions	•Enhances riparian conditions along about 3,540 ft of channel	•Enhances riparian conditions along about 3,540 ft of channel	•Enhances riparian conditions along about 8,500 ft of channel
Natural Stream Processes	•Does not affect stream processes	•Treats headcut area preventing further degradation •Enhances sediment storage in headcut area	•Enhances channel complexity •Improves sediment conditions in lower study area •Increases LWD recruitment •Allows for channel migration	•Treats headcut area preventing further degradation •Enhances channel complexity •Improves sediment conditions in lower study area •Increases LWD recruitment •Allows for channel migration	•Allows for natural sediment transport through the study area •Enhances channel complexity •Increase channel length and floodplain connectivity •Increases LWD recruitment •Allows for channel migration

Table 6: Summary of logistic considerations.

	Alternative 1: No Action	Alternative 2: Enhanced Fish Passage	Alternative 3: Reroute around Bug Lake	Alternative 4: Reroute and enhance channel	Alternative 5: Large scale rehabilitation
Required Infrastructure Improvements	•No improvements necessary	•Remove and reset culvert at Squalicum Parkway •Install grade control below I-5 •Fit I-5 culverts with baffles •Modify the outlet of Sunset Pond	•Install flood control weir between creek and Bug Lake	•Fit I-5 culverts with baffles •Install flood control weir between creek and Bug Lake •Install grade control below I-5	•Install flood control weir between creek and Sunset Pond •Install two new bridges through RR grade •Install new bridge at James Street •Install berm with weir across Bug Lake
High Flow Conveyance	•Does not affect high flow conveyance	•Redistributes high flows into Tributary V area	•Redistributes high flows south of Bug Lake •Uses Bug Lake for flood storage	•Redistributes high flows into Tributary V area •Redistributes high flows south of Bug Lake •Uses Bug Lake for flood storage	•Redistributes high flows into new channel areas •Uses Sunset Pond and Bug Lake for flood storage
Land Acquisition or Owner Agreements needed from	•No land owner agreements needed	•Peacehealth •City of Bellingham •WSDOT	•Peacehealth •City of Bellingham •WDFW	•Peacehealth •City of Bellingham •WDFW •Saroya •WSDOT	•Peacehealth •City of Bellingham •WDFW •Lakeview Associates •Talbot Real Estate LLC •Edelstein, Hammer, and Halmo •WSDOT
Additional Evaluation and Design Requirements	•Continued monitoring of Coho stock conditions	•Culvert modeling for baffle placement •Assessment of discharge displacement to Tributary V •Design grade control structures	•Evaluate design height for flood weir •Monitor headcut activity	•Culvert modeling for baffle placement •Evaluate design height for flood weir •Design grade control structures •Develop riparian planting plan	•Evaluate design height for flood weir •Design new channel configurations •Design new bridges •Design berm with flood weir

Table 7: Summary of estimated costs.

Required Infrastructure Improvement	Alternative 1: No Action	Alternative 2: Enhanced Fish Passage	Alternative 3: Reroute around Bug Lake	Alternative 4: Reroute and enhance channel	Alternative 5: Large scale rehabilitation
Remove and reset culvert at Squalicum Creek	$0	$15,000			
Modify outlet of Sunset Pond	$0	$10,000			
Install grade control below I-5	$0	$18,000		$18,000	
Fit I-5 culverts with baffles	$0	$12,000		$12,000	
Install flood control weir between creek and Bug Lake	$0		$20,000	$20,000	
Install flood control weir between creek and Sunset Pond	$0			$20,000	$20,000
Install two foot bridges through RR grade	$0				$60,000
Install new bridge at James Street	$0				$250,000
Install berm across Bug Lake	$0				$300,000
Riparian plantings	$0			$10,000	$50,000
50% Contingency	$0	$27,500	$10,000	$40,000	$340,000
Total	$0	$82,500	$30,000	$120,000	$1,020,000

*Project costs do not include planning, permitting, design, or additional analysis.

DISCUSSION

Squalicum Creek is underutilized by salmonids within and above the study area. This underutilization is because of the ecological factors summarized in Table 5. For purposes of comparing alternatives the following general recommendations were developed based upon those ecological considerations:

- Reduce interaction of salmon and trout fry with warm-water fish in Sunset Pond and Bug Lake.
- Improve upstream fish passage through the study area to provide access to the upper watershed.
- Enhance natural sediment transport processes and in-channel storage of sediments.
- Enhance natural channel migration and opportunities for LWD recruitment.
- Increase riparian habitat to provide shade and leaf litter and reduce open canopy area.
- Enhance floodplain connectivity.
- Allow self sustaining natural processes to improve conditions for salmonids over time.

Alternative 5, large-scale rehabilitation, is the only alternative that addresses all of these recommendations. Alternative 5 is a much more comprehensive effort than the other alternatives and will require significantly more planning, design, and implementation costs. In addition, Alternative 5 will require extensive landowner/agency coordination and approval and will likely need to be implemented in phases. Therefore, we feel that Alternative 5 represents a long term plan and should not be chosen as a preferred alternative at this time. Alternative 5 identifies ideal stream locations and configurations within the study area and should be used as a framework for interim actions.

Some species of salmon migrate long distances up stream networks to spawn in stream headwaters and tributary channels. The fact that very little spawning activity has been documented, and little rearing was identified, upstream of Sunset Pond are strong indicators that passage to the upper watershed is a primary concern. It has been documented that extensive habitat exists upstream of Hannegan Road, but confirming this was not part of our scope.

Implementing Alternative 2 will treat current barriers providing easier upstream access to the upper watershed. This will provide opportunities for greater spawning productivity and promote greater utilization of existing habitat above the pond. Choosing Alternative 2 as the sole strategy for stock recovery places high importance on underutilized habitat above the pond and de-emphasizes the predation concerns within Sunset Pond and Bug Lake. It also disregards the importance of habitat conditions within the study area, relegating the creek from the inlet of Sunset Pond to its mouth as a migration corridor to the upper watershed. In addition, the installation of baffles in the I-5 culverts will redistribute high flows into Tributary V and under the I-5 overpass into Bug Lake. The exact quantity of displaced flow and likely return interval is uncertain and beyond our scope.

Alternate 3, reroute around Bug Lake, does not provide significant benefits individually, but can be constructed as an incremental step in implementing Alternative 5. On its own, this alternative transforms a segment of the creek to more natural conditions with a mature riparian canopy and increases the LWD recruitment potential to the stream. This would lead to improved channel conditions over time, but improvements are limited by sediments continuing to be stored in Sunset Pond. By rerouting the creek around Bug Lake, predation benefits would be realized, but would likely be short lived in that warm-water fry from Sunset Pond may soon seed this area. In addition, this alternative does not treat the I-5 culverts such that upstream passage would still be a significant issue.

Alternative 4 routes the creek around Bug Lake and treats the adjacent channel segments and the I-5 culverts. This alternative transforms the local creek segment to more natural conditions with a mature riparian canopy and increases the LWD recruitment potential to the stream and improves riparian conditions downstream. Habitat conditions would improve overtime but sediment sources would continue to be limited. In addition, passage issues to the upper watershed are treated such that upstream habitat utilization should increase. Similar to Alternative 3, predation benefits would likely be short lived. In summary, this alternative treats passage issues, but habitat improvement is limited. However, this alternative could be used as an integral step in implementing Alternative 5.

RECOMMENDATIONS

We recommend installing Alternative 4 as an incremental step in implementing Alternative 5. By completing Alternative 4, upstream passage issues would be treated and the lower segment of the creek would be placed in its desired long term configuration. This would provide some immediate benefit while logistic considerations for the remainder of Alternative 5 are being worked out.

It will likely be several years before Alternative 5 could be fully implemented. At least two significant infrastructure components, the bridge at James Street and the berm through Bug Lake, would need to be constructed as well as several lengths of new channel. Some utility lines may also need to be relocated. These components could be done independently as funding sources were identified and secured until all the necessary components were in place.

LIMITATIONS

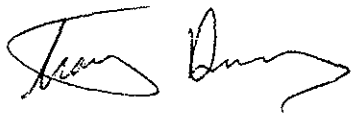
We have prepared this report for use by the Nooksack Salmon Enhancement Association in evaluating the feasibility of rerouting portions of Squalicum Creek near Bug Lake and Sunset Pond. Within the limitations of scope, schedule, and budget our services have been executed in accordance with generally accepted scientific and engineering practices in this area at the time this report was prepared. No warranty or other conditions, express or implied, should be understood.

Please refer to the Appendix A titled Report Limitations and Guidelines for Use for additional information pertaining to use of this report.

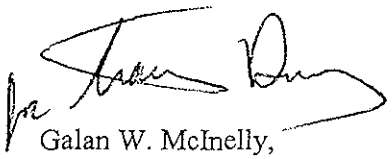
We appreciate the opportunity to work on this project with you. Please call with any questions that you have or if there is anything else that we can do for you.

Respectfully Submitted,

GeoEngineers, Inc.



Tracy A. Drury,
River Science and Engineering



Galan W. McInelly,
Principal

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APPENDIX A

REPORT LIMITATIONS AND GUIDELINES FOR USE

APPENDIX A

REPORT LIMITATIONS AND GUIDELINES FOR USE[1]

This appendix provides information to help you manage your risks with respect to the use of this report.

GEOENGINEER'S SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for the exclusive use of Nooksack Salmon Enhancement Association and their authorized agents. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical, geomorphic, or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical, geomorphic, or geologic study is unique, each geotechnical engineering, geomorphic, or geologic report is unique, prepared solely for the specific client and project site. Our report is prepared for the exclusive use of our Client. No other party may rely on the product of our services unless we agree in advance to such reliance in writing. This is to provide our firm with reasonable protection against open-ended liability claims by third parties with whom there would otherwise be no contractual limits to their actions. Within the limitations of scope, schedule and budget, our services have been executed in accordance with our Agreement with the Client and generally accepted practices in this area at the time this report was prepared. This report should not be applied for any purpose or project except the one originally contemplated.

A GEOTECHNICAL ENGINEERING, GEOMORPHIC, OR GEOLOGIC REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

This report has been prepared for the Nooksack Salmon Enhancement Association. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

[1] Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org .

A GEOTECHNICAL ENGINEERING, GEOMORPHIC, OR GEOLOGIC REPORT COULD BE SUBJECT TO MISINTERPRETATION

Misinterpretation of this report by other design team members can result in costly problems. You could lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering, geomorphic, or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

GIVE CONTRACTORS A COMPLETE REPORT AND GUIDANCE

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering, geomorphic, or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A pre-bid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

CONTRACTORS ARE RESPONSIBLE FOR SITE SAFETY ON THEIR OWN CONSTRUCTION PROJECTS

Our recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

READ THESE PROVISIONS CLOSELY

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering, geomorphic, or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

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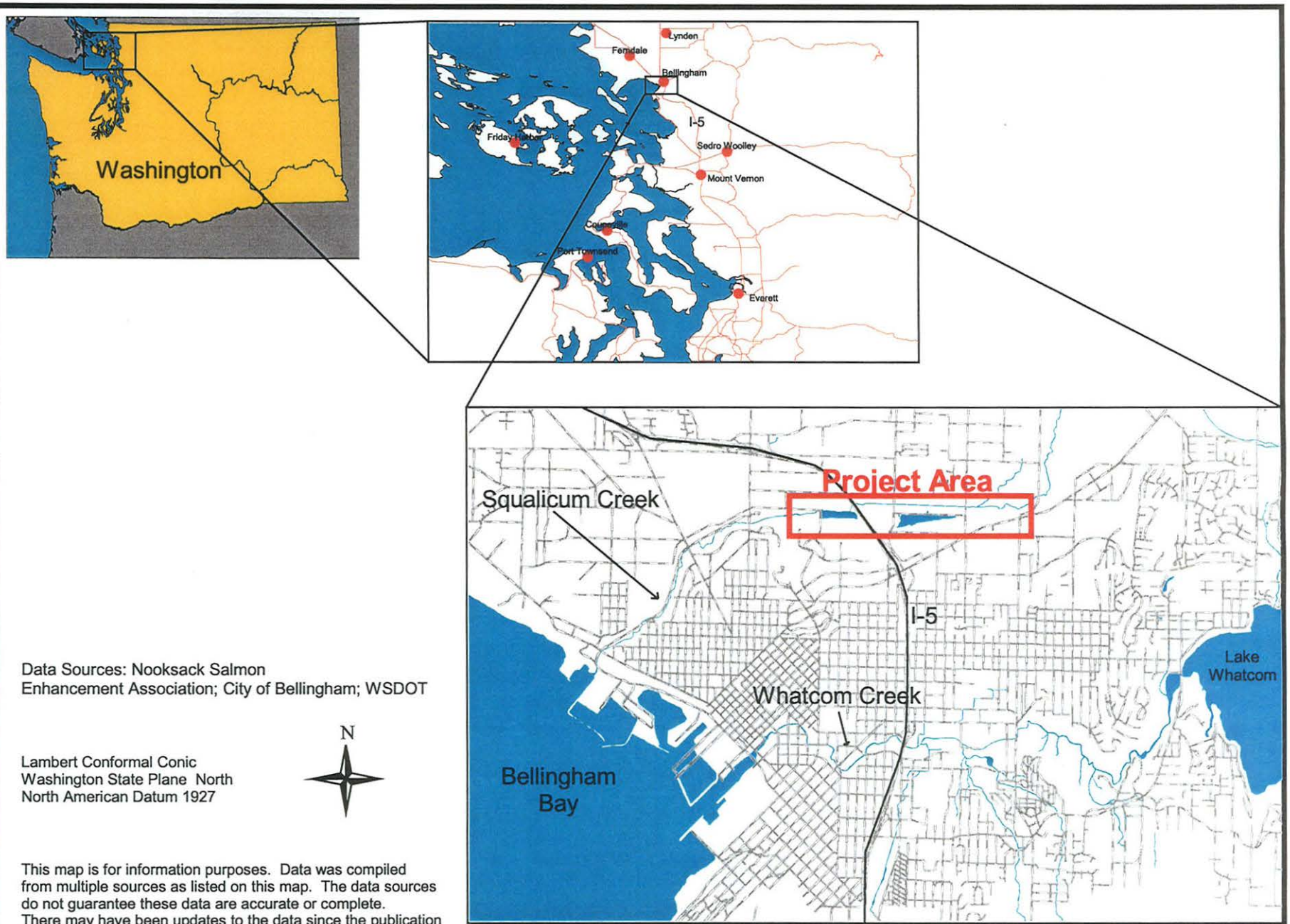
The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical, geomorphic, or geologic study and vice versa. For that reason, a geotechnical engineering, geomorphic, or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical, geomorphic, or geologic concerns regarding a specific project.



Data Sources: Nooksack Salmon Enhancement Association; City of Bellingham; WSDOT

Lambert Conformal Conic
Washington State Plane North
North American Datum 1927

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All locations are approximate.

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REGIONAL SITE MAP

FIGURE # 1

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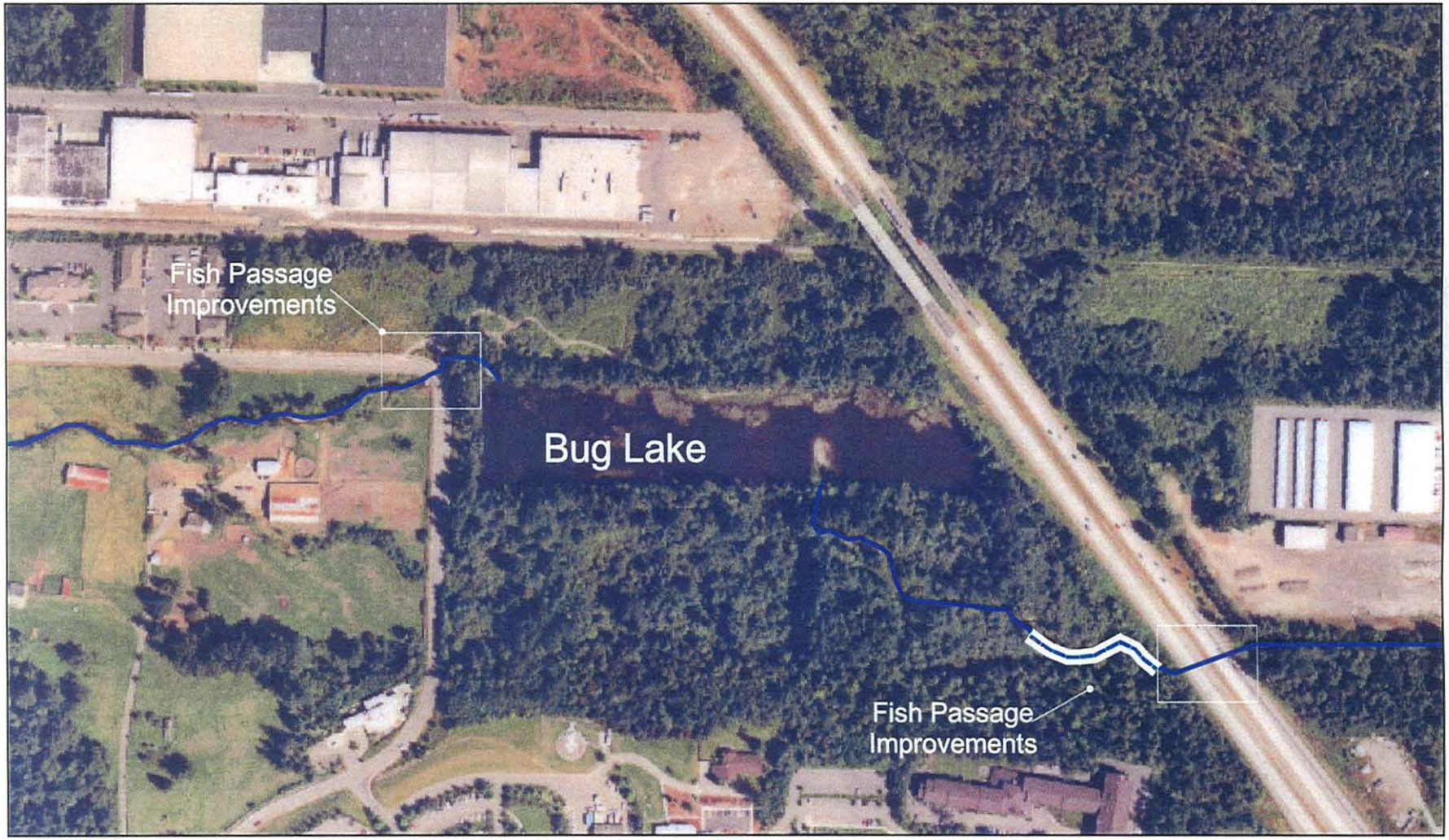

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The locations of all features shown are approximate.

Data Sources: Nooksack Salmon Enhancement Association; City of Bellingham

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Alternative 2

FIGURE # 3

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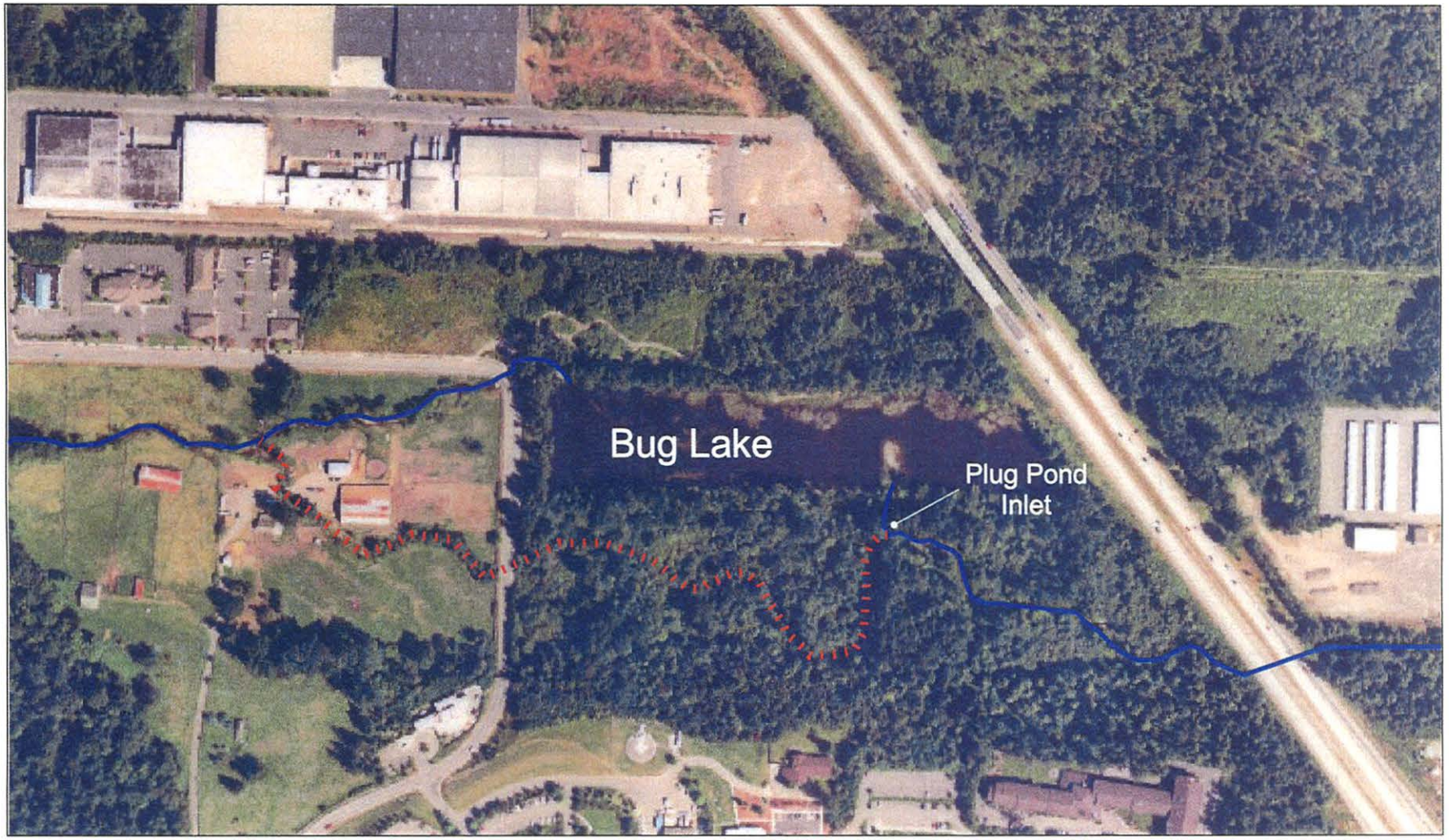

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Alternative 3

FIGURE # 4

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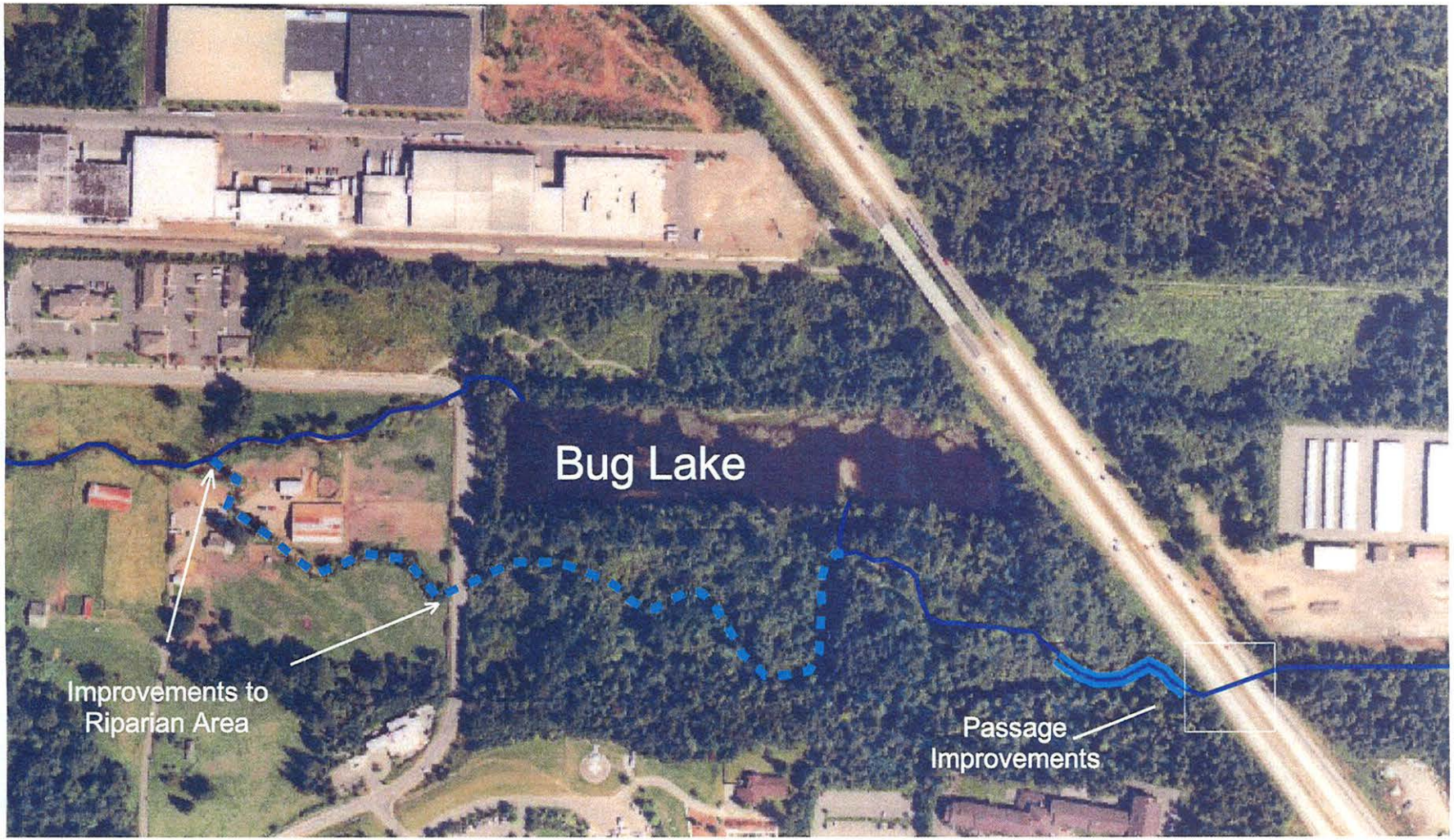

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Alternative 4

FIGURE # 5

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