Skagit County

South Fidalgo Island
Stormwater Management Plan

July 2010

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Skagit County

SOUTH FIDALGO ISLAND STORMWATER MANAGEMENT PLAN

JULY 2010

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Project #135-27049-08-116

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ACRONYMS AND ABBREVIATIONS

ac—acre

CaRD—Conservation and Reserve Developments

CMP—Corrugated Metal Pipe

du—dwelling unit

Ecology—Washington State Department of Ecology

FEMA—Federal Emergency Management Agency

FPA—Forest Practice Application

GIS—geographic information system

HCA—habitat conservation area

HDPE— high-density polyethylene

H:V—horizontal to vertical (slope)

LID—Low Impact Development

NRCS—Natural Resource Conservation Service

OSRSI—Public Open Space of Regional/Statewide Importance (land use zone)

RB—Rural Business (land use zone)

RC—Rural Center (land use zone)

RCW—Revised Code of Washington

RI—Rural Intermediate (land use zone)

RMI—Rural Marine Industrial (land use zone)

RRc-NRL—Rural Resource – Natural Resource Lands (land use zone)

RRv—Rural Reserve (land use zone)

RV—Recreational Vehicle

SCC—Skagit County Code

SEPA—State Environmental Policy Act

SFSA—South Fidalgo Study Area

SSB—Small Scale Business (land use zone)

USFWS—U.S. Fish and Wildlife Service

WAC—Washington Administrative Code

WDNR—Washington State Department of Natural Resources

WWHM—Western Washington Hydrologic Model

EXECUTIVE SUMMARY

Fidalgo Island is located in the westernmost part of Skagit County, Washington. South Fidalgo Island's landscape is shifting from mostly rural to predominantly single-family residences; Skagit County Public Works developed this plan to evaluate the resulting impacts on local stormwater. The primary goal of this plan is to outline projects that correct existing drainage deficiencies and to plan for future stormwater infrastructure which will accommodate anticipated growth while recognizing local slope instability issues related to stormwater input.

Unlike the flat river deltas and rolling hills comprising much of western Skagit County, Fidalgo Island consists of a combination of ancient bedrock and glacial soil. The bedrock has significant relief, from the island's steep shorelines to the peak of Mount Erie, and was glacially sculpted which created pockets in the bedrock surface. Glacial deposits, landslides, and erosion have filled the low areas with soils and organics to varying depths. This complex mixture of permeable and impermeable sediments can be sensitive to surface water inputs which creates an additional challenge for stormwater management on Fidalgo Island.

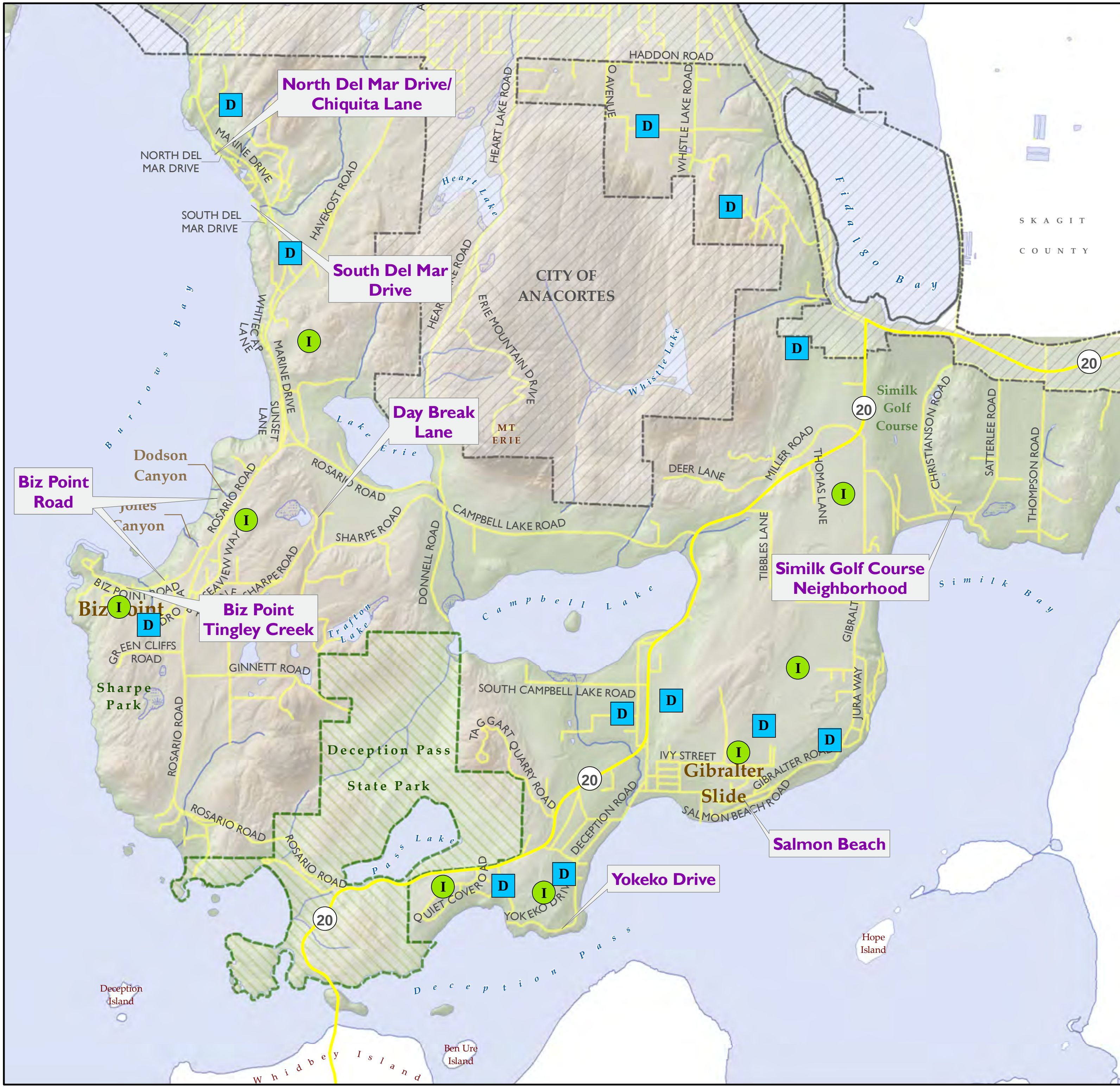
The plan addresses the unincorporated area of Fidalgo Island south of the City of Anacortes, excluding Deception Pass State Park and the City area surrounding Mount Erie. Chapter 1 includes an introduction to the study area and outlines the report's objectives. Chapter 2 provides an overview of the region's physical setting and describes the characteristics of the island's hydrology. Chapter 3 summarizes the regulatory setting of the study area, including county ordinances, regulations, and policies related to stormwater and slope stability. Chapters 4 and 5 describe the existing zoning and land use, current stormwater conveyance networks, historical slope instability regions, and reported problem areas. Chapter 6 contains the stormwater analysis, including the hydrologic modeling of the 116 delineated subbasins within the study area. The modeling aided the identification of future stormwater concern areas.

Chapters 7 and 8 contain both programmatic and project recommendations to address policy and infrastructure deficiencies which will ultimately improve stormwater management on South Fidalgo Island. The recommended project solutions and costs are conceptual level proposals; more detailed hydraulic, hydrologic, survey, or geotechnical analysis will be necessary to confirm these solutions when Skagit County Public Works moves forward with individual projects.

Figure ES-1 presents an overview of the programmatic and conceptual project-based recommendations, including: locations of concentrated future development where drainage easements or other methods to discharge future stormwater runoff should be considered, areas where infiltration should be limited to protect steep downslope properties from stormwater impacts, and the locations of the projects to address current problem areas. Table ES-1 summarizes the recommended programs and projects.

TABLE ES-1
SUMMARY OF RECOMMENDATIONS

Programmatic Recommendations	
Limit infiltration in the following areas	Quiet Cove, Yokeko Point, Salmon Beach & South end of Gibralter Road, North end of Gibralter Road, Jura Lane, East of Rosario Road (south of Marine Drive), East of Marine Drive, South of Biz Point Road
Obtain drainage easements for future development (high flow subbasins)	Quiet Cove, Yokeko Point, Salmon Beach & South end of Gibralter Road, Southeast of Lake Campbell, Intersection of Havekost Road and Marine Drive, Lake Erie’s Rosario Road (east of Marine Drive), Eaglecrest Lane & Seaview Way, Trafton Road and Crater Lake Road, Intersection of Sharpe Road and Donnell Road, Northwest corner of study area (Marine Drive and Peace Cliff Lane), Northeast corner of study area (south of Haddon Road, north of San Juan Hill Lane, west of SR 20 Spur), North of Similk Bay
Steep slope management	Activities to reduce the impact on steep slopes
Drainage system inventory	Continue to build data base of drainage system
Drainage infrastructure maintenance	Update maintenance program for more frequent inspection of ponds, catch basins and ditches.
Project Recommendations	
Projects by Problem Area	Planning Level Cost Opinion
North Del Mar Drive/Chiquita Lane	$119,000
Biz Point–Tingley Creek	$10,000
Yokeko Drive	$294,000
Similk Golf Course	$15,140,000
Day Break Lane	$72,000
Salmon Beach	$10,000
Biz Point Road	$294,000
South Del Mar Drive	$15,140,000
Regional Detention Pond	$1,295,000



SOUTH FIDALGO ISLAND

FIGURE ES-1

RECOMMENDATION LOCATIONS SUMMARY

- City of Anacortes
- Roads
- Waterbodies
- Streams
- Wet Areas
- Deception Pass State Park
- Projects
- D Concentrations of Future Development
- I Minimize Infiltration Practices

N W E S

1 inch = 4,000 feet

Feet 0 1,000 2,000 3,000 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010

CHAPTER 1.
INTRODUCTION

South Fidalgo Island is experiencing growth that is leading to a transition from a mainly rural region to one dominated by single-family housing. As development occurs, natural forest cover is replaced with impervious surfaces such as rooftops, driveways, parking lots and streets. The conversion of natural ground cover to impervious surfaces impacts stormwater runoff and its contribution to groundwater and surface water. Increased areas of impervious surfaces cause both the volume and rate of storm runoff to increase, leading to larger peak flows than would occur in a naturally forested watershed.

In response to recent planning effort findings and significant rainfall events, Skagit County Public Works has identified a need for a comprehensive look at stormwater problems in the South Fidalgo Island area, including an investigation into ways to address current system deficiencies and identify potential future deficiencies due to growth. This Stormwater Management Plan has been prepared to provide such a comprehensive look and investigation.

STUDY AREA

The formal study area for this plan is the unincorporated portion of Fidalgo Island south of the City of Anacortes, excluding Deception Pass State Park (see Figure 1-1). Some evaluation was conducted for the state park and the area around the highest point on Fidalgo Island, Mount Erie which is in the center of the island within the Anacortes city limits; these areas were evaluated only as part of the hydrologic investigation to account for their contribution of runoff to the formal study area.

OBJECTIVES

This Stormwater Management Plan will serve as a guide for the management of stormwater impacts in South Fidalgo Island as the area continues to evolve from a natural landscape to a more developed one. The primary goal of the plan is to effectively manage stormwater by correcting existing drainage deficiencies and by planning for future infrastructure that is consistent with anticipated growth, will provide adequate drainage, and will mitigate slope instability and shoreline erosion issues related to stormwater. The following objectives were established for the preparation of this plan:

- Review existing ordinances, regulations and policies and recommend appropriate changes.
- Conduct site visits to evaluate known drainage and geotechnical issues.
- Prepare a detailed drainage basin delineation for stormwater analysis.
- Perform hydrologic modeling to evaluate existing and future stormwater runoff potential.
- Identify problem areas and recommend improvements for control and mitigation of stormwater quantity and its effect on slope stability.

REPORT OVERVIEW

This plan provides recommendations for capital improvements and programmatic changes for stormwater management in the South Fidalgo Island area. It consists of the following chapters:

- Chapter 1, Introduction—Statement of goals and objectives and report overview
- Chapter 2, Study Area Characteristics—Description of the physical features, climate, soils, sensitive areas, topography, and geologic characteristics affecting the island’s hydrology

- Chapter 3, Regulatory Setting—Summary of existing county ordinances pertaining to activities affecting stormwater and slope stability, including forest practices, sensitive areas, septic installation, property development, and drainage; a review of procedures related to development or use of property in the County
- Chapter 4, Existing Conditions—Descriptions of the existing zoning and land use, stormwater collection system, and problem areas
- Chapter 5, Geotechnical Analysis—A review of areas of historical slope instability for reported and observed problems and detailed evaluations of slope geology
- Chapter 6, Stormwater Analysis—Hydrologic modeling of the existing and future development conditions to identify areas of concern for stormwater runoff
- Chapter 7, Programmatic Recommendations—Recommendations for policies and programs to improve stormwater management in the South Fidalgo Island area: drainage standard revisions, public education, operation and maintenance, and forest practices permitting
- Chapter 8, Project Recommendations—Review of problem areas and recommendation of projects to address them.

SOUTH FIDALGO ISLAND

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FIGURE 1-1
STUDY AREA

City of Anacortes
Deception Pass State Park
Roads
Streams
Waterbodies
Wet Areas

N W E S

1 inch = 4,000 feet

Feet
0 1,000 2,000 3,000 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

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Cartography by Tetra Tech, Inc.
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CHAPTER 2.
STUDY AREA CHARACTERISTICS

The South Fidalgo Study Area (SFSA) is approximately 8,600 acres and is bordered by Burrows Bay to the west, Deception Pass to the south, Fidalgo Bay and Anacortes to the north, and Similk Bay to the east (see Figure 1-1). The adjacent areas of Deception Pass State Park (1,100 acres) and the portion of the City of Anacortes around Mount Erie (2,600 acres) are included in the stormwater analysis for hydrologic continuity, but are not otherwise a part of the study area.

There are six major lakes in the study area, several unnamed ponds and streams, and a few wetland complexes. The only creek that has been identified as potentially fish-bearing is Meadow Creek, which flows from Lake Campbell to Deception Pass. Land use is predominantly rural residential, with concentrations of residences in the northwest and southeast portions of the study area.

There are approximately 4,000 to 5,000 residences, which is predicted to about double in the next 10 years. There are two small commercial areas, three significant quarries, one golf course, one elementary school, three fire stations, a hotel, a large private RV park, and the Walla Walla College facility at Rosario Beach. Police service is provided by the Skagit County Sheriff's department; fire and medical response are provided by County Fire Districts 11 and13; solid waste is collected by a private contractor; and drinking water is provided by the Anacortes Water Department, Skagit County PUD #1, Del Mar Water system, or private wells or well systems. All homes and businesses in the study area use septic tanks for sewage disposal. There are no plans for sewer service to any part of the unincorporated area; Anacortes does have sewers and a wastewater treatment plant.

The following sections describe the study area characteristics that affect watershed hydrology.

CLIMATE AND PRECIPITATION

The climate of the study area is mild. Air temperature is influenced by the surrounding water bodies and remains seasonally consistent. Based on historical records in Anacortes, average air temperatures range from the 40s to the 60s, with highs and lows of about 75ºF and 35ºF, respectively, and extreme highs and lows of around 100ºF and 5ºF.

Average annual precipitation is 26.6 inches in Anacortes (4 miles north), 32.3 in Mount Vernon (16 miles east) and 20.0 inches in Coupeville (22 miles south), the nearest historical rain gages (www.wrcc.dri.edu). Typically, 2-4 inches fall each month October through April and 1-2 inches per month May through September. In Anacortes, the highest recorded annual rainfall was 39.4 inches in 1990; the lowest was 16.0 inches in 1952.

Per the records collected since 1948, average annual snowfall in Anacortes is 5.2 inches total. The east side of the study area is generally slightly wetter than the west side. The National Oceanic and Atmospheric Administration's *Precipitation-Frequency Atlas of the Western United States* (NOAA, 1973) gives precipitation amounts for the general study area as summarized in Table 2-1.

SOILS

The Natural Resources Conservation Service Soil Survey (NRCS 2009) shows the soils in the study area as a mixture of highly pervious gravel-cobble matrices, bare bedrock outcrops, sandy and gravelly loam, and some silt, clay and muck. Because the hydrologic subbasins extend beyond the study limits, soils within the Mount Erie portion of Anacortes and within the state park were included in this assessment. Figure 2-1 shows the areal extent and 25 soil classifications in the study area.

TABLE 2-1.
STUDY AREA PRECIPITATION

Precipitation Event Recurrence Interval	24-Hour Precipitation (inches)
2-Year	1.36
5-Year	1.74
10-Year	2.02
25-Year	2.45
50-Year	2.68
100-Year	3.07

The largest soil unit is the Whistle-Fidalgo-Rock outcrop complex, covering over 4,000 acres or about 37 percent of the study area (including Mount Erie and the state park). Bedrock dominates this unit in steep outcrop areas. Catla gravelly fine sandy loam, which covers much of the upland surface, and Swinomish-Fidalgo-Rock outcrop complex both total over 1,000 acres in the study area (about 10 percent). Table 2-2 presents characteristics of these three primary soils. By general soil type, there are about 6,000 acres (52 percent) in rock outcrop complexes and over 4,000 acres (35 percent) in gravelly loam.

An unusual soil found in a small portion of the study area is Dystric Xerochrepts, a gravelly to very gravelly sandy loam on 45- to 90-percent slopes. These soils consist of colluvium in areas near Salmon Beach, Jura Way, Biz Point Road, and west of Rosario Road.

TOPOGRAPHY

Elevations in the study area range from sea level on the coastal margins to 1,273 feet on the top of Mount Erie. The lakes are generally in large bowl areas. The shorelines all exhibit steep slopes to nearly vertical bluffs. Drainage occurs in steep-sided ravines that generally are dry between storm events.

Although there are large, relatively flat pasture areas in the study area, the majority of the land can be classified as “steep.” The coverage of slopes is listed in Table 2-3 and shown on Figure 2-2. Skagit County has classified multiple areas as geologically hazardous critical areas, as described below.

ENVIRONMENTALLY SENSITIVE AREAS

Skagit County Code (SCC) includes a Critical Areas Ordinance addressing the following critical areas:

- Wetlands
- Aquifer recharge areas
- Geologically hazardous areas
- Fish and wildlife habitat conservation areas
- Frequently flooded areas.

**TABLE 2-2.
STUDY AREA SOILS**

Name	Composition	Description	Location
Whistle-Fidalgo-Rock outcrop complex, 30 to 65 percent slopes	Whistle and similar soils: 50 percent Fidalgo and similar soils: 20 percent Rock outcrop: 15 percent	Found in a mountain slope setting, formed from volcanic ash materials and glacial drift. Typically 0-3 inches gravelly loam, underlain by 2-4 feet of gravelly sandy loam or loamy sand, underlain by unweathered bedrock, with random patches of bare lithic bedrock.	Predominantly Mount Erie, north Burrows Bay area and southwest corner of Fidalgo Island.
Catla gravelly fine sandy loam, 0 to 15 percent slopes	Catla soils: 100 percent	Generally found as hill slopes, formed from glacial drift. Typically greater than 5-foot depth of gravelly fine sandy loam and very gravelly loam.	Mostly upland areas above south end of Burrows Bay. Some areas upland above Similk Bay and Deception Pass.
Swinomish-Fidalgo-Rock outcrop complex, 3 to 30 percent slopes	Swinomish and similar soils: 40 percent Fidalgo and similar soils: 35 percent Rock outcrop: 15 percent	Generally found on ridges and mountain slopes, formed from volcanic ash materials and glacial drift. Typically 0-20 inches gravelly loam, underlain by 2-5 feet of very gravelly fine sandy loam and very or extremely gravelly sandy loam. Locally underlain at a depth of 3 feet with unweathered bedrock. Mixed with random patches of bare lithic bedrock.	Scattered throughout Fidalgo Island. Largest areas are at north end of Similk Bay and above Deception Pass.

**TABLE 2-3.
STUDY AREA TOPOGRAPHY**

Slope Class	Percent Slope	Percent of Land Area
Flat	0-5	16%
Moderate	5-15	30%
Steep	> 15	48%

ENVIRONMENTALLY SENSITIVE AREAS

Skagit County Code (SCC) includes a Critical Areas Ordinance addressing the following critical areas:

- Wetlands
- Aquifer recharge areas
- Geologically hazardous areas
- Fish and wildlife habitat conservation areas
- Frequently flooded areas.

The areas are critical either because of the public hazard they present (flood areas or geologically hazardous areas) or the public benefit they provide (wetlands, aquifer recharge areas, fish and wildlife habitat conservation areas). With the exception of the Federal Emergency Management Agency (FEMA) maps used to designate frequently flooded areas, map identification of critical areas provides only approximate boundaries and is not considered a regulatory standard or substitute for site-specific assessments by qualified professionals. Maps of the critical areas can be found in the map gallery of the GIS/Mapping Services Department on Skagit County's website.

Wetlands

Wetlands are areas that are saturated by surface or groundwater often enough to support vegetation adapted for life in saturated soil conditions. The protection of wetlands is important for management of stormwater and for providing wildlife habitat. During storm events, streams can overflow their banks and spread out into adjacent wetlands. Wetland soils act like a reservoir, storing surplus water during wet periods and discharging this water into streams later to augment base flows. Wetlands also filter pollutants by a combination of physical, chemical, and biological processes.

Most of the wetlands in the SFSA are associated with creeks and lakes, but additional ones are located in the southwest portion of Fidalgo Island—one above Gibralter Road, and several in the lowlands between northern Similk Bay and southern Fidalgo Bay. Within the study area, the following types of wetlands have been identified (USFWS, 1979):

- Emergent Wetland—Characterized by erect, rooted, herbaceous hydrophytic plants excluding mosses and lichen. This vegetation is present for most of the growing season most years.
- Forested Wetland—Consists of woody vegetation typically 20 feet or taller. Exists where moisture is abundant. Typically possesses an overstory of trees, an understory of young trees or shrubs, and a herbaceous layer.
- Shrub Wetland—Consists of woody vegetation typically less than 20 feet tall. The species include true shrubs, young trees, and trees or shrubs that have been stunted because of environmental conditions (saturated soils). Also called "Shrub-Scrub" wetland.
- Ponds and Lakes—Permanent open bodies of water and small, shallow, ephemeral water bodies such as intermittent ponds. Depending on soil conditions, edges can be any type of vegetated wetland in natural conditions.

Aquifer Recharge Areas

Aquifer recharge areas are critical for maintaining groundwater as a potable water source or as a significant source of base flow to a stream. The Skagit County Aquifer Recharge Area Map, Category I Areas (Feb. 1, 2009) shows that the SFSA contains three of the four types of Category I areas:

- Potential sea water intrusion areas—The potential sea water intrusion area extends approximately a half-mile inland from the shoreline around the perimeter of Fidalgo Island.
- Wellhead protection areas—There are six Group A well system locations. One is near the outlet of Lake Erie (within its buffer). Four well sites in the Biz Point and Burrows Bay area have a wellhead protection zone around them. Two wells at Rosario Beach do not have wellhead protection zones around them. The Burrows Bay and Rosario Beach well sites all lie within the Category I zone for sea water intrusion.
- One-half mile around a surface water source limited stream—Lake Erie has been identified as a "closed stream" indicating it is a surface water source limited stream; the half-mile buffer around the lake is a Category I zone.

Geologically Hazardous Areas

Geologically hazardous areas include areas susceptible to the effects of erosion, landsliding, earthquake or other geologic events. They pose a threat to the health and safety of citizens when incompatible residential, commercial, industrial or infrastructure development is sited within them. Geologically hazardous areas within the study area include the following:

- Slopes greater than or equal to 30 percent
- Specific soil map units such as dystric xerochrepts or lithic haploxerolls
- Coastal beaches and bluffs, especially those identified as Unstable, Unstable Bluff, Unstable Recent Slide, and Unstable Old Slide in the Washington Department of Ecology's *Coastal Zone Atlas of Washington, Skagit County* (Ecology, 1978)
- Slopes of 15 percent or more in permeable soils that intersect plains of bedrock or relatively impermeable soils
- Areas of seismic hazard, such as liquefaction, within a half-mile of an active fault, and tsunami or seiche hazard areas.
- Areas that are potentially unstable due to streambank erosion, rapid stream incision, or undercutting by wave action
- Areas of previous slope failures
- Areas subject to rock fall.

Fish and Wildlife Habitat Conservation Areas

State-defined fish and wildlife habitat conservation areas (HCAs) include areas with which endangered, threatened and sensitive species have a primary association, waters of the state, and natural ponds. HCAs in the study area are associated with streams, lakes, and shorelines. Stream riparian buffers vary from 50 to 200 feet depending on the stream's Washington Department of Natural Resources (WDNR) water type. Lake and marine shoreline buffers range from 100 to 200 feet depending on the shoreline area designation.

Frequently Flooded Areas

Frequently flooded areas are those areas identified by zones representing the floodway and 100-year floodplain on FEMA Flood Insurance Rate Maps. In the SFSA, there are FEMA flood zones identified as A, A1, and V4 (FEMA, 1989).

Lake Erie, Lake Campbell, Whistle Lake, Trafton Lake and several small unnamed lakes and wetlands in the vicinity of Sharpe Road are identified by FEMA as Zone A, meaning they experience flooding during the 100-year flood, but base flood elevations were not determined. The A1 and V4 zones have base flood elevations determined; the latter are coast flood areas that experience velocities or wave action. Table 2-4 lists the locations and zones where base flood elevations were determined (all coastal). All other areas in the study area are Zone C, considered to be areas of minimal flooding (FEMA, 1985).

TABLE 2-4.
MAPPED FLOOD ZONES IN THE STUDY AREA

		Flood Elevation[a] (feet)	
Location	Zone[b]	10-year	100-year
Similk Bay coast	A1	7.6	8.0
Deception Pass coast (Salmon Beach to Bowman Bay)	A1	6.0	8.0
N. side of Bowman Bay to Rosario Beach to Southwest of Biz Point	V4	6.0	8.0
N. side of Biz Point (Langley Bay) to north side of Edith Point to Alexander Beach	V4	7.0	9.0
North of Alexander Beach	A1	6.5	7.0

a. Elevations referenced to National Geodetic Vertical Datum of 1929. Modern references (North American Vertical Datum of 1988) are 3.78 feet higher.
b. Locations of zones may be viewed by searching for Map Panel ID 5301510225C at the FEMA Map Service Center, http://msc.fema.gov

Tidal flooding occurs when a high astronomical tide (one governed by the gravitational effects of the moon and sun) is augmented by a large storm surge, where water levels are increased due to wind and low atmospheric pressure. Additionally, wave run-up can be a significant factor in areas where the shorelines are not sheltered, such as the west side of Fidalgo Island. Previous studies by FEMA have indicated average wave run-up of 1.5 feet for moderately exposed reaches in northern Puget Sound. Tide elevations were determined by using long-term Seattle tide records and short-term Skagit County records and adding the difference between Seattle mean high water and the selected recurrence interval to the mean high water at each Skagit station. Tidal flooding boundaries were derived from Ecology’s 1978 Coastal Zone Atlas, which was based on field observations following the December 1977 tidal flooding event.

The lakes were studied by approximate methods. Field studies were conducted for Lakes Campbell and Erie and floodplain boundaries were determined using information obtained from local residents and hydraulic approximations of the outlet channels and culverts.

GEOLOGIC CONDITIONS

The characterization of geologic conditions in the study area is based on a review of published literature, Skagit County geotechnical reports, and five site visits conducted between July 2008 and June 2009. A complete list of literature reviewed is provided in Appendix A.

Skagit County Overview

Skagit County extends from the crest of the Cascades in the east to the Puget lowland islands in the west. The Cascade Range and its western foothills encompass the eastern two-thirds of the county, featuring steep slopes and bedrock outcrops with intervening alluvial valleys. The western third of Skagit County is part of the Puget Lowland, which generally consists of flat alluvial deltas and low, rolling hills made up of glacial soils. Much of the densely populated part of Skagit County is concentrated in these flat alluvial valleys and deltas. In this part of the County, soil conditions are relatively homogeneous compared to Fidalgo Island and, thus simpler to manage.

South Fidalgo Study Area

Unlike most of the Puget Lowland part of Skagit County, Fidalgo Island consists of a complex mixture of ancient bedrock and glacial soil. The bedrock has significant relief, from the island's shorelines to Mount Erie, and has been glacially sculpted to create many pockets in the bedrock surface. Glacial incursions from the north have eroded and deposited a number of glacial soils on top of the bedrock.

The study area is underlain by bedrock and soil. The bedrock is very old metamorphic rock. The soils are a combination of glacial and non-glacial soils deposited in the past 2 million years, although most of the materials were laid down in the past 20,000 years. Since the disappearance of glacial ice about 13,000 years ago, mass wasting (landsliding and erosion) has further sculpted the landscape, and sediment and organics have filled in topographically low areas.

The bedrock core of the island outcrops on the inner area around Mount Erie, on other high promontories, and sporadically around the shoreline edges of the island. In between the bedrock outcrops, soils overlie the bedrock to varying depths. The soils were deposited primarily during the several glaciations that engulfed the Puget Lowland. They mostly consist of glacial till, outwash and lake deposits. In between the glacial episodes, the previously deposited materials were redistributed by erosion and fluvial processes. The deposits that were overridden by glacial ice were compacted to a high degree and are therefore hard or very dense. Materials deposited after the last glaciation tend to be loose or soft.

With the melting of the glacial ice in the northern Puget Lowland, steep and unstable slopes were left in place. They have regressed and flattened somewhat in the ensuing years, but instability still occurs on hill slopes in the study area.

Much of the study area is a plateau about 100 to 700 feet above sea level. Most of the plateau consists of moderately to steeply inclined hills that reach 400 to 700 feet in elevation and surrounding rolling plains and troughs at elevations of about 100 to 400 feet. Four depressional lakes (Campbell, Erie, Trafton, and Pass) are located on the middle and western parts of the plateau. Smaller lakes and ponds dot the upland. On the east and west sides of the upland, relatively level terraces dominate the landscape. About 90 percent of southern Fidalgo Island is bordered by steep to precipitous slopes and bluffs on its shorelines. Pocket beaches are located between the rocky bluffs.

Geologic units of the study area, from oldest to youngest, are as follows (see Figure 2-3):

- Jurassic and Cretaceous Era Bedrock—Bedrock in the SFSA is part of the Fidalgo Ophiolite complex, consisting of metamorphosed plutonic, volcanic and sedimentary rocks. The rock that outcrops in the western and southern shoreline bluffs of the study area is gabbro, a dark metamorphic plutonic rock. The hills on the interior of the study area are made of metamorphosed basalt and argillite. The bedrock is mostly moderately strong, but contains weak zones, and is moderately to highly fractured and jointed.
- Quaternary Period Deposits—Glacial deposits can be divided into three main subdivisions.
  - Till (Q_{gt}) is a very dense, gravelly, silty sand that is locally referred to as "hardpan." It is relatively impervious and covers much of the upland plateau. Elsewhere in the Puget Lowland, till is known to contain cracks that allow surface water to infiltrate into deeper substrata.
  - Glacial outwash (Q_{ga}, Q_{gas}, Q_{go}, Q_{gos}), both advance and recessional, commonly consists of clean to slightly silty sand, and may contain significant proportions of gravel. It is highly pervious. Advance outwash is very dense, having been overridden by glacial ice; recessional outwash is loose to medium dense, because it was deposited during the

receding and wasting of glacial ice. Outwash deposits are mapped at the ground surface in small patches and long, narrow corridors throughout the plateau, and are of note along the outside edges of the plateau at Jura Way and Rosario Road. Although not shown on the map, a strip of outwash deposits was observed in the field to overlie bedrock along Marine Drive.

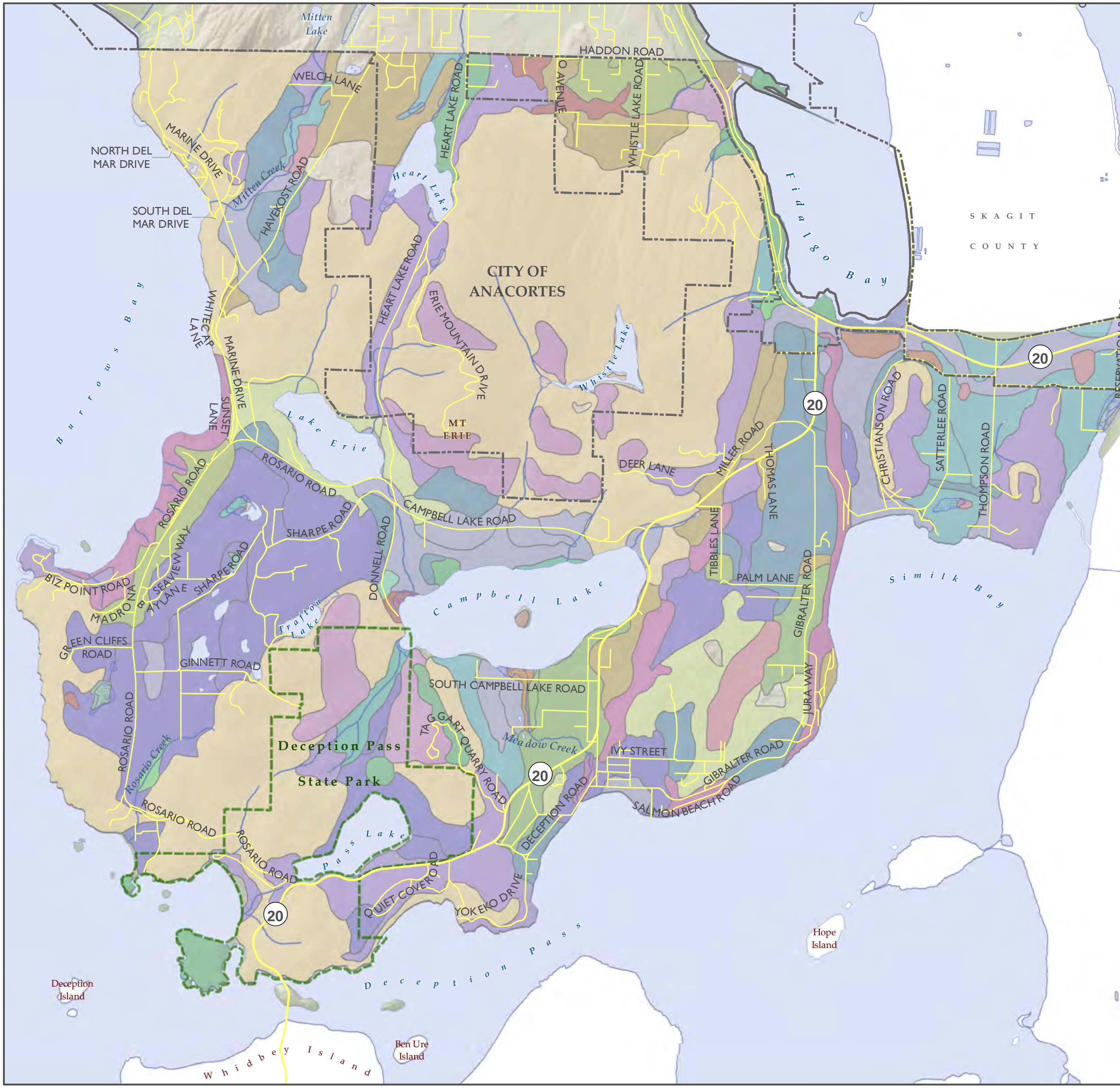
– Glacial lake clay and silt underlie the outwash in some locations, although not shown specifically on published geologic maps. As known from field reconnaissance and drilling completed for geotechnical reports, this layer is hard, layered fine sand, silt and clay that is relatively impervious. These deposits are found underlying outwash to the west of Rosario Road, most notably in Dodson and Jones Canyons, and to the south of Gibralter Drive in the Salmon Beach area.

West of Marine Drive, bedrock is overlain by a mixture of interbedded glacial sediments, including till, outwash and lake sediments. It is unknown whether they have been overridden and compacted by glacial ice.

- Although not specifically shown on the geologic map, nearly all slopes, except bare bedrock, are overlain by colluvium. Colluvium is a blanket up to several feet thick that has developed due to gravity, and includes landslide debris and eroded material. In locations of active or past landslide activity, the colluvium may be tens of feet thick.

SOUTH FIDALGO ISLAND

FIGURE 2-1
SOIL ASSORTMENT



- Bellingham mucky silt loam
- Bellingham silt loam
- Bow gravelly loam, low precipitation
- Catla gravelly fine sandy loam
- Clallam gravelly loam
- Coveland gravelly loam
- Coveland-Bow complex
- Dystric Xerochrepts
- Fidalgo-Lithic Xerochrepts-Rock outcrop complex, 3 to 30 percent slopes
- Field silt loam
- Guemes variant-Rock outcrop complex, 30 to 70 percent slopes
- Hydraquents, tidal
- Keystone loamy sand
- Laconner very gravelly loamy sand
- Lithic Haploxerolls-Rock outcrop complex, 70 to 90 percent slopes
- Mukilteo muck
- Norma silt loam
- Swinomish gravelly loam
- Swinomish-Fidalgo-Rock outcrop complex, 3 to 30 percent slopes
- Tacoma silt loam
- Tacoma silt loam, drained
- Terric Medisaprists, 0 to 2 percent slopes
- Tisch silty clay loam
- Whistle-Fidalgo-Rock outcrop complex, 30 to 65 percent slopes
- Xerorthents, 0 to 5 percent slopes

N W E S

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

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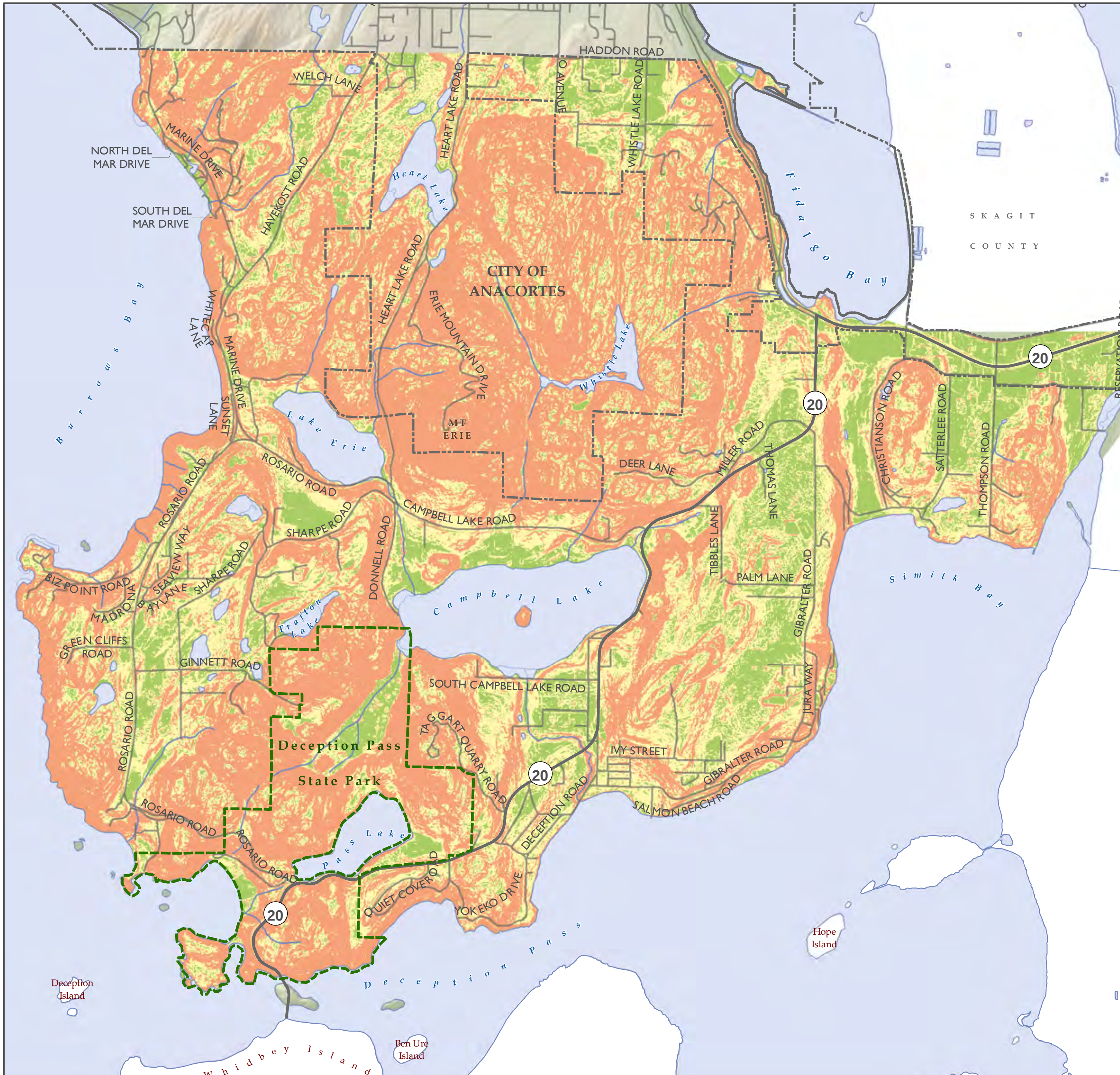
Cartography by Tetra Tech, Inc.
March 2010

SOUTH FIDALGO ISLAND

FIGURE 2-2
SLOPE CLASS



Slope Classification
(Per Hydrologic Model)

- Flat (< 5%)
- Moderate (5-15%)
- Steep (> 15%)

N S W E

1 inch = 4,000 feet

Feet
0 1,000 2,000 3,000 4,000

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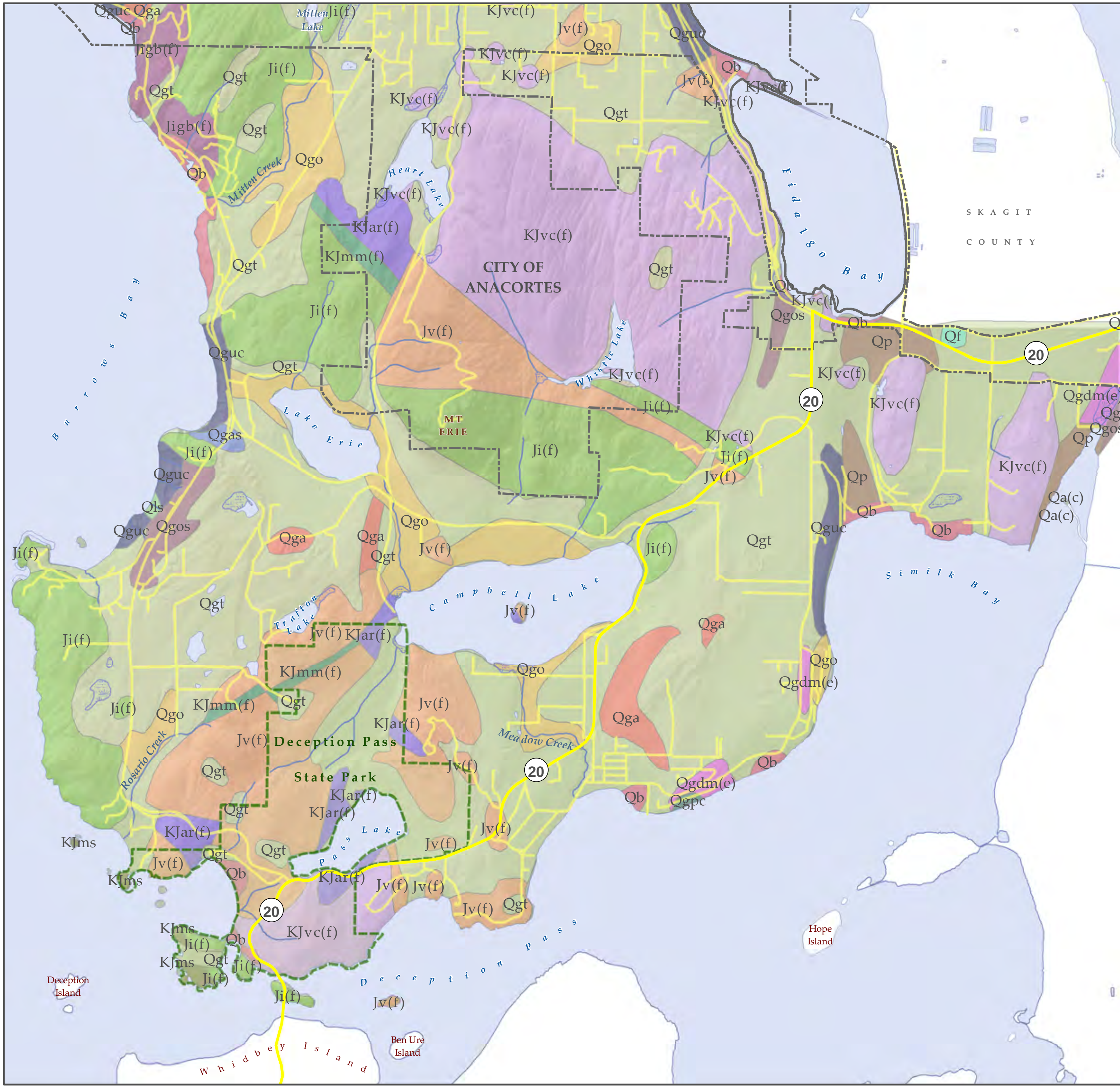

SOUTH FIDALGO ISLAND

FIGURE 2-3
SURFICIAL GEOLOGY

- Ji(f) - intrusive rocks, undivided
- Jigb(f) - gabbro
- Jv(f) - volcanic rocks
- KJar(f) - argillite
- KJm(f) - marine sedimentary rocks
- KJmm(f) - marine metasedimentary rocks
- KJmm(l) - marine metasedimentary rocks
- KJms - metasedimentary rocks
- KJvc(f) - volcaniclastic deposits or rocks
- Qb - beach deposits
- Qf - artificial fill, including modified land
- Qga - advance continental glacial outwash, Fraser-age
- Qgas - advance continental glacial outwash, sand, Fraser-age
- Qgdm(e) - glaciomarine drift, Fraser-age
- Qgo - continental glacial outwash, Fraser-age
- Qgos - continental glacial outwash, sand, Fraser-age
- Qgpc - continental glacial drift, pre-Fraser, and nonglacial deposits
- Qgt - continental glacial till, Fraser-age
- Qguc - glacial and non-glacial deposits, undivided
- Qls - mass-wasting deposits, mostly landslides
- Qp - peat deposits

Geologic Data provided by the
Washington State Department of Natural Resources
www.dnr.wa.gov

N S W E

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

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March 2010

CHAPTER 3.
REGULATORY SETTING

Skagit County's Unified Development Code (SCC Title 14) contains most of the regulations regarding development in the County. SCC Title 12 (Health, Welfare, and Sanitation) contains the regulations for on-site sewage handling (septic systems). The chapters specific to stormwater control and related to development are listed in Table 3-1; summaries of significant elements follow.

TABLE 3-1.
COUNTY CODE CHAPTERS RELATED TO STORMWATER

Chapter	Name
Title 12: Health, Welfare, and Sanitation	
12.05	On-Site Sewage Code — Rules And Regulations
Title 14: Unified Development Code	
14.16	Zoning
14.24	Critical Areas Ordinance
14.26	Shorelines
14.32	Drainage Ordinance
14.34	Flood Damage Prevention

POLICY

Drainage Ordinance

Skagit County's Drainage Ordinance adopts by reference the Department of Ecology's *Stormwater Management Manual for the Puget Sound Basin* (Ecology, 1992) or subsequent manuals adopted by Ecology as Skagit County's stormwater design manual. The current version of the Ecology manual is the *Stormwater Management Manual for Western Washington* (SMMWW; April 2005). Later sections of the County code present stormwater management requirements that are of an earlier standard than the 2005 Ecology manual.

According to the 1992 manual, projects creating more than 5,000 square feet of impervious surface or with more than 1 acre of land-disturbing activity that discharges directly or indirectly to a stream are required to control post-development runoff rates. The post-development peak stormwater discharge rates from the development site for the 10- and 100-year frequency, 24-hour duration storm events shall not exceed the pre-development peak stormwater runoff peak rates for the same design storm events. Also, the post-development peak stormwater discharge rate from the development site for the 2-year frequency, 24-hour duration storm event shall not exceed 50 percent of the pre-development peak stormwater runoff rate for the same design storm event.

Projects creating more than 5,000 square feet of impervious surface or with more than 1 acre of land-disturbing activity require an analysis of downstream impacts resulting from the project and mitigation of these impacts. The analysis must extend a minimum of a quarter-mile downstream from the project. The existing or potential impacts to be evaluated and mitigated include the following:

- Excessive sedimentation
- Streambank erosion
- Discharges to critical areas
- Violations of water quality standards, and spills
- Discharges of priority pollutants.

Existing drainage ways and other conveyance facilities within the scope of the downstream portion of the off-site drainage shall have sufficient capacity to convey the post-development peak stormwater discharge for the 25-year storm event without flooding or otherwise damaging existing or proposed structures. All newly constructed downstream drainage ways and conveyance facilities shall have sufficient capacity to convey the post-development peak stormwater discharge for the 100-year storm event. Exemptions to the runoff control requirements include the following:

- Commercial agriculture and forest practices regulated under Title 222 of the Washington Administrative Code (WAC), except for Class IV general forest practices that are conversions from timber land to other uses.
- Projects that do not increase the 100-year, 24-hour storm peak discharge from within the boundaries of the project more than 0.5 cubic feet per second (cfs).

The 2005 Ecology manual describes the following significant difference between the 1992 and 2005 documents (Ecology, 2005, pg. 1-5):

- "…the 1992 Ecology manual focused primarily on controlling the peak flow release rates for recurrence intervals of concern—the 2, 10, and 100-year rates. This level of control did not adequately address the increased duration at which those high flows occur because of the increased volume of water from the developed condition as compared to the pre-developed conditions. To protect stream channels from increased erosion, it is necessary to control the durations over which a stream channel experiences geomorphically significant flows such that the energy imparted to the stream channel does not increase significantly. Geomorphically significant flows are those that are capable of moving sediments. This target will translate into lower release rates and significantly larger detention ponds than the previous Ecology standard. The size of such a facility can be reduced by changing the extent to which a site is disturbed."

Based on the idea that stream channel erosion is controlled by the number of hours that erosive flows occur, the 2005 Ecology manual's flow duration standard is that the post-development flow duration cannot exceed pre-development values for flows ranging from 50 percent of the 2-year pre-development peak flow to 100 percent of the 50-year pre-development peak flow. This is the range of flows that have been identified to cause the greatest erosive damage in watersheds in western Washington.

Another significant difference between the 1992 and 2005 manuals is described as follows in the 2005 manual (Ecology, 2005, pg. 1-5):

- "In regard to wetlands, it is necessary to not alter the natural hydroperiod. This means control of flows from a development such that the wetland is within certain elevations at different times of the year and short-term elevation changes are within the prescribed limits. If the amount of surface water runoff draining to a wetland is increased because of land conversion from forested to impervious areas, it may be necessary to bypass some water around the wetland in the wet season. (Bypassed stormwater must still meet flow control and treatment requirements applicable to the receiving water.) If however, the wetland was fed by local ground water elevations during the dry season, the impervious surface additions and the bypassing practice may cause variations from the dry season elevations."

Critical Areas Ordinance

The Critical Areas Ordinance helps conserve property values, safeguard the public welfare and provide protection for the following critical areas:

- **Wetlands**—Wetlands are designated through a site visit or a site assessment using the definitions, methods and standards set forth in the *Wetland Identification and Delineation Manual* (Ecology publication No. 96-94). The current SCC requires wetland buffers of 25 to 300 feet, depending on wetland class.
- **Aquifer Recharge**—Aquifer recharge area regulations establish areas determined to be critical in maintaining groundwater quantity and quality and specify requirements for development in these areas. There are two categories of aquifer recharge areas. Category I areas require a higher level of protection and include: sole source aquifer areas, wellhead protection areas and areas within a half-mile of a surface water limited stream. Category I areas are shown on Skagit County's aquifer recharge area map.
- **Fish and Wildlife Habitat Conservation Areas**—Fish and wildlife HCAs are listed in WAC 365-190-130 and include areas with which endangered, threatened, and sensitive species have a primary association, waters of the state (defined by RCW 90.48.020), and naturally occurring ponds. Any project within 200 feet of fish and wildlife HCAs requires a site assessment. Stream riparian buffers vary from 50 to 200 feet depending on the stream's WDNR water type. Lake and marine shoreline buffers vary from 100 to 200 feet depending on the shoreline designation.
- **Frequently Flooded Areas**—Frequently flooded areas are areas identified as A, AO, AH, Al-10, A12, A14, A16, A18, A21-22, V1 and V4 on FEMA Flood Insurance Rate Maps. Cumulatively these zones represent the floodway and 100-year floodplain. Development criteria and associated engineering requirements for frequently flooded areas are addressed in the flood damage prevention portion of the SCC.
- **Geologically Hazardous Areas**—Geologically hazardous areas include areas susceptible to the effects of erosion, landsliding, earthquake, or other geologic events. They pose a threat to the health and safety of citizens when incompatible residential, commercial, industrial, or infrastructure development is sited in them.

  The Critical Areas Ordinance defines landslide hazards, erosion hazard, seismic hazards and volcanic hazards in the SFSA. It requires site assessments of geologically hazardous areas by a geotechnical professional. Its mitigation standards require a drainage plan for geologically hazardous areas, prohibit directing surface water across the face of a landslide, and require that water be collected above a critical area and routed over the landslide in a tightline to a receiving water. It also prohibits the use of stormwater infiltration facilities in geologically hazardous areas or their buffers.

  The ordinance requires a geotechnical analysis as part of the drainage analysis for retention or detention facilities within 200 feet of a 40-percent or steeper slope, or for construction (including infiltration facilities) that could pose a hazard to a geologically hazardous area.

Land use activities that can impair the functions and values of critical areas or their buffers require a critical-areas review and written authorization. Authorizations required under the critical areas ordinance overlay other permit and approval requirements of the Skagit County Code.

On-Site Sewage Code

Skagit County code adopts WAC Chapter 246-272A as minimum requirements for construction and operation of on-site sewage systems. When a section of the SCC conflicts with WAC 246-272A, the more restrictive regulation applies. The Skagit County Health Officer and the Skagit County Board of Health administer county on-site sewage regulations under state authority and requirements. The Health Officer may investigate and take action to minimize public health risk in formally designated areas such as shellfish growing areas, wellhead protection areas, and frequently flooded areas. These actions can include requiring additional design and performance standards for on-site systems, requiring additional land for development, prohibiting development or requiring monitoring of groundwater. Within the South Fidalgo Study Area, Skagit County has identified Yokeko, Dewey Beach, Quiet Cove, Similk Bay and Similk Beach Community as marine recovery areas. The County code includes specific additional design and operations requirements for the Similk Bay “limited area of more intense rural development.”

IMPLEMENTATION

Skagit County critical areas and drainage ordinances are implemented through County-issued building, grading and land use permits:

- Permit applications are reviewed and issued by Skagit County Planning and Development.
- The on-site sewage ordinance is implemented through the septic permit by the Skagit County Health Department.
- Planning and Development and Skagit County Public Works conduct inspections during project construction.
- Planning and Development responds to complaints of code violations.
- Public Works responds to drainage complaints.

The following sections describe the documentation and application requirements for development that have an effect on or are directly related to stormwater.

Grading and Clearing

Excavation, filling, grading, earthwork or embankment construction requires a grading permit. Placement of fill is restricted in flood risk zones and areas of flood hazard. A grading application requires a critical areas review, a drainage plan, and if more than 500 cubic yards is being affected, a State Environmental Policy Act (SEPA) Environmental Checklist.

Residential Development

Development of single-family residences and land subdivisions require documentation submitted to the County that includes the following:

- A building permit application listing fill and excavation quantities, area of new impervious surface, and area of proposed land use change
- A critical areas review
- A drainage plan for projects creating over 1,000 square feet of new impervious surface

- A shoreline review that includes determination of the ordinary high water mark for parcels within 200 feet of a shoreline
- Standard non-stormwater related items of lot certification, water supply, septic design, site plan, construction plans, heating plan, etc.

Tree Removal and Forest Practices

Forest practices are governed under the Revised Code of Washington (RCW 76.09). The WDNR regulates tree removal activities with a Forest Practice Application (FPA). If an FPA is required and future plans include some type of development approval (such as single residence, short plat, subdivision, etc.), then Skagit County's permit requirements and a SEPA checklist must be applied as part of the FPA. Skagit County Planning and Development currently acts as lead agency for SEPA review for Forest Practice Conversion and Conversion Option Harvest plan permitting (Cooper, J., 13 August 2009, personal communication). Forest practices are subject to compliance with the provisions of Skagit County's critical areas ordinance.

According to Skagit County code and the 1992 and 2005 Ecology stormwater management manuals, forest practices regulated under Title 222 WAC are exempt from runoff control requirements, except for Class IV general forest practices, which are conversions from timber land to other uses. When forest lands are converted to other uses, there is a six-year waiting period, though a waiver is available.

Potable Water Supply—Wells

Well site approval is provided by the Skagit County Public Health Department per Skagit County Code. The applicant is responsible for notifying the health department regarding the location of all potential sources of contamination. In general, single-family homes and private roads are not considered a source of contamination for individual systems. Greater well-head protection zones may be required by the Health Department based on geologic or hydrologic data or local water quality. The code requires well sites to be protected from normal drainage and flooding and be located at least 50 feet from septic tanks and 100 feet from drainfields and road right-of-ways.

Drainage Plan

Any project that involves building construction, excavation, grading, filling, vegetation removal or other activities that create new impervious surfaces has to provide a plan for erosion and sedimentation control during construction and permanent stormwater control for post-development. Plan elements to be submitted for approval include the following:

- Methods to prevent mud or dirty water from leaving the site during construction
- Approach for stabilizing bare soils during and after grading activities to prevent erosion
- Specified drainage facilities for runoff from all impervious surfaces such as rooftops, driveways, patios or walkways of asphalt, concrete or compacted gravel.
- Grading information to show land contour changes and driveway specifics.

Runoff control has to be directed so as not to adversely affect adjacent properties, and increased runoff from land use changes has to be controlled to ensure that water quality is not impacted downstream.

Critical Areas Checklist

Project applicants must provide a completed checklist indicating whether there are any critical areas within 300 feet of a proposed project. The checklist covers the following:

- Standing surface water, including continual or periodic streams, saltwater, lakes, ponds, bogs, fens, swamps or marshes
- Identified wetlands or vegetation associated with wetlands or consistently saturated ground
- State or federal listed sensitive, threatened or endangered species or habitats
- Slopes of greater than 15 percent or other geologic hazard areas
- Flood hazard zones.

Shoreline Development

Construction permit applications must include the following:

- Ordinary high water mark and distance of the proposed development from the water
- Delineation of all wetland areas affected by the development
- General description of existing vegetation on the site
- Excavation and fill quantities, composition, source, and location
- Joint Aquatic Resources Permit Application, which documents additional specifics of the proposed development
- SEPA Environmental Checklist when applicable (generally for larger projects).

CHAPTER 4.
EXISTING CONDITIONS

Definition of the current state of the study area provides a baseline against which to compare the effects of future development. Existing conditions are described by zoning, land use, drainage conveyance infrastructure, and drainage concerns.

ZONING

Per the Skagit County Comprehensive Plan (pg 14, Skagit County 2008a):

> "…[The] plan for Fidalgo Island should include the following: provisions for maintaining the existing rural character and lifestyles of the island; an assessment of the natural and built environment such as, but not limited to: shoreline environs, geologically hazardous areas, drainage, marine and upland water quality, suitability of soils and geology for development, fish and wildlife habitat, open space areas/corridors, transportation networks, and availability and cost of public facilities and services."

The Comprehensive Plan calls for development to be managed as follows (pg 5, Skagit County 2008b):

> "Provide for a variety of residential densities and business uses that maintain rural character, respect farming and forestry, buffer natural resource lands, retain open space, minimize the demand and cost of public infrastructure improvements, provide for future Urban Growth Area expansion if needed, and allow rural property owners reasonable economic opportunities for the use of their land."

To implement this guidance, there are eight planning zones in the South Fidalgo Study Area, (see Figure 4-1). Two zoning designations—Rural Reserve (RRv) and Rural Intermediate (RI)—apply to most of the area (see Table 4-1). Land use change in the area will be predominantly development of single-family homes.

TABLE 4-1.
STUDY AREA PLANNING ZONES

Abbreviation	Land Use Designation	Area[a] (acres)
RRv	Rural Reserve	4,640
RI	Rural Intermediate	2,870
RRc-NRL	Rural Resource – Natural Resource Lands	373
OSRSI	Public Open Space of Regional/Statewide Importance	146
RMI	Rural Marine Industrial	27.2
RB	Rural Business	8.7
SSB	Small Scale Business	4.3
RC	Rural Center	0.5

a. Areas do not include parcels inside Deception Pass State Park

SCC Chapter 14.16 specifies the minimum lot size for a single-family dwelling unit, based on zoning. This size can be reduced in some instances by the use of a Conservation and Reserve Development (CaRD). A CaRD is a method of single-family residential land development characterized by building lots or envelopes that are much smaller than typical of the zone, leaving open space for agriculture, forestry, continuity of ecological functions characteristic of the property, and preservation of rural character. Residential development is permitted in RRv, RI, and RRc-NRL (Rural Resource – Natural Resource Lands):

- The purpose of the Rural Intermediate zone is to provide and protect land for residential living in a rural atmosphere, taking priority over, but not precluding, limited non-residential uses appropriate to the density and character of this designation. The minimum lot size for a single-family dwelling unit is 2.5 acres.
- The purpose of the Rural Reserve zone is to allow low-density development and to preserve the open space character of areas not designated as resource lands or as urban growth areas. Lands in this zone are transitional areas between resource lands and non-resource lands for uses that require moderate acreage and provide residential and limited employment and service opportunities for rural residents. The minimum lot size for a single-family dwelling unit is 10 acres, unless a parcel is developed as part of a CaRD; then development can occur at one dwelling unit per 5 acres.
- The purpose of the Rural Resource – Natural Resource Lands zone is to recognize and encourage the conservation of lands that have characteristics of both long-term commercially significant agriculture and forestry on-site or on adjacent sites. These are lands generally not managed as industrial resource lands, because of less productive soils, parcel size and/or geographic location, but they are managed on a smaller scale and provide support for the industrial natural resource land base. It is the intent of this district to restrict incompatible non-resource related uses and to retain a long-term, commercially significant natural resource land base. The minimum lot size for a single-family dwelling unit is 40 acres, unless a parcel is developed as part of a CaRD; then development can occur at one dwelling unit per 10 acres.

Of particular interest for this stormwater management plan are the many historically platted parcels that are smaller than current zoning would permit. These parcels are shown in Figure 4-2 and discussed in more detail in Chapter 6.

LAND USE AND COVER

In order to predict the stormwater impacts of future development, hydrologic models were developed for existing and future conditions. For these models, it was necessary to categorize the land use or land cover of the properties on the island. The hydrologic model classifies land cover as forest, pasture, lawn, open water, or impervious (rooftops, roads, parking lots). Because there are three notable quarries in the study area, a sixth category was added for them.

About half of the parcels have been developed as homes, businesses, and schools; this is shown in Figure 4-3. Each parcel was examined to estimate the type of land cover within its boundaries. The current land use was established using a combination of County GIS data, the ArcGIS Feature Extraction Extension for impervious areas, and manual aerial photo interpretation (for identification of lawn and pasture). The details are described in Appendix B; the results are shown in Figure 4-4 and summarized in Table 4-2.

TABLE 4-2.
EXISTING LAND COVER

	Forest	Pasture	Lawn	Quarry	Impervious	Open Water
Area (acres)	8,486	1,251	991	73	759	724

STORMWATER CONVEYANCE SYSTEM INVENTORY

In keeping with the rural character of the study area, most stormwater is conveyed through roadside drainage ditches or asphalt berms and routed to ravines, streams or outfalls draining to the surrounding bays. In a few locations, conveyance systems of catch basins and pipes have been installed to collect stormwater. The most significant of these is the South Burrows Bay storm drainage system constructed in 2000. Additional smaller systems exist in Gibralter Heights and North Similk Bay. There are a few privately owned detention and infiltration ponds and some detention facilities owned by the Washington State Department of Transportation (WSDOT) associated with the SR-20 upgrades; the County does not own or maintain any ponds.

A system inventory database was assembled from available data. Existing design plans were confirmed through field investigation and a “windshield” survey of roadside ditches and drainage structures. This information was supplemented by the WSDOT and Skagit County culvert databases. Locations of all observed structures were mapped in a GIS database, shown in Figure 4-5; detailed observations were predominantly made in areas with reported drainage concerns.

DRAINAGE CONCERNS

Drainage concerns reported by South Fidalgo Island residents have been collected by Skagit County for several years. There are more concerns in higher-density areas. Figure 4-6 shows the locations of all citizen reports. These concerns cover a range of issues, most due to the natural geology and topography and exacerbated by land use changes. They can be generally broken down into the following groups:

- Stormwater runoff increases due to land use changes
- Slope instability due to increased stormwater infiltrating from collection points (ponds, ditches) or increased erosion by stormwater runoff
- Water quality changes
- Maintenance of existing stormwater infrastructure
- Installation and use of private stormwater lines.

Although natural conditions, such as steep slopes or pervious soils overlying rock or less pervious soil, can be the cause of a drainage problem, development exacerbates the problems in several ways:

- Vegetation loss affects stormwater runoff because plants and trees provide a significant source of precipitation storage and uptake. With vegetation loss, rain that would have been evaporated from or absorbed by trees or plants (a process called evapotranspiration) instead falls to the ground and contributes to standing water or stormwater flows. Estimates are up to 40 percent of rainfall is evapotranspirated (Ecology, 2005).
- The amount of runoff in a watershed is directly proportional to the amount of impervious area (roofs, driveways, streets, sidewalks, etc.), which prevents rainfall from infiltrating into the

soil. As development increases the impervious area, the amount of stormwater runoff increases.

- Development can affect runoff by changing its natural flow pathways. Fill for driveways or homes often eliminates natural depressions. The flow of runoff from streets and roofs is faster than from treed and vegetated areas. The construction of artificial channels, such as storm sewers or ditches, decreases the lag time between when rain falls and when it enters the flow of a receiving stream, thus increasing the peak runoff rate in the receiving stream, scouring streambeds and ravines, and destabilizing slopes.
- Stormwater quality is affected by land use factors such as the type, age and density of development. The quality of stormwater runoff generally is degraded by changes from natural to more developed conditions. In rural areas with steep slopes, the primary contaminant in stormwater is suspended sediment eroded from slopes and streambeds. A secondary source of stormwater pollutants is road runoff, which can have petroleum products or heavy metals. In agricultural areas, fecal bacteria or high nutrient concentrations from fertilizer application can be a cause of stormwater pollution.

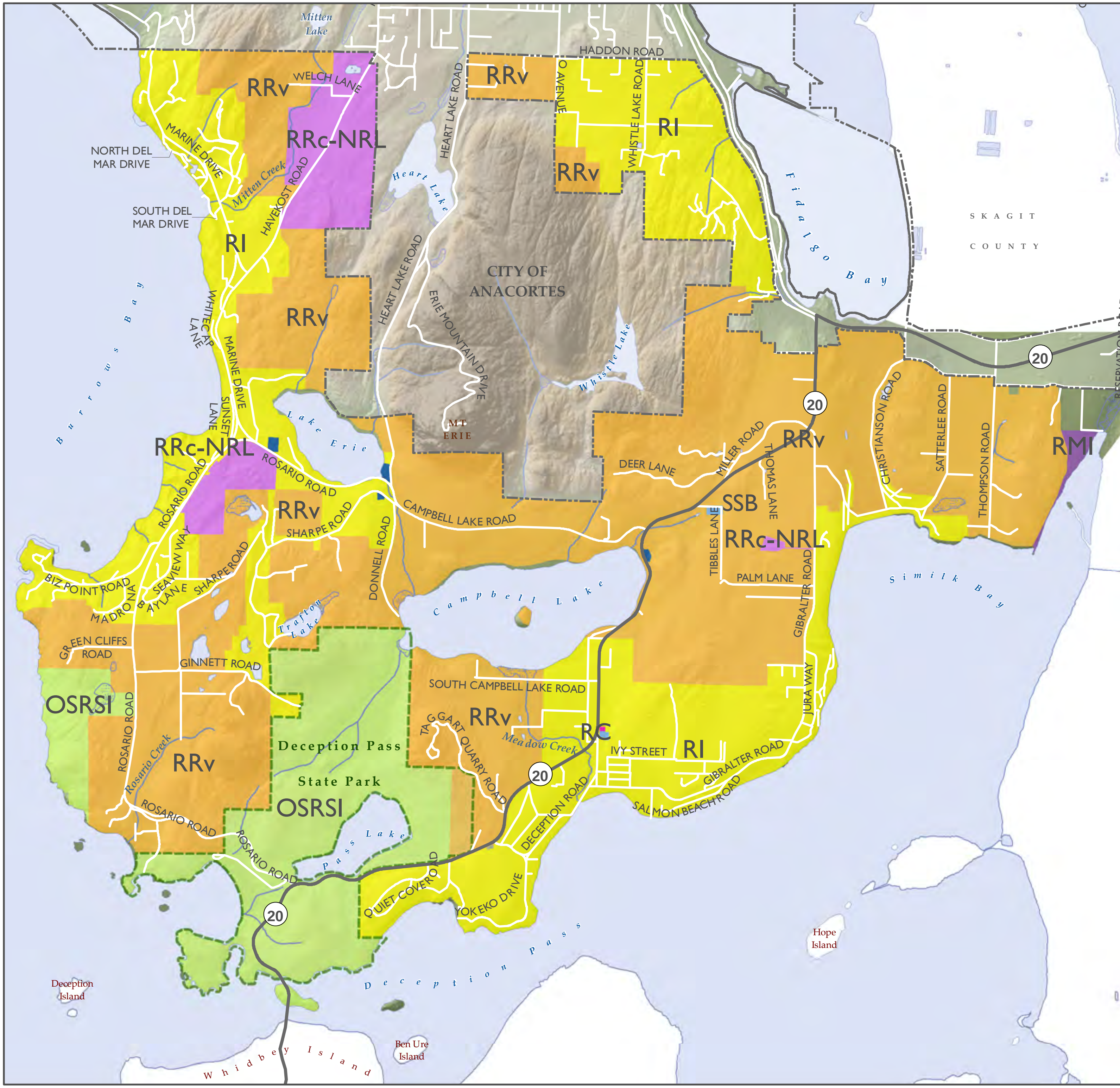
  The open ditches constituting much of the stormwater conveyance network probably provide a water quality benefit, filtering out pollutants in the gravels and grasses in the ditches. As the ditches are lined, converted to curb and gutter, or replaced with piped networks, this benefit is lost and other water quality treatment measures may have to be instituted.

Maintenance concerns and private storm drainage issues are managed by Skagit County Roads Maintenance and Code Enforcement, respectively, so these items are not addressed in this report. Concerns where surface water becoming groundwater may exacerbate geotechnical issues are discussed in Chapter 5. The remaining outstanding drainage concerns in the study area are summarized in Table 4-3.

TABLE 4-3.
CURRENT DRAINAGE CONCERNS

Area	Subbasins[a]	Problem description
North Del Mar Drive	BB02B	Water quality concerns with stormwater coming from road drainage pipe
Chiquita Lane	BB03	Ditch on Marine Drive appears to be infiltrating and contributing to groundwater excess below
Biz Point – Tingley Creek	BB16	Spring fed creek combines with roadside ditch before flowing downhill. Excess water from road runoff.
Yokeko Drive	DP05 – DP06	Ditches are inadequate or infiltrating
Similk Golf Course	SB04B – SB06	Inadequate drainage system in the neighborhood
Day Break Lane	LE02A – LE02B	Discharge from Mayer’s Dam does not have defined flow path to Lake Erie; floods properties.

a. See Figure 6-2 for subbasin locations.



SOUTH FIDALGO ISLAND

SKAGIT COUNTY WASHINGTON Serving With Pride

FIGURE 4-1

ZONING

Skagit County
Comprehensive Plan
Land Use Designation

- RI - Rural Intermediate (1 du/2.5 acres)
- RRv - Rural Reserve (1 du/5 acres CaRD, 1 du/10 acres standard)
- RMI - Rural Marine Industrial
- RC - Rural Center
- RRc-NRL - Rural Resource Natural Resource Lands (1 du/10 acres CaRD, 1 du/40 acres standard)
- SSB - Small Scale Business
- RB - Rural Business
- OSRSI - Public Open Space of Regional/Statewide Importance

N S E W

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

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SOUTH FIDALGO ISLAND

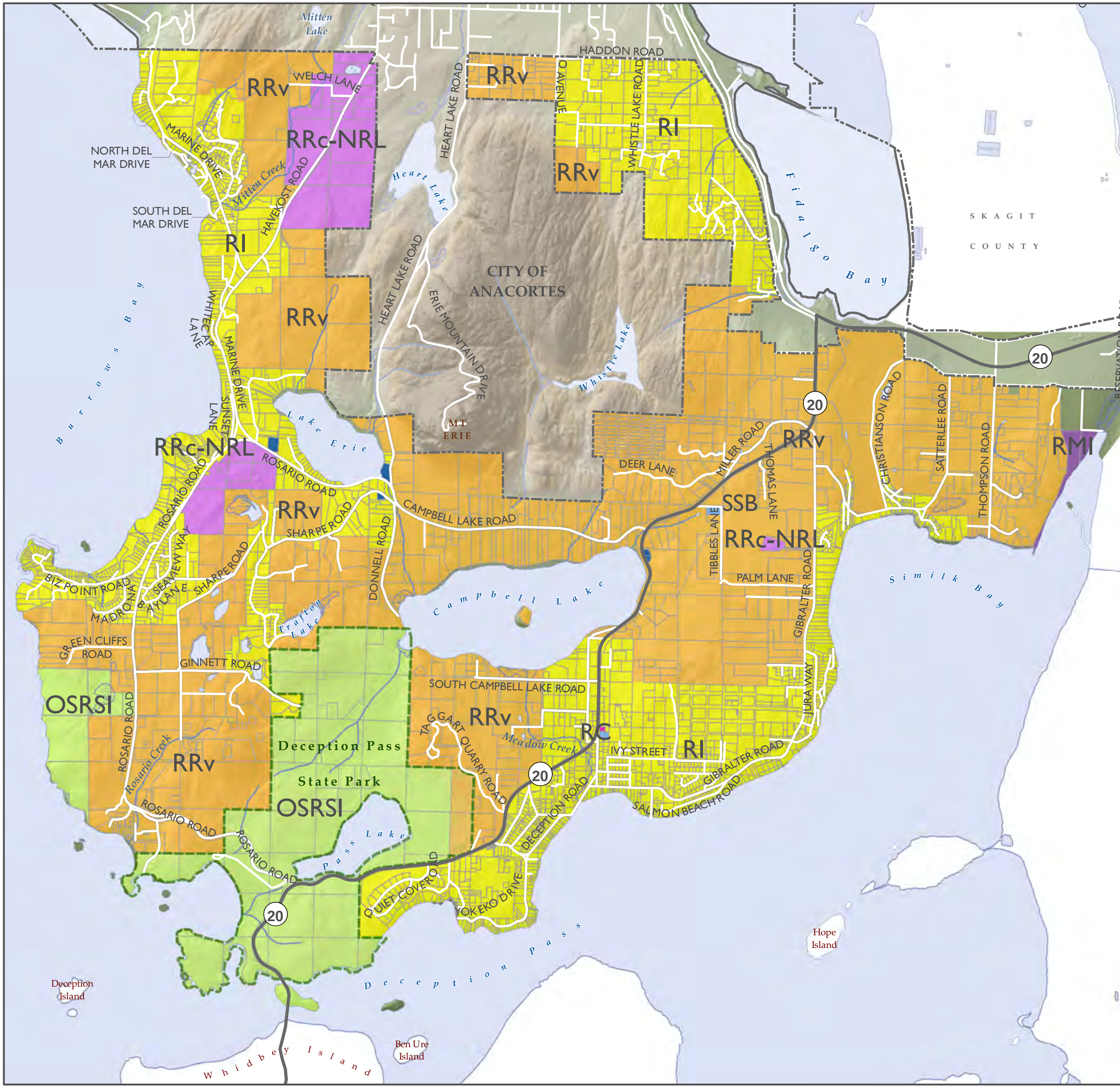


FIGURE 4-2
EXISTING PARCEL SIZES

Skagit County
Comprehensive Plan
Land Use Designation

- RI - Rural Intermediate (1 du/2.5 acres)
- RRv - Rural Reserve (1 du/5 acres CaRD, 1 du/10 acres standard)
- RMI - Rural Marine Industrial
- RC - Rural Center
- RRc-NRL - Rural Resource Natural Resource Lands (1 du/10 acres CaRD, 1 du/40 acres standard)
- SSB - Small Scale Business
- RB - Rural Business
- OSRSI - Public Open Space of Regional/Statewide Importance

N E S W

1 inch = 4,000 feet

Feet
0 1,000 2,000 3,000 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

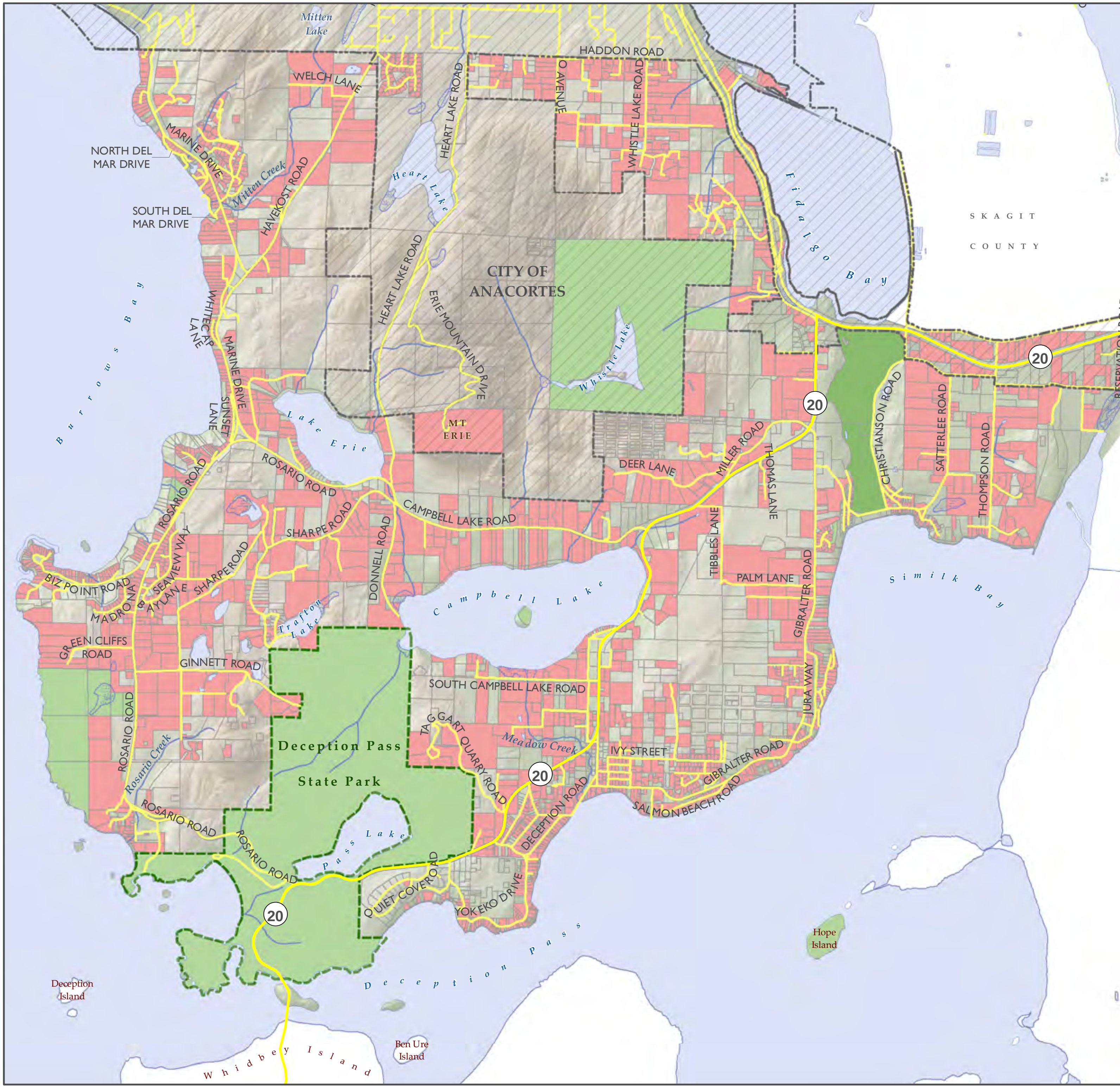
Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010

SOUTH FIDALGO ISLAND

FIGURE 4-3
EXTENT OF DEVELOPMENT

Development Extent by Building Value

- $0 - $10,000.00
- > $10,000.00
- Parks
- Similk Golf Course
- City of Anacortes



N
W E
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1 inch = 4,000 feet

Feet
0 1,000 2,000 3,000 4,000

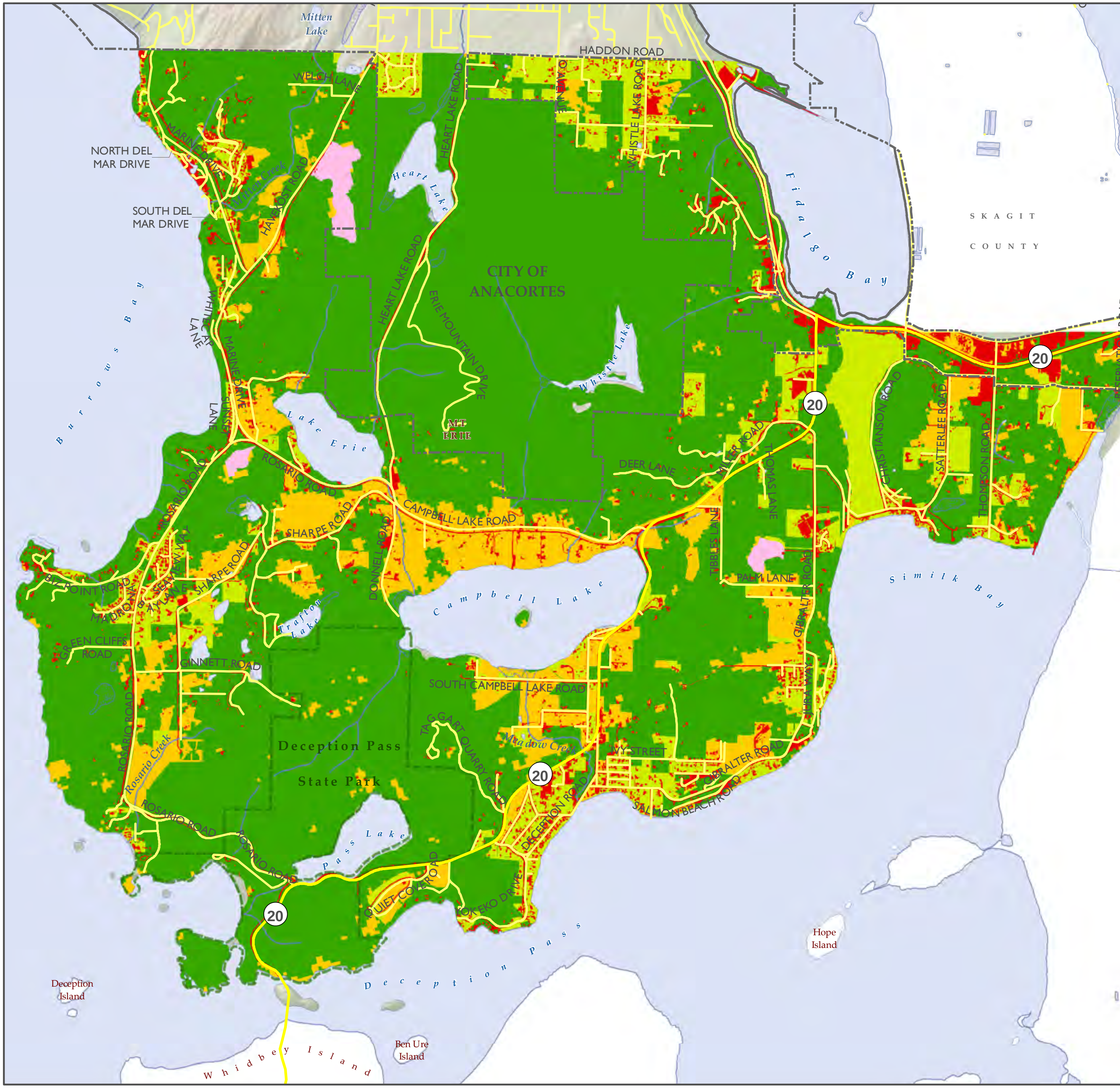
This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.

March 2010

SOUTH FIDALGO ISLAND

FIGURE 4-4
EXISTING LAND USE



- Impervious
- Forest
- Pasture
- Lawn
- Quarry
- Open Water

N
W E
S

1 inch = 4,000 feet

Feet
0 1,000 2,000 3,000 4,000

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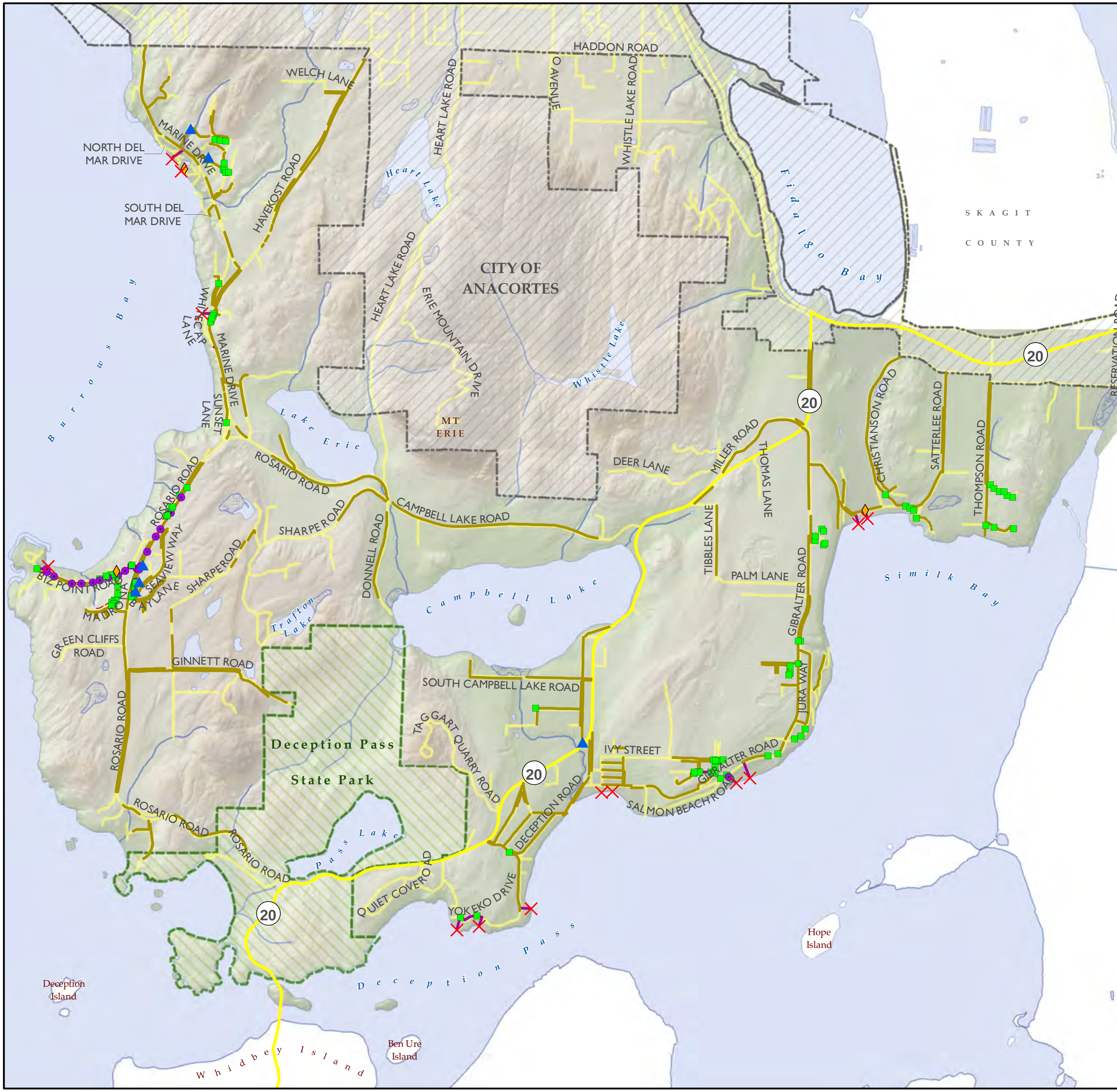
Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010



SOUTH FIDALGO ISLAND

SKAGIT COUNTY WASHINGTON — Serving With Pride

FIGURE 4-5
STORMWATER INVENTORY

Drainage Structures

- Ponds
- CBs and Inlets
- Manholes
- Outfalls
- Pump Station
- Ditches
- Berms
- Pipes

N W E S

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010

SOUTH FIDALGO ISLAND

FIGURE 4-6

DRAINAGE REPORTS

- Drainage Report Location
- City of Anacortes
- Deception Pass State Park
- Roads
- Streams
- Waterbodies
- Wet Areas

N E S W

1 inch = 4,000 feet

Feet

0 1,000 2,000 3,000 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010

CHAPTER 5.
GEOTECHNICAL ANALYSIS

Stormwater can exacerbate the risk of slope failures, especially on steep slopes such as those along the periphery of Fidalgo Island, which are unstable due to glacial soils, steep topography and groundwater pressures. Human development and land management that alter stormwater patterns can contribute to individual landslides. This chapter discusses the geotechnical (unstable slope) relationship to stormwater runoff and the specific areas in the study area where these issues may arise.

CAUSES OF SLOPE INSTABILITY

Groundwater Effect

Slope instability in the study area is the result of above-normal groundwater pressures in soil. The water may be naturally occurring groundwater, infiltrated septic drainfield water, or surface water redirected from its natural path. In all cases, water is a key component. In general, groundwater is high in the interior lake basins. On the plateaus, groundwater is commonly perched on top of the relatively impermeable till or bedrock, and seeps out in springs along creeks that drain the upland. Around the edges of the peninsula, groundwater emerges in minor seeps and from major spring complexes, particularly where glacial lake clay and bedrock underlie outwash soils. Such is the case at Dodson and Jones Canyons and Biz Point Road.

Soil Distribution and Slope

The distribution of soil has a significant impact on slope instability because of the differences in permeability in the soil units. For example, glacial outwash (advance and recessional outwash) allows rapid infiltration of precipitation and may not develop a surface drainage pattern. Glacial till, bedrock and glacial lake clay deposits are relatively impermeable and will perch water on their surfaces, and cause much more surface runoff than glacial outwash.

Reported soil failures have occurred in undisturbed glacial soils, in colluvium derived from the glacial soils, and in fill materials. There have been no citizen complaints indicating rock slope instability. Unstable slopes in the area range from about 25 to 90 degrees in inclination; most are about 30 to 45 degrees.

On-Site Sewage Facility Contribution To Groundwater

Planning level estimates of hydraulic loading from on-site sewer facilities show it to be very low compared to groundwater contribution from stormwater. A conservatively high estimate of hydraulic loading from on-site sewage facilities was developed to assess the contribution of on-site sewage to groundwater. Hydraulic loading was estimated using the following assumptions:

- 100 percent occupancy
- 4 persons/house
- 10 houses/acre
- 100 gallons/person/day.

Using these figures, hydraulic loading was calculated to be 0.01 inches/day. As a comparison, according to the 2005 Ecology stormwater manual, the 2-year 24-hour storm event depth for South Fidalgo is 1.2 inches. A conservatively low estimate of the saturated hydraulic conductivity (the approximate amount of rainfall that can be infiltrated) in the South Fidalgo Island area is 0.34 inches per day.

Still, septic systems near bluffs or steep slopes can provide a localized, concentrated water source that may trigger or reactivate a landslide.

AREAS OF CONCERN

The locations of landslides and potentially unstable areas in the study area were identified from literature review, citizen comments received at two public meetings, written citizen complaints that the County has received, and site visits conducted in 2008 and 2009. Based on these sources, slope-related concerns were identified at the locations described in the following sections. Recommendations for reducing slope instabilities resulting from stormwater impact are presented for each area of concern in Chapter 8.

Jura Way

Jura Way is located on an east-facing slope above Similk Bay. A broad, relatively level plateau dominates the ground to the west of Gibralter Road. Just to the east of Gibralter Road, the ground surface drops steeply down to the east to Jura Way. The slope then continues down to the shoreline of Similk Bay at a moderate inclination. The steep slope between Gibralter Road and Jura Way is likely the headscarp of an ancient, deep-seated landslide, the toe of which may be offshore. However, no signs were observed that indicate that this feature is active.

The geologic map indicates that the upland at Gibralter Road and to the west is underlain by glacial till. From exposures in a gravel pit on this upland, the till appears to be relatively thin and is underlain by glacial outwash. To the west of the ancient headscarp, the upper slope is underlain by recessional deposits from the last glaciation of the Puget Lowland, and the lower slope is underlain by outwash deposited during the same glaciation. Miller’s slope stability map classifies about half of the Jura Way area as Class 3, the most unstable category (Miller et al., 1985).

The surface drainage system on the upland is ditch and culvert. Water is collected along the western side of Gibralter Road and conveyed down to Similk Bay by tightline. Road drainage to the east of Gibralter Road is ditch and culvert, eventually leading to Similk Bay.

Only one written concern about this area has been recorded by the County, at the southern end of Jura Way. At that location, the property owner reportedly had not captured deck runoff and it resulted in a shallow landslide that filled the drainage ditch along Jura Way. The property owner subsequently captured this residential stormwater in a pipe and discharged it into the ditch. The landslide scar continues to erode but is slowly revegetating.

At a public meeting, a citizen reported that there was a landslide at the northern end of Jura Way in the 1970s. No sign of this landslide was observed during the field reconnaissance.

Salmon Beach and Gibralter Slide

Salmon Beach is located on a south-facing slope above Similk Bay. Carolina Street and Gibralter Drive are located on an upper ridge that slopes down moderately to the east and west and steeply down to the south. To the south of Gibralter Drive, the ground surface drops very steeply down to Gibralter Road, which is located on a narrow bench. The ground surface then continues down to Salmon Beach Road, south of which is a wide terrace. Residential housing is situated throughout most of this slope. The slope between Gibralter Road and Gibralter Drive is the headscarp of a deep-seated landslide. The toe of this feature is off-shore.

The geologic map indicates that the ridge north of the headscarp is underlain by till and the body of the landslide is underlain by recessional deposits of the last glaciations in the Puget Lowland. Older glacial deposits underlie these younger deposits. Miller's slope stability map classifies about the lower half of the Salmon Beach Road area as Class 3, the most unstable category, and the upper half as Class 2, the intermediate stability category. The Coastal Zone Atlas (Ecology, 1978) indicates that the entire feature is Unstable, except for two small areas near the beach, which are classified as Unstable Recent Slide.

The Gibralter landslide in this area was studied intensely in 1991, after reactivating in December 1990. One investigation, including six geotechnical borings, was performed in 1991 for the Skagit County Public Works Department. The study concluded that the new movement was within an ancient landslide complex and consisted of large, intact blocks of soil slowly moving toward Similk Bay. Springs were observed along or near the beach along the entire breadth of the landslide mass. Evidence indicated that movement of the landslide mass has been ongoing for thousands of years and may reactivate every 10 to 40 years. The report concluded that the overall landslide mass is marginally stable, and that the probability of renewed movement in the future in response to prolonged precipitation and offshore erosion is high.

Recommendations to reduce the recurrence interval and severity of landsliding included the installation of a new seawall, a stormwater collection system throughout the Salmon Beach area, a permanent flexible lining in the ditches along Gibralter Road and Gibralter Drive, and a system of subsurface collector drains to capture groundwater. As far as could be determined, none of these measures have been implemented.

Concerns have been reported to Skagit County about road drainage along Gibralter Road and Gibralter Drive and about stormwater management problems on individual private properties.

Biz Point Road

Biz Point Road is located on a north- and northwest-facing slope above Burrows Bay. The upper plateau, east of Rosario Road is moderately sloping down to the west to a relatively level bench on which Rosario Road is located. To the west of Rosario Road, the ground slopes moderately to steeply down to the west; Biz Point Road traverses this slope. The slope along the shoreline is a precipitous bluff that ranges from about 20 to more than 100 feet high. To the north of the intersection of Biz Point Road and Rosario Road, the bluff is higher than 200 feet.

The geologic map indicates that much of the upland to the east of Rosario Road is underlain by till. The till blankets the slope all the way down to the western end of Biz Point Road in a 1,000-foot wide corridor. Much of the terrace along Rosario Road (more than 300 to 500 feet east and west of the road) is underlain by glacial outwash; more than 100 feet thick. Older fine-grained glacial deposits underlie the sand to the west of Rosario Road. At the western end, seepage above Biz Point Road indicates that unexposed fine-grained deposits also are present there.

Springs emerge from many places on the hillsides in the Biz Point Road/Rosario Road area. Groundwater seeps out of the roadside bank along most of the western half of Madrona Drive. A significant spring emerges from the same hillside in an incised drainage to the north of the western end of Madrona Drive. This water flows as a small stream (Tingley Creek) to Biz Point Road. Seepage is also common along the eastern side of Biz Point Road between about elevations 100 and 160 feet. The slope uphill from the road shows many signs of instability in this area. Groundwater was pumped by the Del Mar Water Association in a wellfield on the north side of the road for many years, before recent deactivation of the well system;

after deactivation, water was routed into the South Burrows Bay drainage system. Small seeps proliferate along Biz Point Road, just before reaching Biz Point. Lower springs also emerge from the steep bluffs to the west of Biz Point Road. A major spring flows from the hillside at about elevation 200 feet in Jones Canyon, a deeply incised landslide bowl near the eastern end of Biz Point Road.

Miller's slope stability map classifies the shoreline bluff to the north and west of the residences as Class 3, the most unstable category, and much of the remaining hillside up to Rosario Road as Class 2, the intermediate stability category. Most of the northern part of Biz Point Road and north along Rosario Road are Class 1, the more stable category. The Coastal Zone Atlas indicates that the shoreline bluff is Unstable, except for Jones Canyon and adjacent bluffs, which are classified as Unstable Recent Slide.

In response to citizens' concerns about the effects of road drainage on slope instability in the Biz Point Road area, Skagit County implemented the South Burrows Bay Storm Drainage Improvements project in 1997. The purpose of the project was to capture surface water (particularly that associated with road runoff) and deliver it to Burrows Bay, so it would not contribute to a rise in groundwater level in the study area. The project included roadside ditches, stormwater inlets, manholes, raised curbs along some roads, an outfall pipe and structure. In addition to Biz Point Road, the project collected water from Rosario Road (as far north as 2,000 feet north of the intersection of Biz Point Road and Rosario Road), from the Seaview and Bay Lane subdivisions, and from Madrona Drive and its contributor streets.

In response to concerns by local citizens, Skagit County retrofitted the surface collection facilities along Biz Point Road in 1997. This work included the addition of inlets, road curbs, and cross culverts. This retrofit improved the system, but stormwater still bypasses the inlets on the steep-gradient portion of Biz Point Road during large storm events.

Concerns by private property owners in public meeting testimony, complaint letters and field meetings attest to continued instability on the steep, high shoreline bluff to the north and west of Biz Point Road in the past few years. A concern was also received from a property owner at the western end of Madrona Drive regarding instability in the natural ravine to the north of the road.

Dodson Canyon

Dodson Canyon is a large bowl to the west of Rosario Road. The terrace-like topography along Rosario Road forms the upper edge of this feature. The very steep slopes of the canyon are the headscarps of an active landslide area. The toe of the headscarp is about 80 feet below the surrounding bench on which Rosario Road is located.

The headscarp area of the feature consists of glacial outwash, and large springs emerge at the contact with glacial lake deposits. The springs reportedly run throughout the year.

Dodson Canyon was used as a local water source, but that facility has been abandoned in lieu of a water source from the City of Anacortes.

The headscarp of Dodson Canyon is only several feet from the western edge of Rosario Road. An extruded cement curb was installed along the western side of Rosario Road as part of the South Burrows Bay Storm Drainage Improvements project to prevent roadway water from entering Dodson Canyon. This project also included inlets on the eastern and western sides of the road to a 30-inch diameter tightline along the eastern side of the roadway. No concerns have been reported to the County concerning Dodson Canyon.

Miller's slope stability map classifies the lower part of Dodson Canyon as Class 3, the most unstable category, and the upper part as Class 2, the intermediate stability category. The Coastal Zone Atlas indicates that Dodson Canyon is Unstable.

Sunset Lane

Sunset Lane is a short street parallel to and west of Marine Drive, just north of Rosario Road. The eastern edge of this area is a high roadway embankment for Marine Drive. The two-lane Sunset Lane is located on north-sloping ground just west of the toe of the fill embankment. A row of residences is located on a narrow strip of land between the road and a 200-foot high, precipitous bluff.

Geologic maps indicate that Sunset Lane is underlain by undifferentiated glacial deposits. This means that a number of types of deposits make up the bluff. The soil is of moderately high permeability (NRCS, 2009). It is likely that surface water readily infiltrates the surface soils and then emerges on the bluff where the water encounters less permeable soil layers. Miller's slope stability map classifies the Sunset Lane area as Class 3, the most unstable category. The Coastal Zone Atlas indicates that the entire feature is Unstable, except for parts of the bluff that are classified as Unstable Recent Slides.

There was a citizen concern that stormwater from Marine Drive was directed to the west and onto the terrace on which the residences were located. The water was reportedly infiltrating there and causing slope instability to the west of the residences. In response to the public's concerns, Skagit County implemented a stormwater drainage project last year at this site. The project included the regrading of the Sunset Lane ditch and the roadside ground surface and the installation of stormwater inlets. The project captures stormwater and conveys it to a discharge into Lake Erie, preventing the stormwater from infiltrating below the surface and discharging onto the bluffs.

Whitecap Lane

Whitecap Lane is a short, gravel and dirt road parallel to Marine Drive. A high, near-vertical rock outcrop borders the eastern side of Marine Drive. A steep rock fill slopes down to the west from the western edge of Marine Drive to the eastern edge of Whitecap Lane. Residential units are located along a narrow terrace between Whitecap Lane and a steep slope that is about 100 to 150 feet high.

Geologic maps indicate that the southern end of the lane is underlain by undifferentiated glacial deposits. This means that a number of types of deposits make up the bluff. The northern end of the lane is shown to be underlain by till. Exposures in the backyards of two residences from relatively recent landslides indicated highly permeable outwash deposits. The NRCS Web Soil Survey indicates that the soil along Whitecap Lane is of moderately high permeability. It is likely that surface water readily infiltrates the surface soils and then emerges on the bluff where the water encounters less permeable soil layers. Miller's slope stability map classifies the Sunset Lane area as Class 3, the most unstable category. The Coastal Zone Atlas indicates that the entire feature is Unstable.

In the early 1990s, citizens expressed concerns that stormwater from Marine Drive was infiltrating into the rock fill along the eastern edge of the roadway and emerging along the toe of the rock fill at Whitecap Lane and in springs on the bluff to the west of the residences. This water was reportedly causing slope instability to the west of the residences. In response to the public's concerns, Skagit County implemented a stormwater drainage project at this site. The project included the installation of five stormwater inlets along the eastern ditch of Marine Drive, partial paving of the roadside ditch and installation of a stormwater outfall pipe to Burrows Bay. This system is reported by local residents to be working well.

Other residents report recent seepage from the rock fill slope and ponding of water on Whitecap Lane. This condition appears to be the result mainly of the topography along this private road. One recent landslide in the backyard of a residence appears to be caused primarily by roof runoff delivered by a drainage pipe from the residence.

South Del Mar Drive

South Del Mar Drive is a narrow, steeply graded road to the west of Marine Drive. The road is situated on a steep hillside between Marine Drive and Burrows Bay. The bench on which Marine Drive is built slopes moderately down to the west. South Del Mar Drive was constructed on a very steep slope that consists of glacial soils over the top of bedrock; however, cut slopes for the road only expose glacial till and outwash. Bedrock is exposed in a creek just north of the road alignment, and may underlie the till. The eastern approximately 400 feet of the roadway is moderately graded and appears to be underlain by outwash sand. Water seeps out of the road cut and is captured by a road ditch at about elevation 100 feet. This ditch water is directed into a deep ravine to the south of a hairpin turn in the road. The published geologic map erroneously indicates that South Del Mar Drive is underlain by beach deposits. That is only true for the portion of the road that is on the beach terrace, where it parallels the shoreline.

The middle 200 feet of roadway is a cut-and-fill section, the outside half of which is cracked and in the process of failing, as evidenced by pavement cracks and asphalt patches. The outside half is likely underlain by loose fill. The cut slope exposes outwash sand over till. A shallow landslide scar is located on this very steep slope, and no ditch is on the inside of the road. Drainage on the middle part of the roadway drains either off the southern side of the pavement down a residential driveway, or to the bottom of the hillside.

Citizen concerns have referred to the instability of the roadway. The NRCS Web Soil Survey indicates that the soil on South Del Mar Drive is of moderately high permeability. It is likely that surface water readily infiltrates the surface soils, including the outwash sand, and then emerges on the bluff where the water encounters less permeable soil layers, such as the till. Miller’s slope stability map classifies South Del Mar Drive as Class 2 for rock slopes, erroneously assuming that bedrock is exposed throughout the shoreline area. The Coastal Zone Atlas indicates that the lower part of the road is on stable ground and the upper road is of intermediate stability.

CHAPTER 6.
STORMWATER ANALYSIS

The stormwater analysis performed for this stormwater management plan used hydrologic modeling to understand current stormwater conditions and evaluate how future development may affect runoff in the study area.

HYDROLOGIC MODEL

Hydrologic models assess the physical characteristics of a basin and determine the amount of stormwater runoff that will be generated during a storm or series of storms. Typically, hydrologic models are event-based or continuous simulation:

- Event-based modeling provides a simple method for comparing runoff results under different land use conditions for statistically relevant design storms. Event-based modeling is commonly used for evaluating flood risk and peak flows in drainage systems.
- Continuous modeling allows accounts for soil moisture and infiltration and other losses over an extended period of time. Continuous simulation incorporates the full probability distribution of storms, including flood events, frequent erosive flows at levels less than the 2-year storm flow, drought and high rainfall periods, antecedent conditions and back-to-back storms. A continuous simulation model is particularly important in the Puget Sound region because high runoff is generally experienced after a series of back-to-back storms, rather than one isolated rainfall event.

The model used for this stormwater management plan was the Western Washington Hydrologic Model (WWHM), a continuous-simulation model maintained by the Department of Ecology. Stormwater runoff is simulated from pervious and impervious land surfaces, soil moisture dynamics, and hydrologic routing on a continuous basis. WWHM was selected for this project because it provides long-term rainfall records and pre-determined soil parameters for specific regions in Western Washington based on the provided land use characteristics. This makes it well-suited to assess the cumulative impact of development on stormwater runoff.

The WWHM program creates the rainfall record and regional soil parameters based on the location by county. A south-centralized location on Fidalgo Island was selected for the model. Basins were characterized by land use as a function of soil type and slope. For each basin, these data were generated for existing and future conditions by the GIS analysis; the resultant data are provided in Appendix D. The following sections describe input data used for the model.

Basin Delineation

For the stormwater analysis, South Fidalgo Island was divided into 15 watersheds, based on the significant stream, the receiving water body, or the general geographic location. These are shown in Figure 6-1. Using 2-foot topographic contours, the watersheds were further subdivided into 116 subbasins, as shown in Figure 6-2. Generally, sources and direction of expected runoff were defined based on topography.

The subbasin naming convention is sequential numbering following a two letter abbreviation for the watershed. Where a subbasin is divided by a creek or where a subbasin discharges into another subbasin rather than directly to the receiving water, the number is followed by a letter. For example, CL03A and

CLO3B are the drainage areas on either side of the creek flowing from Lake Erie to Lake Campbell. BB05B is a tributary drainage to BB05A in Burrows Bay.

Several subbasins have no defined flow pathway to a discharge location or there was a major road before the discharge location. It was assumed that stormwater in these subbasins is conveyed through un-inventoried culverts, localized overland flooding, or ephemeral stream channels.

It should be noted that few basins have actual stream discharge locations. Many of the lake subbasins show clear topographic depressions toward the lake without stream channels. Most of the coastal subbasins, with the exceptions of the canyons along Burrows Bay, are sloped straight down to the water's edge. The Fidalgo Bay subbasins all must cross SR-20 or the SR-20 Spur, but the WSDOT culvert database shows few culverts in this area; it was assumed these culverts do exist. These are not included in the table; only subbasins lacking culvert information for a main road or without a clear inter-basin transfer mechanism are listed.

Basins that are not within the formal study area (e.g., CL01 and PL01 in Deception Pass State Park and the basins surrounding Mount Erie in Anacortes) are included in the analysis to account for drainage that flows into the study area.

Several subbasins along the northern edge of the study area drain into the City of Anacortes, but a portion of the subbasin lies within the formal study area. These mostly undeveloped subbasins are modeled to provide an understanding of the amount of expected future stormwater runoff.

Future Land Use

Future land use was modeled based on the current zoning shown in Figure 4-1. Approximately half of the acreage in the study area is currently undeveloped, as shown in Figure 6-3. Most of the future development will happen through single-family infill. Some small developments will continue to occur, mostly through the CaRD process. Large, master-planned communities are unlikely because of the rural character of the study area.

Defining Full Build-Out

Typically, future land use scenarios assume a "full build-out" based on development density allowed by present zoning. However, two conditions in the South Fidalgo study area have an impact on the full build-out definition: the presence of non-developable parcels; and the number and size of parcels as currently divided. CaRD projects were not included because their use is limited and they have stricter guidelines for stormwater management, so should not cause cumulative drainage concerns.

Non-Developable Parcels

Figure 6-4 shows zoning-exempt areas within the study area. Most of these areas restrict future development, such as the protected open space area in the southwest and several conservation easements in Burrows Bay and Salmon Beach. Some areas were set as "non-developable" based on current land use (retail, school, cemetery, etc), ownership (e.g., tribal), non-residential zoning (RB, RC, etc), or critical area (wetland, stream buffer, steep slope). For this study, it was assumed that current land use will not change in the exempt zones.

Number and Size of Parcels

Figure 6-5 shows the residential-zoned parcels in the study area. The parcels are colored by zone and by size, and it can be seen that the majority of the parcels are smaller than the minimum lot size for single-family development in their zone. The color-coding also shows the potential for subdivision. If a parcel is more than twice the minimum parcel size, it could be subdivided in the future for permissible added density. These subdividable parcels are comparatively few in number.

Table 6-1 presents estimates of the number of future residential-possible parcels by zoning in the study area. The data in the table excludes zoning-exempt parcels and parcels less than 2,000 square feet in area, assumes that parcels with a building value greater than $10,000 will not be redeveloped, uses only the standard zoning densities, and ignores development limitations that may be imposed by sensitive areas.

It was assumed that parcels would develop at their existing density where they are smaller than zoning. Where parcels are larger than current zoning, it was assumed these parcels would subdivide to the minimum allowable. The following is an example of how these assumptions affect the estimates of potential new homes, for the RI zone:

- It is assumed that 621 undeveloped parcels that are smaller than the minimum size defined by the RI zone would be developed with one home each (621 new homes).
- It is assumed that 83 undeveloped parcels that are larger than the minimum size defined by the RI zone but less than twice the minimum size would be developed with one home each (83 new homes).
- It is assumed that 43 undeveloped parcels that are more than twice the minimum size defined by the RI zone would be split and developed with two new homes each (86 new homes).
- These assumptions give a total of 790 new homes.
- By comparison, at the allowed density of 1 dwelling unit per 2.5 acres over the 1,110 acres of undeveloped RI parcels, only 444 new homes would be developed.

TABLE 6-1.
POTENTIAL FUTURE RESIDENTIAL PARCELS

	RI (1 dwelling unit/2.5 acres)		RRv (1 dwelling unit /10 acres)		RRc-NRL (1 dwelling unit /40 acres)	
	#	acres	#	acres	#	acres
Total Parcels in Study Area	2,079	2,540	715	4,025	40	350
Total Undeveloped Parcels[a]	747	1,110	326	2,191	24	247
Parcels Less Than Minimum Size	621	429	262	697	24	247
Subdividable Parcels (Larger Than Twice Minimum Size)	43	416	23	896	0	0
Non-subdividable Parcels Larger Than Minimum Acreage (Smaller than Twice Minimum Size)	83	265	41	598	0	0

a. Excludes zoning-exempt parcels and parcels less than 2,000 square feet in area; assumes parcels with a building value greater than $10,000 will not be redeveloped; uses only standard zoning densities; ignores development limitations that may be imposed by sensitive areas.

Because the future buildout development is denser than the zoning would indicate, it was necessary to base the estimate of future land use on more than just the zoning densities. Thus, a “hybrid” land use model was necessary, combining both the zoning and the number and size of parcels.

Land Cover

Future land cover was estimated based on observed existing land cover on currently developed parcels in the two residentially dense zones, as shown in Table 6-2.

TABLE 6-2.
AVERAGE LAND COVER

	Average Percentage Land Cover on a Developed Parcel			
	Forest	Pasture	Lawn	Impervious
RI Zone	30%	2%	40%	28%
RRv Zone	45%	10%	34%	11%

The rules for land conversion assumed some retention of existing forest and pasture, consistent with existing developed parcels and the study area's continuing rural development patterns. Land conversion was assumed to progress to a more developed state: forest and pasture areas being converted to lawn and impervious. Full details of the future land use derivation are provided in Appendix B. Figure 6-6 shows the areas where new impervious and lawn surfaces were added for the future scenario; percentages are a function of existing land use and zoning. The higher-percentage zones indicate areas that will receive the greatest development pressure.

The parcel land coverage was summed for each drainage basin. The total future land use coverage for the study area is shown in Table 6-3; existing areas are provided for comparison. Appendix D provides the values for each drainage basin.

TABLE 6-3.
FUTURE COMPARED TO EXISTING LAND COVER

	Area (acres)					
	Forest	Pasture	Lawn	Quarry	Impervious	Open Water
Existing Land Use	8,486	1,251	991	73	759	724
Future Land Use	6,812	963	2,271	73	1,441	724

Soil and Slope Classification

The hydrologic model input includes a definition of soil type and slope for each subbasin. The 25 soil types within the SFSA (see Figure 2-1) were simplified into four groups, A-D, defined by NRCS based on soil grain size and infiltration/runoff-producing potential. This process is described in more detail in Appendix C; the results are shown in Figure 6-7. Hydrologic model input simplifies basin slopes into three classes: flat, moderate, and steep, as shown on Figure 6-8.

SIMULATION RESULTS

A hydrologic model was created for each of the 116 subbasins to help identify areas of future surface water problems. Using the built-in 50-year precipitation and evaporation records, long-term records of basin runoff were simulated; WWHM further calculated flow frequency statistics for each subbasin. Results are summarized in the following sections.

Peak Flows

The WWHM model simulated 2-, 10-, and 100-year recurrence interval events for existing and future development conditions. In general, the peak runoff associated with future development is predicted to be higher than existing peak runoff; the magnitude of the increase varies depending on change in level of development. The majority of the future runoff increase occurs in the densest zone (RI) where the greatest future development will occur. This coincides with the areas in Figure 6-3 shown as presently undeveloped. Table 6-4 summarizes the model results by local area; model results for each individual subbasin are provided in Appendix D.

TABLE 6-4.
MODEL RESULTS BY LOCAL AREA

		2-Year Peak Flow			100-Year Peak Flow		
Local Area	Subbasins[a]	Existing (cfs)	Future (cfs)	Increase	Existing (cfs)	Future (cfs)	Increase
Burrows Bay–north	BB01	0.9	1.6	64.9%	2.4	4.0	65.5%
Burrows Bay–north	BB02A - BB02C	1.8	7.0	296.8%	4.6	18.0	292.5%
Chiquita Lake	BB03 - BB04	6.8	10.5	53.5%	18.8	28.7	52.1%
Havekost Rd. & Marine Dr.	BB05A - BB05B	3.8	10.1	168.2%	15.4	32.0	108.4%
Whitecap Lane	BB06 - BB09	3.7	6.4	75.2%	9.8	17.0	72.5%
Edith Canyon	BB10A - BB10B	1.1	2.3	109.7%	4.0	7.0	74.1%
Dodson Canyon	BB11	0.2	0.5	99.8%	0.6	1.3	99.6%
West Canyon	BB12	0.3	0.4	39.1%	0.8	1.1	38.0%
Burrows Bay Cliffside	BB13	0.1	0.2	41.0%	0.3	0.4	42.2%
Jones Canyon	BB14A - BB14B	0.8	1.3	61.5%	3.9	4.9	26.4%
Beebe Canyon & Seaview	BB15A - BB15B	3.2	4.2	28.9%	9.1	11.6	27.2%
Biz Point–South Burrows Bay	BB16 - BB18	6.2	9.6	55.5%	20.7	30.4	46.9%
leading to Anacortes–west	CA01 - CA03	3.8	5.0	32.9%	10.2	13.6	32.7%
mostly in Anacortes–north	CA04A - CA04B	2.2	2.6	20.2%	6.6	7.7	15.9%
leading to Anacortes–east	CA05 - CA06	6.5	15.5	137.5%	23.7	46.6	96.3%
Mostly in Deception Pass SP	CL01	5.1	7.0	35.9%	28.7	33.6	17.2%
Lake Campbell–west	CL02A - CL02B	7.4	12.1	62.6%	27.4	39.4	43.9%
Lake Campbell–NW	CL03A - CL03B	5.2	9.1	74.4%	21.6	32.1	48.6%
Lake Campbell–north	CL04 - CL05	43.2	48.0	10.9%	119.6	133.5	11.6%
Lake Campbell–NE	CL06	5.8	9.2	58.7%	16.7	26.6	59.3%
Lake Campbell–east	CL07 - CL10	28.8	32.5	13.0%	81.4	91.6	12.5%
Lake Campbell–south	CL11 - CL12	15.3	17.4	14.1%	42.8	49.7	16.1%
Deception Road	DP01	6.9	7.6	10.1%	22.8	23.8	4.5%
Yokeko Point	DP02 - DP04	3.9	7.3	86.8%	14.2	24.0	68.6%

TABLE 6-4 (continued).
MODEL RESULTS BY LOCAL AREA

		2-Year Peak Flow			100-Year Peak Flow		
Local Area	Subbasins[a]	Existing (cfs)	Future (cfs)	Increase	Existing (cfs)	Future (cfs)	Increase
Quiet Cove	DP05 - DP06	2.4	7.6	221.0%	10.7	25.0	133.6%
Deception Pass	DP07 - DP08	1.5	1.5	0.7%	8.1	8.3	3.0%
Fidalgo Bay–north	FB01 - FB02	7.6	14.7	92.5%	20.6	39.2	90.4%
Fidalgo Bay–San Juan Hill	FB03 - FB05	9.0	21.8	142.7%	23.7	56.7	139.3%
Fidalgo Bay–Aqua Lane	FB06	1.8	3.9	113.4%	5.3	10.7	101.5%
Fidalgo Bay–southwest	FB07A - FB07B	7.4	18.8	152.9%	29.3	63.8	118.1%
Fidalgo Bay–south	FB08 - FB10	33.3	37.8	13.5%	111.2	124.8	12.3%
Heart Lake (mostly Anacortes)	HL01 - HL02	15.1	15.1	0.0%	42.4	42.4	0.0%
Sharpe Road	LE01	13.9	16.6	18.9%	40.1	47.5	18.4%
Mayer's Dam	LE02A - LE02B	4.0	6.7	68.6%	16.3	23.0	41.6%
Lake Erie–west	LE03A - LE03B	6.2	7.7	22.7%	20.2	23.6	16.6%
Lake Erie–northwest	LE04 - LE05	5.7	11.9	110.1%	16.8	33.4	99.4%
Lake Erie north–mostly Anacortes	LE06 - LE08	6.5	8.9	35.8%	20.0	26.2	31.0%
Mitten Creek	MC01A - MC02B	4.2	8.2	96.2%	17.5	27.7	57.9%
Meadow Creek	MW01 - MW03B	13.3	24.3	83.0%	43.9	74.7	70.3%
Pass Lake in Dec. Pass SP	PL01	26.3	26.7	1.7%	80.7	81.8	1.4%
Rosario Creek	RC01A - RC01E	9.0	15.3	70.2%	43.8	59.1	34.9%
Salmon Beach	SA01 - SA04	14.3	26.2	83.7%	50.8	83.0	63.3%
Similk Bay–south	SB01 - SB03	6.5	11.6	77.4%	24.0	38.1	58.8%
Similk Bay–northwest	SB04A - SB04B	8.1	11.6	43.1%	29.4	39.1	33.1%
Similk Bay–north	SB05 - SB07	14.5	22.6	55.3%	49.3	73.7	49.6%
Southwest Subbasins	SW01 - SW04	3.7	5.1	37.2%	22.9	26.2	14.6%
Bowman Bay	SW05 - SW09	4.9	7.7	57.2%	22.3	29.4	31.4%
Whistle Lake (mostly in Anacortes)	WL01 - WL02B	8.8	9.8	10.8%	24.1	26.7	10.8%

a. Subbasin locations shown on Figure 6-2

Subbasins of Interest

Subbasins of interest were identified from the modeling results based on the following criteria:

- 100-year flow increase (future over existing) greater than 50 percent
- Future 100-year flow greater than 10 cfs

- Future 2-year flow greater than 3 cfs
- Percentage impervious area increases by more than 10 percentage points.

This was done to focus the analysis on subbasins with large flows that increase considerably and subbasins with significant development. Table 6-5 lists the subbasins defined as high flow subbasins based on these rules.

TABLE 6-5.
MODEL RESULTS FOR HIGH FLOW SUBBASINS

Subbasin	2-Year Future Flow (cfs)	100-Year Flow Existing (cfs)	100-Year Flow Future (cfs)	100-Year Flow Increase	Total Basin Area (acres)	Impervious Coverage Existing	Impervious Coverage Future	Impervious Coverage Increase
BB02A	5.9	2.5	15.2	510.3%	86.1	4.2%	25.3%	21.1%
BB05A	5.3	7.2	15.9	120.0%	69.3	9.8%	28.3%	18.4%
BB17	5.1	8.2	16.3	98.6%	100.9	7.6%	18.1%	10.5%
CA06	12.2	13.4	34.2	155.3%	311.1	5.2%	15.3%	10.1%
DP02	3.6	7.3	12.0	65.0%	45.4	12.9%	27.1%	14.2%
DP05	7.6	10.7	25.0	133.6%	100.0	4.4%	24.0%	19.6%
FB04	8.6	4.9	21.8	342.4%	130.9	5.8%	25.7%	19.8%
FB07B	15.2	21.4	49.9	133.2%	320.3	6.2%	16.4%	10.1%
MW02B	4.4	6.9	13.4	92.7%	67.7	12.6%	27.5%	15.0%
MW03B	7.1	8.1	19.2	137.2%	93.2	12.5%	29.9%	17.4%
SA02	7.2	10.7	23.8	123.6%	122.9	5.1%	20.9%	15.8%
SA03	5.3	8.5	16.0	88.5%	66.1	12.8%	28.7%	15.9%
RULE:	***>3 cfs***		***>10 cfs***	***>50%***				***>10%***

Flow Duration Modeling

The 12 subbasins of interest were examined in further detail to investigate the detention requirements necessary to meet the 2005 Ecology flow-duration standard for post-development flow (that post-development flow duration not exceed pre-development values for flows ranging from 50 percent of the 2-year pre-development peak flow to 100 percent of the 50-year pre-development peak flow). Flow duration is computed by counting the number of flow values that exceed a specified flow level over the period of record analyzed. The criteria by which flow durations values are compared are:

1. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 50% and 100% of the 2-year predevelopment peak flow values (100 Percent Threshold) then the flow duration requirement has not been met.
2. If the postdevelopment flow duration values exceed any of the predevelopment flow levels between 100% of the 2-year and 100% of the 50-year predevelopment peak flow values more than 10 percent of the time (110 Percent Threshold) then the flow duration requirement has not been met.
3. If more than 50 percent of the flow duration levels exceed the 100 percent threshold then the flow duration requirement has not been met. (Ecology 2005)

In peak flow control-based standards, the stormwater facilities are designed such that the post-development runoff peak discharge rate is controlled at one or more specified recurrence intervals. A flood frequency analysis determines the probability of a flood flow being equaled or exceeded in any given year. Flow duration control-based standards differ in that they evaluate how many times flows of specified levels are equaled or exceeded. Exceedance probability for flow duration (the fraction of the total historical record that flows are exceeded) is different from the "annual exceedance probability" associated with flood frequency statistics, and there is no practical way of relating annual exceedance probability statistics to flow duration statistics (Seattle 2009).

Detention Pond Design

In WWHM, calculations are automatically made to determine the flow duration criterion upper and lower limits, based on the 50+ years of hourly runoff generated by the model. WWHM also defines 100 incremental flow levels within the 2- to 50-year peak flow range and calculates the number of hours that pre- and post-development flows exceed each of those levels.

WWHM has a feature called AutoPond to generate stormwater control facility pond designs that in most cases are optimally sized to meet the flow duration standard. AutoPond selects pond dimensions and outlet orifice diameters and heights. Once AutoPond has made an initial selection of pond and orifice sizes, the model is run to generate 40+ years of hourly runoff. The runoff is routed through the stormwater control facility and a flow duration comparison is made with the pre-development flows. If the post-development flow duration results do not meet the flow control standard, then AutoPond changes dimensions and tries again. If the post-development flow duration results pass the standard, then AutoPond tries to make the pond smaller. The optimization in the program produces the smallest pond possible to meet the flow control standard. As an example of the model output data, Table 6-6 shows these results for Subbasin BB02A.

TABLE 6-6.
FLOW DURATION EXAMPLE FOR SUBBASIN BB02A

	Existing Conditions	Future Conditions (no detention)	Future Conditions (with WWHM pond)
2-year flow (cfs)	0.914	5.65	0.32
50-year flow (cfs)	2.095	12.73	0.68
Lower bound for flow duration criteria (cfs):	0.457 (= ½ of 0.914)		
Upper bound for flow duration criterion (cfs):	2.095		

	Number of hours subbasin discharges at this rate		
Peak Flow Limit	Existing Conditions	Future Conditions (no detention)	Future Conditions (with WWHM pond)
0.457 (50% of 2-year)	637	15,155	148
1.00 *	38	7,519	31
1.50 *	5	3,679	0
2.095 (50-year)	1	1,256	0

* Note: WWHM checks 100 levels between upper and lower bound; a subset is shown for illustrative purposes

AutoPond only uses the future conditions runoff flow rate to determine how often it is exceeding the peak flow limit. The analysis sizes the pond and outlet control structure to match durations as closely as possible across the range of the upper and lower bound while minizing size. The resultant future conditions peak flow release is the outcome of this sizing.

AutoPond was run for each of the subbasins of interest listed in Table 6-5. Initial pond sizing assumed a square pond with 3:1 (H:V) side slopes, a 4-foot effective depth, and a riser height of 3 feet with a rectangular notch at the top and a circular orifice at the bottom. The pond design retains the post-development runoff on-site and discharges at rates less than the pre-development rates. Using the resultant pond bottom dimensions, the surface area was calculated to estimate the land requirements to detain the runoff from the entire, fully-developed subbasin. The pond dimensions are shown in Table 6-7.

To understand the size of the ponds relative to development in the basins, the ratio of pond surface area to total future impervious area in the built-out subbasin was calculated. Values ranged from 10 to 18 percent; the average is 12 percent. This information can be used to estimate future regional-scale detention requirements.

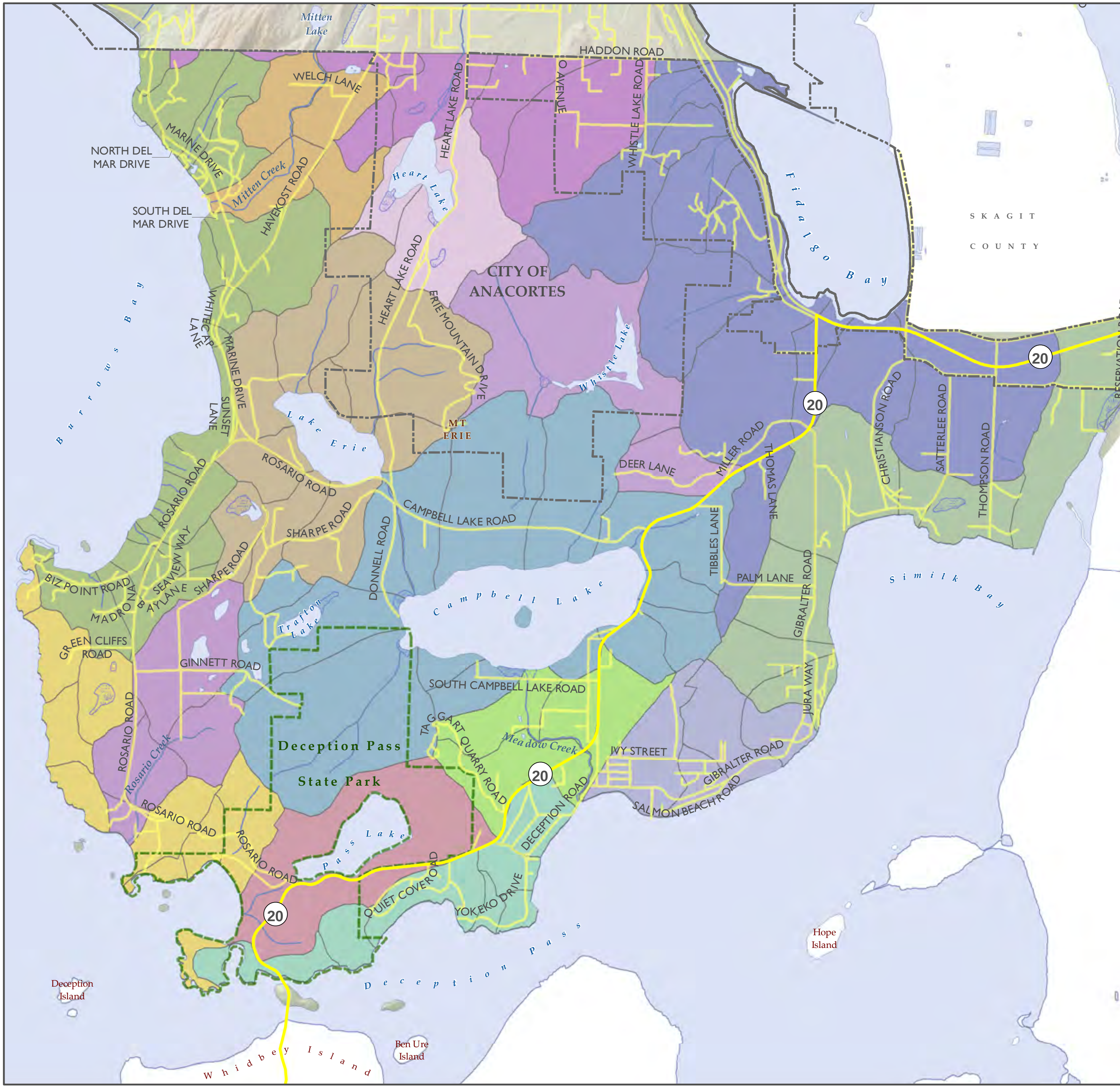
TABLE 6-7.
WWHM AUTOPOND DETENTION POND SIZING FOR FLOW DURATION CONTROL

Subbasin	Subbasin Size (acres)	Pond Bottom Dimensions Length = Width (feet)	Resulting Surface Area at Ground Level (acres)	Future Subbasin Impervious Percentage	Future Subbasin Impervious Area (acres)	Ratio of Pond Area to Impervious Area
BB02A	86.1	348.3	3.0	25.3%	21.8	13.7%
BB05A	69.3	304.1	2.3	28.3%	19.6	11.7%
BB17	100.9	323.3	2.6	18.1%	18.3	14.1%
CA06	311.1	434.3	4.6	15.3%	47.7	9.6%
DP02	45.4	230.8	1.4	27.1%	12.3	11.0%
DP05	100.0	372.2	3.4	24.0%	24.0	14.1%
FB04	130.9	385.4	3.6	25.7%	33.6	10.8%
FB07B	320.3	593.6	8.4	16.4%	52.4	16.1%
MW02B	67.7	243.9	1.5	27.5%	18.6	8.1%
MW03B	93.2	300.9	2.2	29.9%	27.9	8.1%
SA02	122.9	438.7	4.7	20.9%	25.7	18.2%
SA03	66.1	289.4	2.1	28.7%	19.0	11.0%

Stormwater detention facilities that impound more than 10 acre-feet of water are subject to the state’s dam safety requirements. If only one regional pond were constructed in each of the subbasins in Table 6-7, those with a resulting surface area of greater than 2.5 acres (i.e., BB02A, BB17, CA06, DP05, FB04, FB07B, and SA02) would be subject to these additional requirements.

SOUTH FIDALGO ISLAND

FIGURE 6-1
WATERSHEDS



- Burrows Bay (BB)
- City of Anacortes (CA)
- Campbell Lake (CL)
- Deception Pass (DP)
- Fidalgo Bay (FB)
- Heart Lake (HL)
- Lake Erie (LE)
- Mitten Creek (MC)
- Meadow Creek (MW)
- Pass Lake (PL)
- Rosario Creek (RC)
- Salmon Beach (SA)
- Similk Bay (SB)
- Southwest (SW)
- Whistle Lake (WL)

N E S W

1 inch = 4,000 feet

Feet: 0, 1,000, 2,000, 3,000, 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

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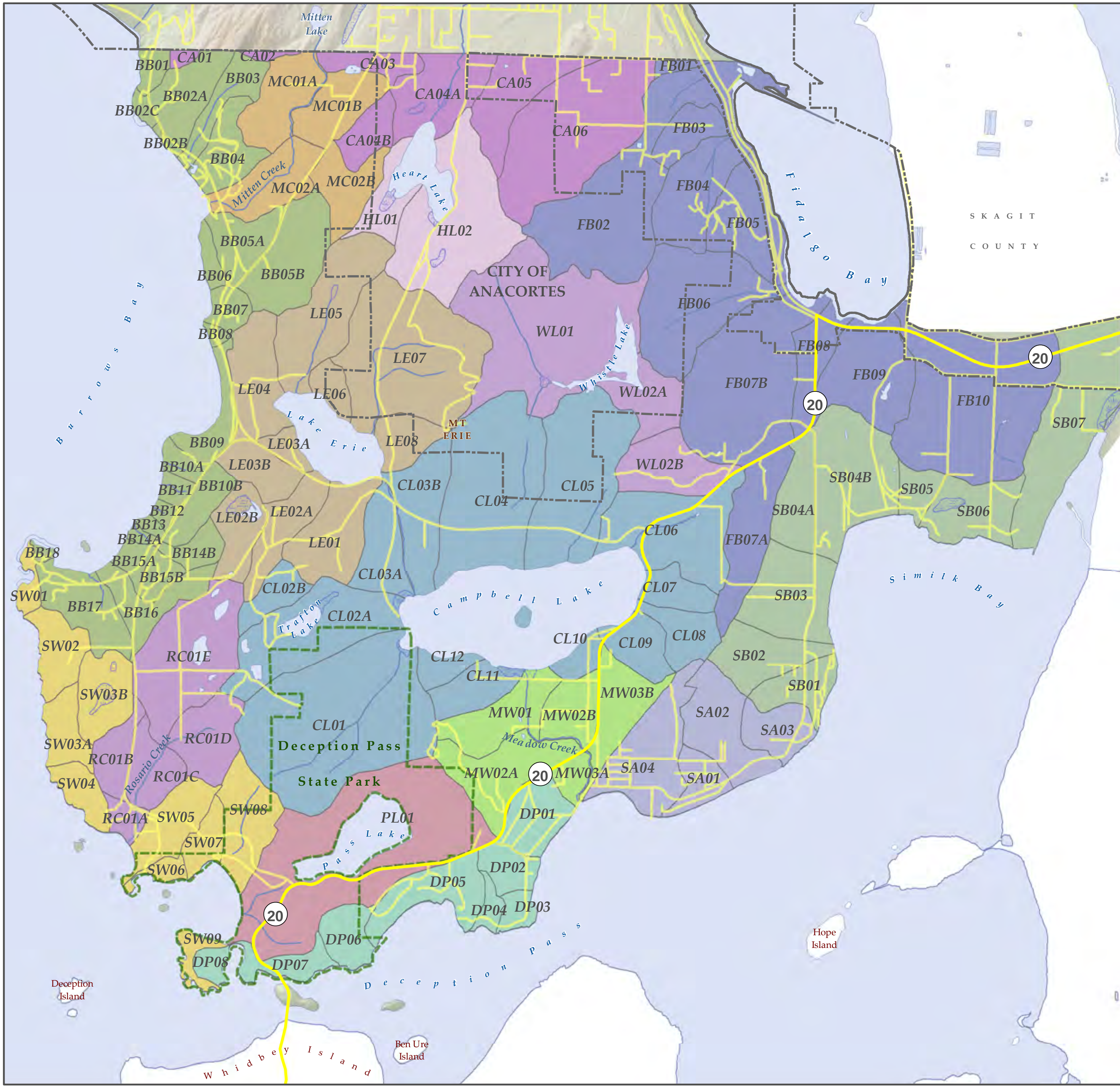
Cartography by Tetra Tech, Inc.
March 2010

SOUTH FIDALGO ISLAND

FIGURE 6-2
SUBBASINS



- Burrows Bay (BB)
- City of Anacortes (CA)
- Campbell Lake (CL)
- Deception Pass (DP)
- Fidalgo Bay (FB)
- Heart Lake (HL)
- Lake Erie (LE)
- Mitten Creek (MC)
- Meadow Creek (MW)
- Pass Lake (PL)
- Rosario Creek (RC)
- Salmon Beach (SA)
- Similk Bay (SB)
- Southwest (SW)
- Whistle Lake (WL)

N E S W

1 inch = 4,000 feet

Feet: 0, 1,000, 2,000, 3,000, 4,000

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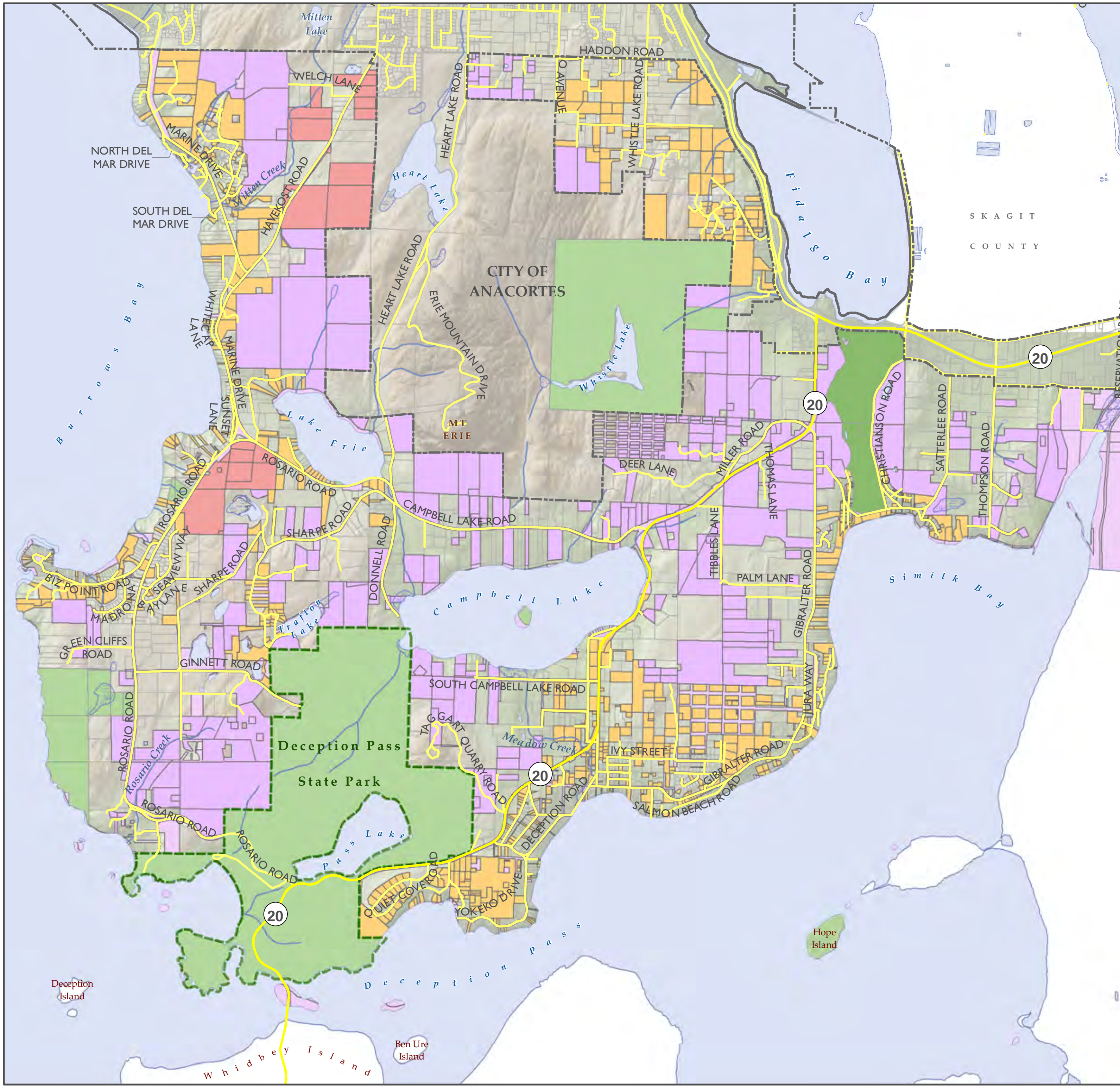
SOUTH FIDALGO ISLAND

SKAGIT COUNTY WASHINGTON Serving With Pride

FIGURE 6-3
UNDEVELOPED PARCELS



Undeveloped parcels as defined by those having a building value < $10,000

- RI
- RRc-NRL
- RRv

(Zoning exempt parcels not included in building value assessment.)

- Parks
- Similk Golf Course

N S E W

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

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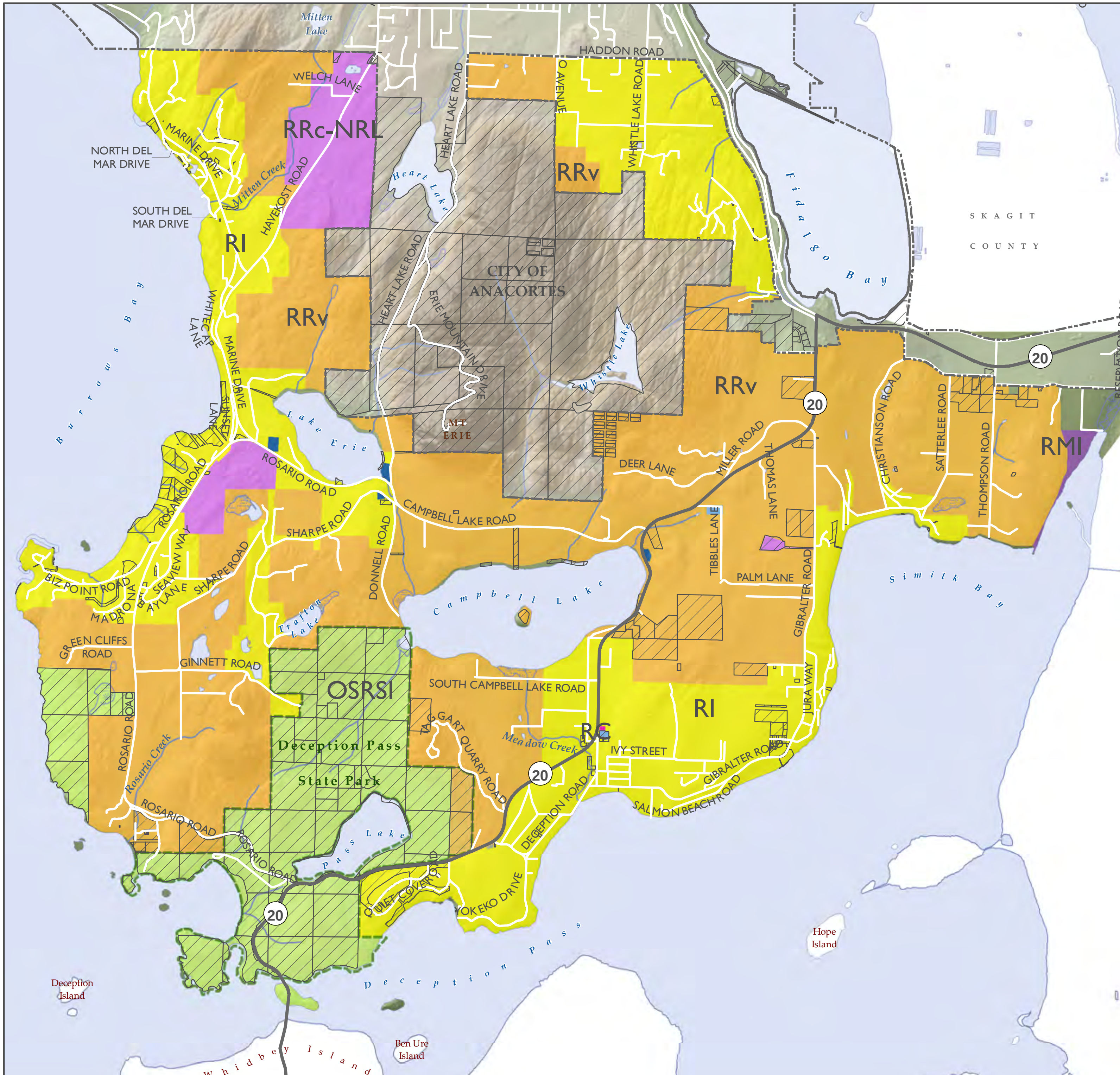

SOUTH FIDALGO ISLAND

FIGURE 6-4
ZONING EXEMPT AREAS

Skagit County
Comprehensive Plan
Land Use Designation

- Zoning Exempt Areas
- RI - Rural Intermediate (1 du/2.5 acres)
- RRv - Rural Reserve (1 du/5 acres CaRD, 1 du/10 acres standard)
- RMI - Rural Marine Industrial
- RC - Rural Center
- RRc-NRL - Rural Resource Natural Resource Lands (1 du/10 acres CaRD, 1 du/40 acres standard)
- SSB - Small Scale Business
- RB - Rural Business
- OSRSI - Public Open Space of Regional/Statewide Importance

N S W E

1 inch = 4,000 feet

Feet
0 1,000 2,000 3,000 4,000

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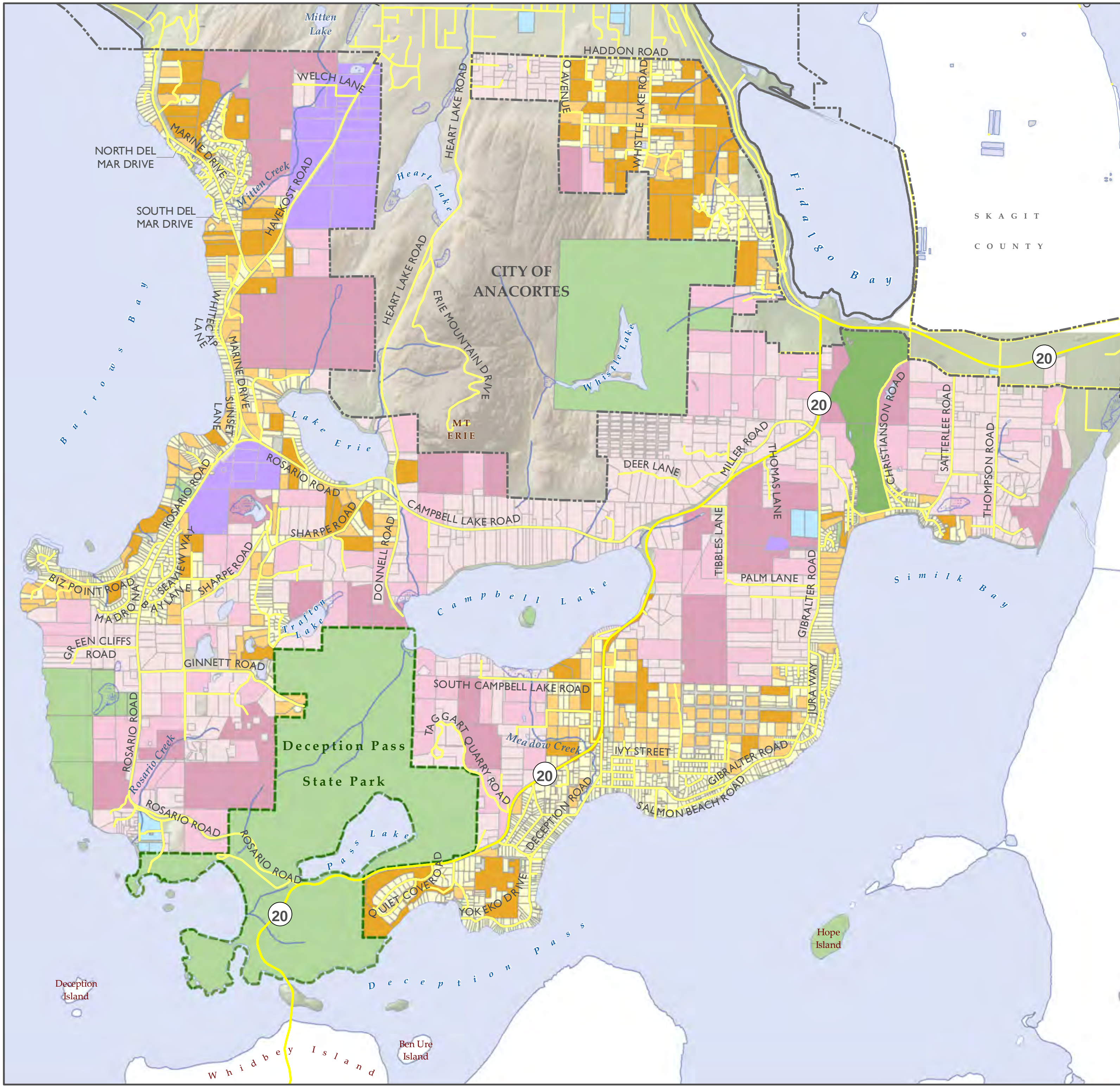

SOUTH FIDALGO ISLAND

SKAGIT COUNTY WASHINGTON

FIGURE 6-5
PARCEL SIZE BY ZONING

- Zone RI < 2.5 acres
- Zone RI 2.5 - 5 acres
- Zone RI > 5 acres
- Zone RRv < 10 acres
- Zone RRv 10 - 20 acres
- Zone RRv > 20 acres
- Zone RRc-NRL < 40 acres
- Parks
- Similk Golf Course
- Schools

N S W E

1 inch = 4,000 feet

Feet: 0 1,000 2,000 3,000 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

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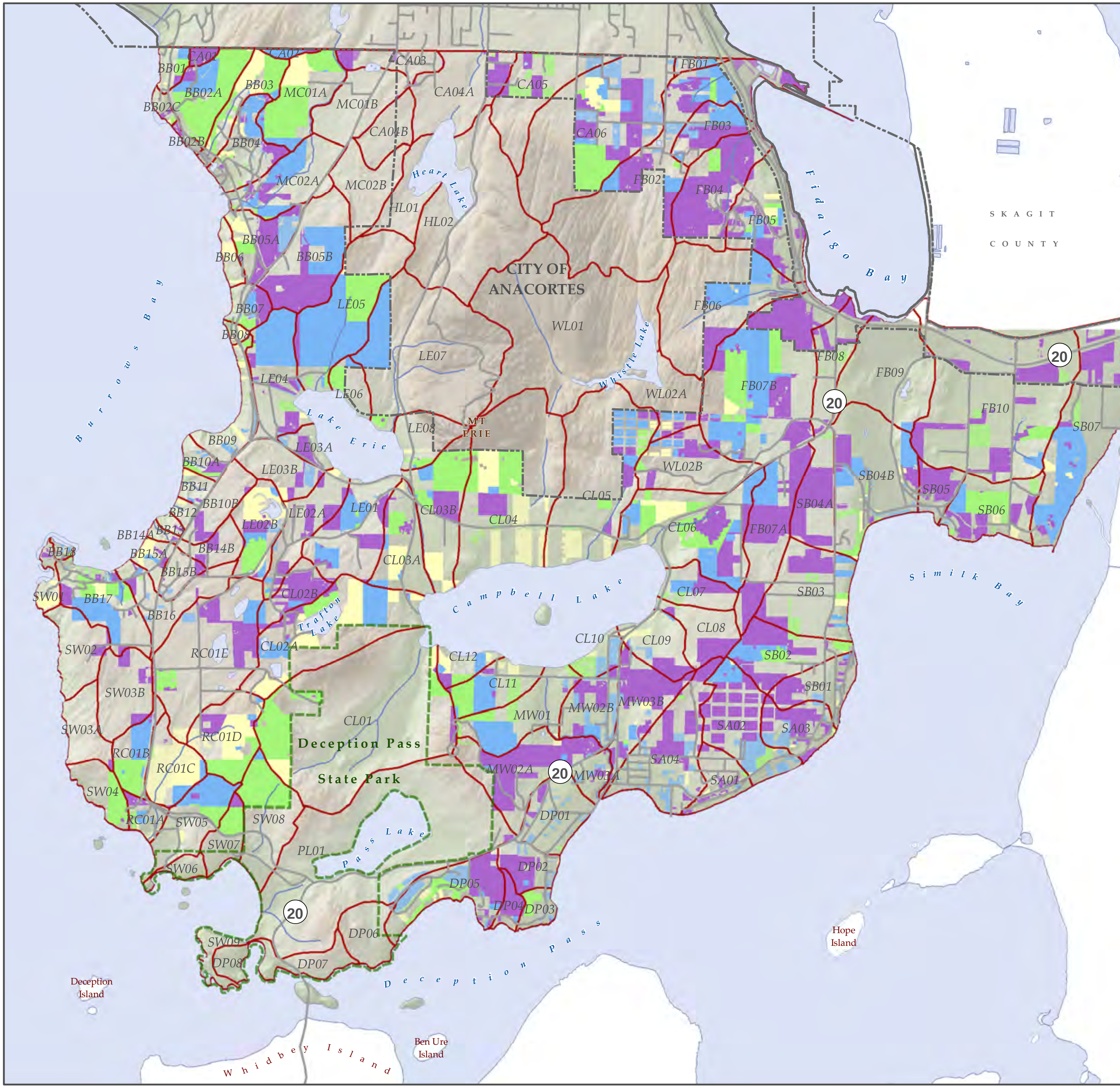
SOUTH FIDALGO ISLAND

FIGURE 6-6

FUTURE LAND USE DIFFERENT FROM EXISTING USE



Estimated Cover on Parcel (retained forest & pasture areas not shown)

- < 10% New Impervious & < ~25% New Lawn
- 11-20% New Impervious & ~25-35% New Lawn
- 21-30% New Impervious & ~30-40% New Lawn
- > 30% New Impervious & >60% New Lawn
- Roads
- Subbasins
- Streams & Lakes

N S E W

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

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March 2010

SOUTH FIDALGO ISLAND

FIGURE 6-7

A-D SOILS

Soil Type

- A
- B
- C
- D
- Subbasins

Group A is sand, loamy sand or sandy loam types of soils with high infiltration rates.

Group B is silt loam or loam soils with moderate infiltration rates.

Group C soils are sandy clay loam and have low infiltration rates.

Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. They have very low infiltration rates.

N S E W

1 inch = 4,000 feet

Feet

0 1,000 2,000 3,000 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit ". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

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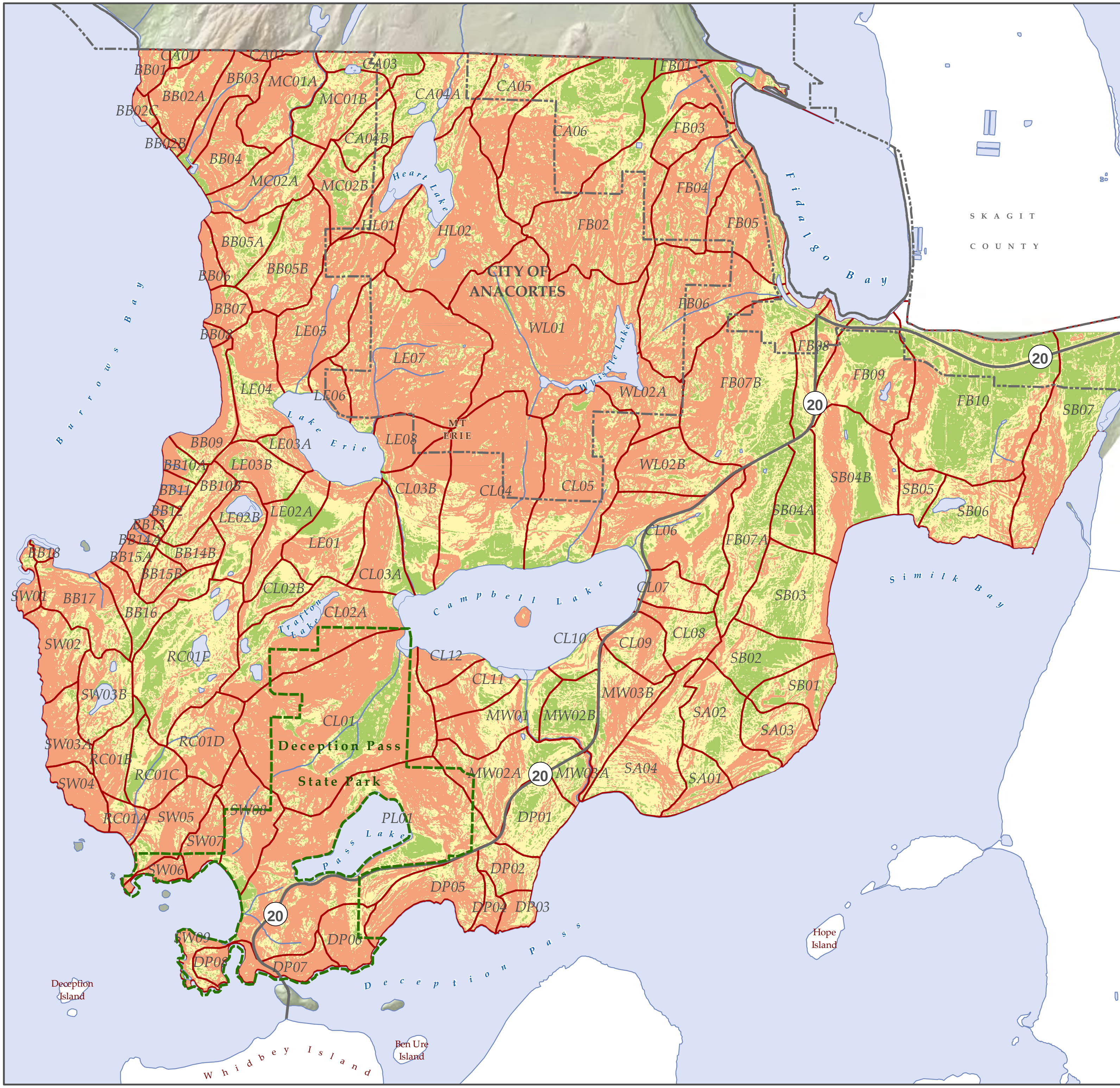
Cartography by Tetra Tech, Inc.
March 2010



SOUTH FIDALGO ISLAND

FIGURE 6-8
SLOPES BY SUBBASIN

WWHM Slope Class
- Flat (< 5%)
- Moderate (5-15%)
- Steep (> 15%)
- Subbasins

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

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Cartography by Tetra Tech, Inc.
March 2010

CHAPTER 7.
PROGRAMMATIC RECOMMENDATIONS

Fidalgo Island's combination of steep slopes and complex subsurface bedrock and glacial soils creates complicated drainage conditions, which may warrant stormwater regulations specific to the South Fidalgo Island area that account for the area's subsurface geology and groundwater movement. This chapter presents programmatic recommendations to address the special drainage problems that confront the South Fidalgo study area.

SITE DEVELOPMENT

Infiltration

In most of the study area, development practices that improve infiltration and on-site management of stormwater and preserve natural vegetation should be encouraged. However, in areas upgradient of steep slopes, infiltrating surface runoff into groundwater may contribute to landslide concerns. These areas are:

- Quiet Cove
- Yokeko Point
- Salmon Beach & South end of Gibralter Road
- North end of Gibralter Road
- Jura Lane
- East of Rosario Road (south of Marine Drive)
- East of Marine Drive
- South of Biz Point Road.

Development in these areas should discourage practices that increase infiltration, such as

- Grading that detains or slows surface flows, such as rain gardens
- Unlined stormwater infiltration ponds
- Rooftop dispersion
- Conveyance of flows in unlined surface channels such as ditches or swales
- Grading of impervious surfaces, such as sidewalks and driveways, to pervious surfaces.

Preserving natural vegetation and revegetation of slopes increases interception and evapotranspiration and should be encouraged.

Monitor Low-Impact Development Use

Low-impact development (LID) is a popular approach to decrease the stormwater impacts of new development on streams, fish and wildlife. However, most LID techniques utilize increased infiltration to reduce surface water runoff. This addition to existing groundwater in areas that are on or upgradient of landslides or potentially unstable land may be detrimental to slope stability and erosion. Where development is permitted upgradient of the recognized geologically hazardous areas, care should be taken to capture all stormwater and bypass the hazard area. This is particularly important in areas that allow on-site septic drainfields.

The following areas in the SFSA may have acceptable soils for the infiltration components prevalent in LID methods and are not upgradient from geologically hazardous areas:

- Fidalgo Bay subbasins west of SR20 (FB01 – FB07B, not to include FB07A)
- Whistle Lake subbasin within SFSA (WL02B)
- Lake Erie subbasins north of the lake (LE05 – LE07)
- Lake Campbell subbasins east of the lake (CL06 – CL09).

Many of the surface soils around Mount Erie are the Whistle-Fidalgo-Rock Outcrop complex (see Figure 2-1), which may or may not provide adequate drainage, depending on the location and permeability of the rock outcrops. This may limit infiltration-based methods in Fidalgo Bay, Whistle Lake and Lake Erie watersheds. Design of infiltration-based elements should follow current guidelines for methods and materials. An overview of LID approaches is provided in Appendix E.

PLANNING AND OPERATIONS

Obtain Drainage Easements

Skagit County should consider a program to obtain drainage easements that future development could use to discharge stormwater flows, especially in areas upgradient of landslide areas that are expected to experience heavy development and that do not currently have a stormwater outlet to a receiving water body. Areas upgradient of steep slopes are listed in the previous section; areas facing development pressure are:

- Quiet Cove
- Yokeko Point
- Salmon Beach & South end of Gibralter Road
- Southeast of Lake Campbell
- Intersection of Havekost Road and Marine Drive
- Lake Erie’s Rosario Road (east of Marine Drive)
- Eaglecrest Lane & Seaview Way
- Trafton Road and Crater Lake Road
- Intersection of Sharpe Road and Donnell Road
- Northwest corner of study area (Marine Drive and Peace Cliff Lane)
- Northeast corner of study area (south of Haddon Road, north of San Juan Hill Lane, west of SR 20 Spur)
- North of Similk Bay

Public Education and Public Involvement

Education of the public regarding the relationship between stormwater drainage and slope instability plays an important role in reducing the amount and severity of landslides. A small percentage of the public does understand this relationship and the public’s stewardship of the land with regard to this issue;

however, most do not. This is particularly important to those who live on or near landslides or potentially unstable ground.

The City of Seattle has successfully presented public landslide workshops for 11 years. Two meetings are held each year at venues close to landslide-prone areas of the city. At these meetings, geologists present the scientific and technical aspects of landsliding and the best proactive practices for property owners, engineers explain the City's landslide mitigation program, an arborist presents the relationships between vegetation and slope instability and erosion, and a planner explains City codes related to sensitive areas. A question-and-answer session completes the presentation. Residents are then free to visit booths staffed by the American Society of Civil Engineers, the Association of Engineering Geologists, the American Society of Arborists, the Associated Building Contractors, and members of the City of Seattle departments responsible for building permits, road maintenance and utilities. The meetings are well publicized in local media and held on Saturday mornings so the public is able to attend.

Seattle's program has been credited with having a significant effect on the reduction of landslides. In concert with the City's in-house landslide mitigation program, landsliding has been much reduced over previous years. A similar program could be implemented for the residents of southern Fidalgo Island on an annual basis in November or December, before the landslide season.

Steep Slope Management

Homeowners and the County can take several actions to reduce the impact of human encroachment on steep slopes:

- Do not dump grass clippings or other debris on slopes; this can add weight to the bank crest, smother stabilizing vegetation, and strip soil from the slope downhill if the crest fails.
- Connect all roof and clean-water foundation drains to a "tight-line" pipe directly to a beach, a stream, or a roadside drainage ditch; provide appropriate energy dissipation at the tight-line's point of discharge.
- Prevent standing water from ponding on top of banks.
- Revegetate small erosion sites on steep slopes.
- Prevent concentrations of water flowing over-bank to avoid causing erosion.
- Locate septic tanks away from hill slopes.
- Minimize lawn watering in order to avoid saturating subsurface materials.
- Deactivate irrigation systems once vegetation is established on or next to steep slopes.

Drainage System Inventory

An initial inventory of drainage system infrastructure in the South Fidalgo Island area has been created. Skagit County should continue to build on this database by creating a complete stormwater outfall inventory, collecting design and as-built drawings for all drainage projects as they are proposed and constructed by private developers or Public Works, and updating the database with additions and corrections.

Drainage Infrastructure Maintenance

Inspection, maintenance and cleaning of flow control facilities such as detention ponds and infiltration facilities will improve system performance and reduce erosion. Flow control facilities should be inspected on an annual basis. Debris and vegetation should be removed when it interferes with facility operation. Accumulated sediment should be removed when it exceeds 10 percent of the designed pond depth.

Inspection, cleaning and maintenance of catch basins and ditches can reduce flooding and erosion and improve downstream water quality. Ditches and catch basins may be inspected on a less than annual basis depending on prior inspection findings. Debris and vegetation should be removed when it interferes with stormwater collection or conveyance. Sediment should be removed from catch basins when it exceeds 60 percent of sump depth. Street waste solids and liquids should be disposed of properly.

New infrastructure should be inspected every six months until a less frequent inspection and cleaning schedule can be determined. More detailed maintenance procedures are found in the Ecology Stormwater Management Manual.

Water Quality Treatment

The 1992 Ecology manual requires water quality treatment for projects that develop or redevelop more than 5,000 square feet of impervious surface or disturb more than one acre of land and discharge to surface water systems. Water quality treatment alternatives include bioswales, vegetated filter strips, wet ponds and infiltration devices. Bioswales and filter strips are perhaps most applicable to new roads in South Fidalgo. These devices are effective at pollutant removal, can be used for stormwater treatment and conveyance and have low maintenance and construction costs. In areas where contribution of surface runoff to groundwater should be limited, both of these devices may need to be constructed with impermeable clay or a compacted till layer to reduce infiltration.

The 2005 Ecology manual requires water quality treatment for a greater range of projects:

- Adding 5,000 square feet of impervious surface
- Converting 3/4 acre of native vegetation to lawn or landscaping
- Converting 2.5 acres of native vegetation to pasture

In the 1992 manual, stormwater management exemptions were granted to forest practices (except conversions to other uses) and commercial agriculture. In 2005, this was modified to add road maintenance as an exempt practice and make impervious surface construction on commercial agriculture parcels subject to the same requirements as any development (non-exempt).

Water quality treatment alternatives in the 2005 manual are much the same as in the 1992 manual with the addition of new approaches (e.g., improved dispersion methods, pervious pavement, oil-water separators, and emerging technologies) and requirements for pretreatment in some situations.

Additionally, the 2005 manual updates the method of sizing stormwater facilities to use the Western Washington Hydrology Model (WWHM) demonstrated in Chapter 6. WWHM sizing will result in larger facilities than earlier design methods using single event models.

CHAPTER 8.
PROJECT RECOMMENDATIONS

Solutions to drainage problems usually require a mix of non-structural and structural approaches. Non-structural methods, in the form of programmatic recommendations, are presented in Chapter 7. This chapter provides an overview of conceptual structural solutions to surface water problems, a description of project cost components, and recommendations for specific drainage concern areas. Also included is a description of a regional pond that could be used in the future to address the impacts of new development.

OVERVIEW OF POTENTIAL SOLUTIONS

Conveyance System Improvements

A conveyance system is made up of large and small channels, culverts, and storm drain pipelines. Improvements include activities such as building overflow channels, increasing capacity, or increasing system efficiency.

New or replacement culverts in roadside ditches at road crossings can increase flow capacity and reduce the potential for upstream flooding. Stormwater backs up when culverts are too small to convey the flow. Increasing the size or number of culverts reduces the possibility of upstream damage and road failure. Potential negative effects of increasing conveyance capacity include the risks of erosion in a new location or additional downstream flooding caused by the loss of the storage upstream of the affected culvert.

Underground storm drain lines are commonly installed to convey stormwater runoff from urban development to a receiving body such as a lake or stream. Small pipes are inexpensive to install, but may result in frequent flooding. This can be alleviated by installing pipelines of adequate size to convey larger flows. Storm drains work only where there is adequate gradient to maintain flow rates and keep the pipe from filling with sediment. Typically, these lines are installed in road rights-of-way, so there is little land acquisition cost, although some temporary easements may be required. Installation of new pipelines in developed areas is always more expensive and disruptive than the installation of pipelines in an undeveloped area.

Where roadside ditches contribute to groundwater concerns, paving or lining them is a cost effective way to reduce infiltration, rather than replacing them with catch basins and pipelines. Because the vegetation in the ditches in Skagit County provides a basic level of water quality treatment, it is desirable to maintain this simple system. This can be done using a lined bioswale, in which organic material and plants (generally grasses) are placed on top of a liner (geotextile or thick plastic film). The lining must be keyed into the top of the side slopes periodically along its length. This solution is not suitable for steeply sloped ditches, in which high water velocities will scour the plant materials. In these situations, an asphalt-paved ditch will need to be used.

Steep Slope Pipelines

On steep erosive slopes, high-density polyethylene (HDPE) pipes should be used to convey stormwater to the bottom of the slope in place of an open channel. These pipes can efficiently convey large quantities of water on much steeper slopes than can concrete or metal pipes. They also can be fuse-welded into one continuous pipeline and can be installed on top of the ground, thereby avoiding the need to disturb the site. HDPE is a strong, long-lasting material that requires little maintenance and resists damage from vandalism or natural causes. Installation of these pipes is expensive, but it can be cheaper than other structural solutions to prevent stormwater erosion on steep slopes. A control structure is needed at the upstream end of the pipe to fix the pipe in place and to back the water up to a sufficient depth to allow the design flow to enter the pipe. At the downstream end of the pipe, an energy dissipater is needed to prevent erosion and to stabilize the end point of the pipe. Normally, several anchors are installed along the length of the pipe to maintain its alignment and prevent it from flexing uncontrollably.

Detention Facilities

The temporary storage of stormwater in detention facilities can reduce peak flow rates, flooding extent and downstream erosion; change the timing of flood peaks; and provide for water quality treatment by deposition of sediment. Detention facilities are constructed for any one or a combination of these reasons.

Providing detention upstream of an inadequate conveyance system and reducing the peak flow rate can eliminate the need for upgrading the conveyance system. If the land is available, this is frequently less expensive than installing new pipes and is preferred due to its multiple benefits. Detention basins can also be used to mitigate stormwater runoff downstream of development, reducing peak flows before discharge to a creek or over a steep slope.

Detention facilities can be constructed in the stream channel or outside the riparian corridor (off-channel). Both options can be effective. Although in-stream sites are attractive because they make use of existing flooded lands, disadvantages include requirements for fish passage, potential disturbance of habitat, and complex permitting for construction and maintenance. Off-channel sites offer greater flexibility in siting, but may require a great deal of excavation to create an effective storage volume.

Detention facilities require an outlet flow control structure, an emergency spillway, possibly excavation to increase storage volume, revegetation of the site once construction is complete, and frequently a dike or dam to contain water within the facility.

Detention ponds must be maintained in order to function effectively. Otherwise, the pond will become choked with vegetation, storage volume will be reduced, and the outlet control structure will become plugged. The pond can then overflow, resulting in flooding and other drainage problems downstream (such as erosion). Vegetation should be trimmed and removed as required, typically every other year. The outlet control structure should be inspected and repaired annually. All public facilities should be located and referenced on a map and a maintenance log maintained.

COST ESTIMATING APPROACH

Cost estimates for the recommended projects account for the following standard elements. Where additional study is advised in the recommended project, its cost is not included in the cost used to calculate construction add-ons. For example, if a project has both study and construction in it, the dewatering cost is calculated only on the construction subtotal.

- Unit Costs—Unit costs are based on the 2009 WSDOT bid items list. These prices are quantity sensitive. They are appropriate for common projects without unusual conditions. They are adjusted if a project requires special consideration.
- Dewatering—This element pertains to removal of groundwater or surface water necessary to properly construct the project. A typical value is 5 percent of the construction cost.
- Erosion and Sedimentation Control—This element represents erosion prevention measures required during project construction. These may include such items as silt fencing, catch basin inlet protection, and spreading straw over disturbed soils during idle construction periods. A typical value is 10 percent of the construction cost.

- Traffic Control—This element reflects the cost of signage, flagging, and detours for construction within the right of way, if necessary. Costs are higher for larger arterials and lower for neighborhood streets. A typical value is 5 percent of the construction cost.
- Contingency—The contingency assigned to each project is 30 percent. This relatively high value is used since there are considerable uncertainties associated with the identified projects. These uncertainties include the lack of detailed site topography, design constraints, potential utility interference, alignment and easement requirements, unanticipated subsurface conditions, and ancillary drainage components (such as inlets) that may require replacement.
- Mobilization—This element represents the cost of the contractor gathering and transporting equipment to the construction site and removing the equipment when the project is completed. A value of 10 percent of the construction cost is used.
- Sales Tax—The County is required to pay state sales tax on drainage construction improvements. The rate of 8.2 percent for Skagit County is applied to the construction cost in the estimate.
- Engineering/Legal/Administration—The cost to design the improvement and County legal and administration costs are assigned using the following sliding scale:
  - Construction cost of $0 to $10,000, use 100 percent of the construction cost
  - Construction cost of $10,001 to $50,000, use 85 percent of the construction cost
  - Construction cost of $50,001 to $100,000, use 50 percent of the construction cost
  - Construction cost of $100,001 to $250,000, use 35 percent of the construction cost
  - Construction cost greater than $250,000, use 25 percent of the construction cost.
- Construction Management—This cost is assigned 20 percent of the construction cost and covers the cost of County or engineering consultant staff to monitor and document the construction to ensure that it is built to the project plans and specifications.
- Permitting—Permitting costs are assigned using the following sliding scale:
  - Construction cost of $0 to $50,000, use 20 percent of the construction cost
  - Construction cost of $50,001 to $250,000, use 10 percent of the construction cost
  - Construction cost greater than $250,000, use 5 percent of the construction cost.

RECOMMENDED PROJECTS TO ADDRESS CURRENT CONCERNS

This section describes projects that have been developed to address the concerns identified in Chapters 4 and 5. Projects were not developed for all of the areas of concern because some were determined not to require any action at this time. Table 8-1 summarizes all the areas of concern and the proposed actions to address them, if any. Descriptions of recommended projects follow.

TABLE 8-1.
DISPOSITION OF IDENTIFIED AREAS OF CONCERN

Areas of Concern	Disposition
Previously Addressed	
Dodson Canyon	South Burrows Bay Storm Drainage Improvements
Jura Way	Previously reported problem addressed by property owner
Sunset Lane	County storm drainage project; regrading ditch and installing stormwater inlets
Whitecap Lane	County storm drainage project; partial paving of ditch, installing stormwater inlets, new outfall to Burrows Bay
Addressed by Recommendations in This Plan	
Chiquita Lane	North Del Mar Drive/Chiquita Lane Recommendation
North Del Mar Drive	North Del Mar Drive/Chiquita Lane Recommendation
Biz Point–Tingley Creek	Biz Point–Tingley Creek Recommendation
Yokeko Drive	Yokeko Drive Recommendation
Similk Golf Course	Similk Golf Course Recommendation
Day Break Lane	Day Break Lane Recommendation
Salmon Beach	Salmon Beach Recommendation
Biz Point Road	Biz Point Road Recommendation
South Del Mar Drive	South Del Mar Drive Recommendation

Note that maps in this chapter were created from existing maps and other available public records. Discrepancies between sources may be reflected as alignment errors in some figures.

North Del Mar Drive/Chiquita Lane Recommendation

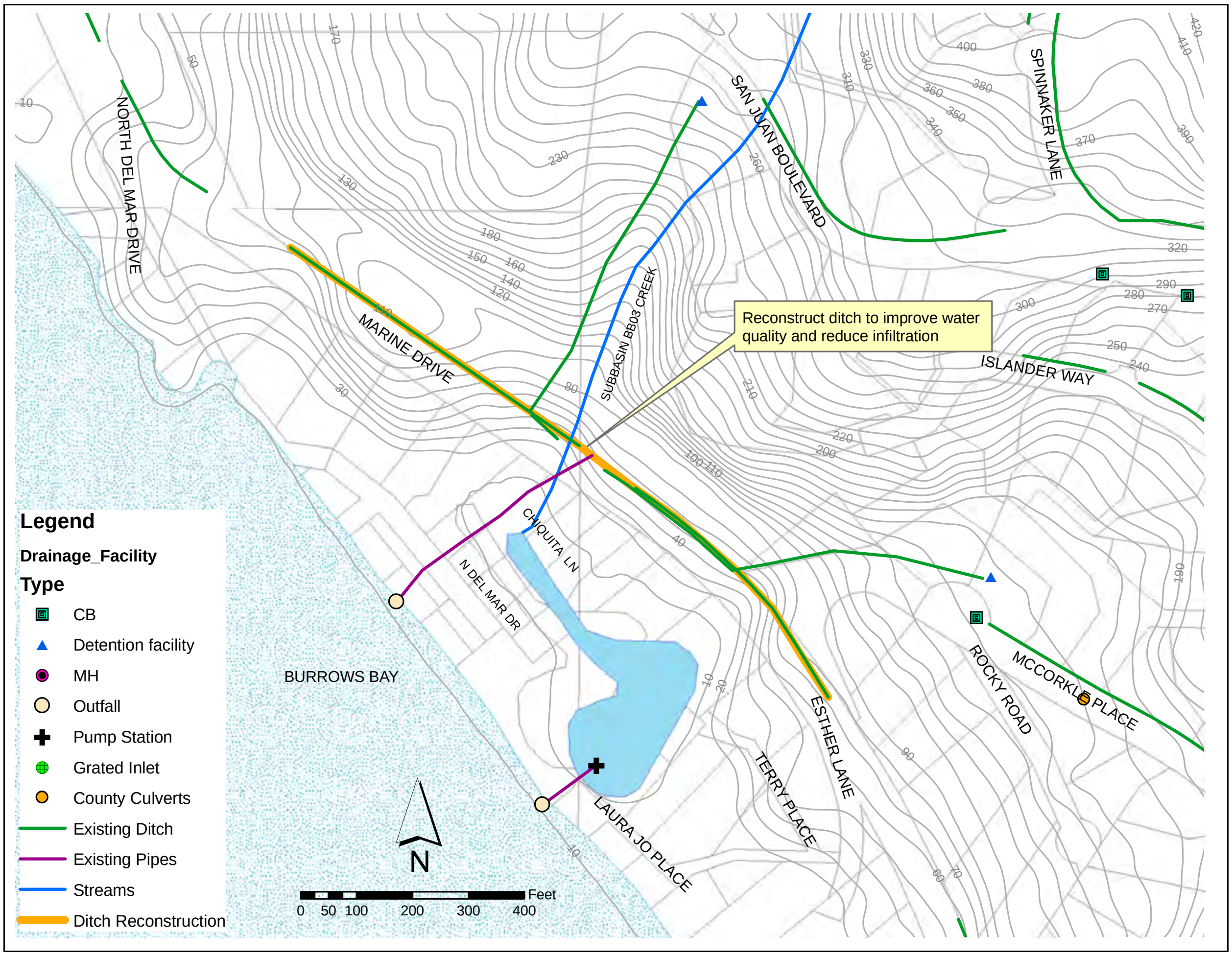


Figure 8-1. North Del Mar Drive and Chiquita Lane Problem and Recommendation Location Map

Problem Description

Groundwater levels appear to lead to flooding and structural problems at properties along Chiquita Lane. Increased groundwater may be due to local drainage or to infiltration from runoff in roadside ditches adjacent to Marine Drive. Concerns about runoff water quality may indicate that existing roadside ditches do not provide adequate water quality treatment.

The drainage inventory of the area shows one piped outfall from Marine Drive. The stream flows to Chiquita Lake, which has a pump station discharge to Burrows Bay. Road runoff from Marine Drive does not enter the stream; stream flow from the creek in Subbasin BB03 does not intersect the road or existing pipe.

Recommendation

The recommended solution includes the following:

- Conduct an inventory of drainage structures to identify the location of culverts, ditches, pipes and outfalls in the North Del Mar area.
- Assess how local drainage along Chiquita Drive may lead to increased groundwater levels.

- Reconstruct roadside ditches along Marine Drive to improve water quality treatment and decrease infiltration.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT:	**North Del Mar Drive / Chiquita Lane**		**BY:**	**smf**
DESCRIPTION:	**Groundwater and Water Quality Improvements**		**CHECKED BY:**	
BASIN/SUBBASIN:	**Burrows Bay - BB03 & BB04**		**DATE:**	**10-Mar-10**

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
ADDITIONAL STUDY				
DETAILED DRAINAGE INFRASTRUCTURE INVENTORY	1	EA	$ 5,000.00	$ 5,000
LOCAL DRAINAGE REVIEW	1	EA	$ 4,000.00	$ 4,000
			Study Subtotal	$ 9,000
CONSTRUCTION				
RECONSTRUCT ROADSIDE DITCHES	1,300	LF	$ 25.00	$ 32,500
			Construction Subtotal	$ 32,500
DEWATERING	5%			$ 1,625
EROSION & SEDIMENTATION CONTROL	10%			$ 3,250
TRAFFIC CONTROL	5%			$ 1,625
CONTINGENCY	30%			$ 9,750
			Subtotal	$ 48,750
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 4,875
			Project Subtotal (Rounded)	$ 63,000
STATE SALES TAX	8.2%			$ 5,166
ENGINEERING/LEGAL/ADMIN	50%			$ 31,500
CONSTRUCTION MANAGEMENT	20%			$ 12,600
PERMITTING	10%			$ 6,300
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$ 119,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

Biz Point Road–Tingley Creek Recommendation

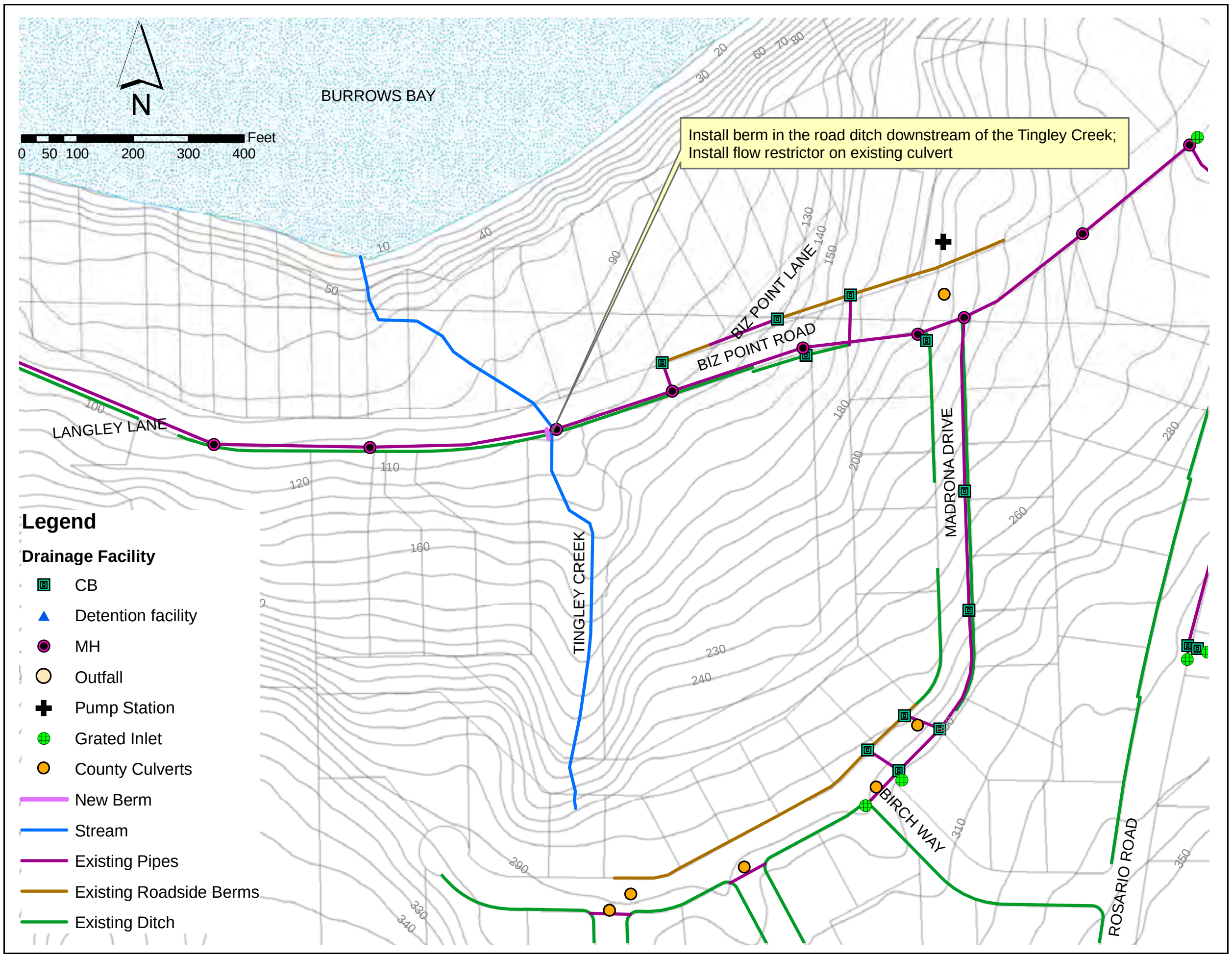


Figure 8-2. Biz Point Road–Tingley Creek Problem and Recommendation Location Map

Problem Description

Flows in Tingley Creek are currently diverted into a roadside ditch on the south side (upstream side) of Biz Point Road, reducing flows in Tingley Creek downstream of Biz Point Road. High flows in Tingley Creek endanger property downstream of Biz Point Road. Homeowners along Tingley Creek downstream of Biz Point Road would like to have base flows returned to the creek but maintain storm flows in the ditch.

The roadside ditch on the south side of Biz Point Road conveys the road drainage, Tingley Creek, and upstream hillside seepage to a piped system that discharges to Burrows Bay. A 12-inch corrugated metal pipe (CMP) culvert under Biz Point Road conveys a portion of these flows to Tingley Creek downstream of Biz Point Road. Skagit County recently constructed a temporary berm within the ditch to divert low flows from the seepage area through the culvert. The berm is located upstream of Tingley Creek and creek flows are diverted into the ditch. High flows pass over the berm and drain along the ditch.

Recommendation

The recommended solution includes the following:

- Install a low berm in the Biz Point Road ditch west of Tingley Creek to divert base flows from Tingley Creek and seepage from the hillside east of the creek to the 12-inch CMP culvert and to Tingley Creek downstream of Biz Point Road. The berm elevation should be designed to divert only base flows to the 12-inch CMP culvert. The berm should be constructed using riprap, gravel and compacted native soil.
- Install an orifice/restrictor plate on the inlet of the 12-inch CMP to divert storm flows into the ditch and around downstream sections of Tingley Creek. The orifice plate would be sized such that downstream flows in Tingley Creek and the ditch do not exceed their conveyance capacity. The orifice plate could be modified at a later date to optimize the flow split.

This option was selected as the least expensive and most flexible solution. Alternatively, a catch basin could be installed to collect base flows from Tingley Creek upstream of Biz Point Road. The catch basin would tie into the existing 30-inch CMP culvert under Biz Point Road.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: Biz Point Road - Tingley Creek — **BY:** JCT
DESCRIPTION: Regrade ditch berm and install orifice/restrictor plate — **CHECKED BY:**
BASIN/SUBBASIN: Burrows Bay - BB17 — **DATE:** 10-Mar-10

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
REGRADE DITCH AND BERM	1	EA	$ 2,000.00	$ 2,000
INSTALL ORIFICE/RESTRICTOR PLATE	1	EA	$ 500.00	$ 500
			Subtotal	$ 2,500
DEWATERING	5%			$ 125
EROSION & SEDIMENTATION CONTROL	10%			$ 250
TRAFFIC CONTROL	5%			$ 125
CONTINGENCY	30%			$ 750
			Subtotal	$ 3,750
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 375
			Construction Subtotal (Rounded)	$ 4,000
STATE SALES TAX	8.2%			$ 328
ENGINEERING/LEGAL/ADMIN	100%			$ 4,000
CONSTRUCTION MANAGEMENT	20%			$ 800
PERMITTING	20%			$ 800
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$ 10,000**

Notes:
1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

Yokeko Drive Recommendation

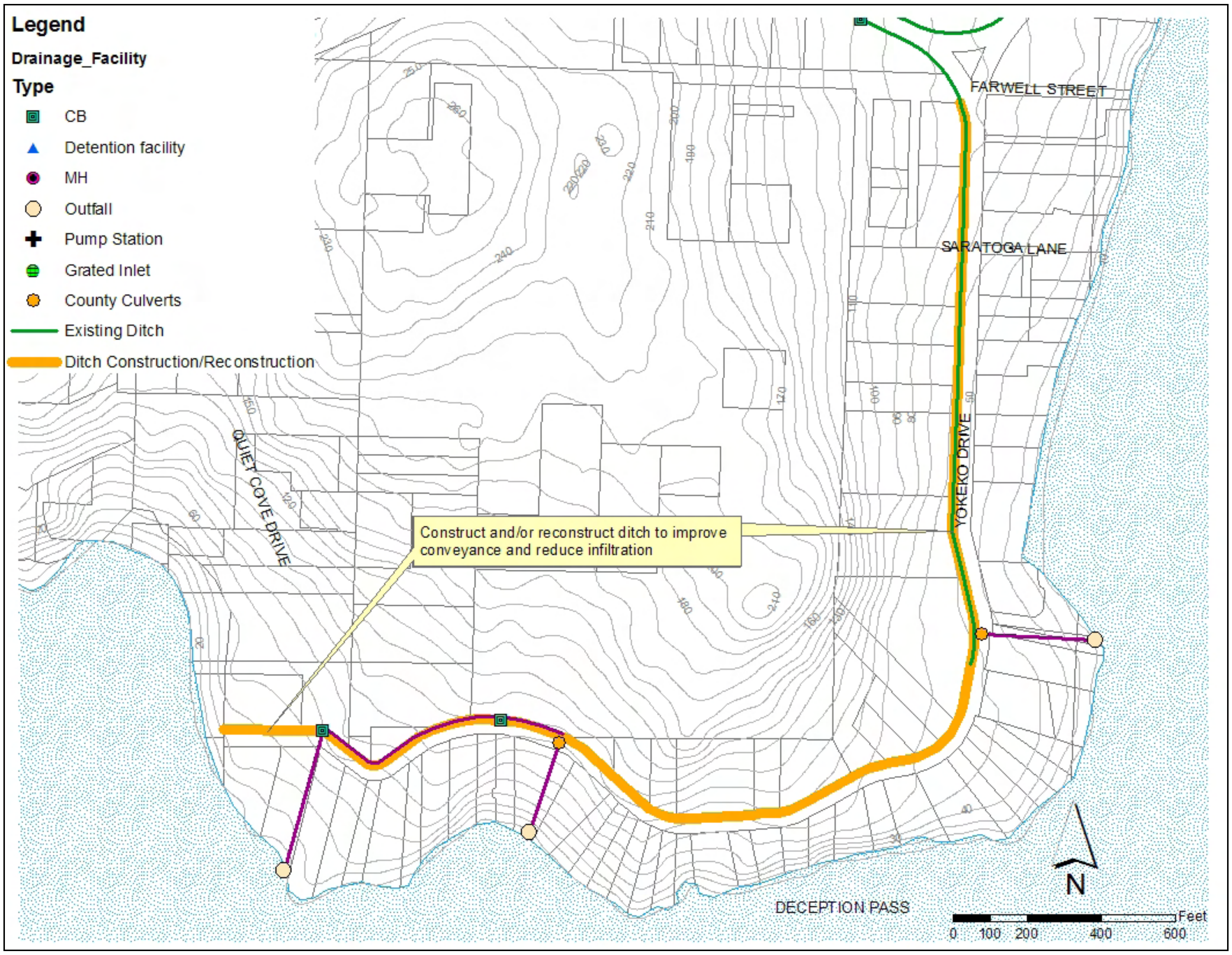


Figure 8-3. Yokeko Drive Problem and Recommendation Location Map

Problem Description

Slopes below Yokeko Drive are potentially susceptible to groundwater outflow over the existing bedrock. Groundwater from infiltration of runoff in roadside ditches adjacent to Yokeko Drive may increase the chance of property flooding. A drainage inventory of the area shows two culverts along Yokeko Drive but does not show transmission pipes, outfalls or a ditch along the last 2,300 feet of Yokeko Drive; the culverts were not located. Roadside ditch conveyance may be inadequate and may cause flooding along Yokeko Drive.

Recommendation

The recommended solution includes the following:

- Conduct a detailed inventory of drainage structures to identify the location of culverts, ditches, pipes and outfalls in the Yokeko Drive area.
- Reconstruct approximately 4,000 feet of ditch adjacent to Yokeko Drive to improve conveyance and reduce infiltration of runoff.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: **Yokeko Point Drainage** | **BY:** smf
DESCRIPTION: **Roadside Ditch Improvements** | **CHECKED BY:**
BASIN/SUBBASIN: **Deception Pass - DP05-DP08** | **DATE:** 10-Mar-10

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
ADDITIONAL STUDY				
DETAILED DRAINAGE INFRASTRUCTURE INVENTORY	1	EA	$ 5,000.00	$ 5,000
			Study Subtotal	$ 5,000
CONSTRUCTION				
RECONSTRUCT ROADSIDE DITCHES	4,000	LF	$ 25.00	$ 100,000
			Construction Subtotal	$ 100,000
DEWATERING	5%			$ 5,000
EROSION & SEDIMENTATION CONTROL	10%			$ 10,000
TRAFFIC CONTROL	5%			$ 5,000
CONTINGENCY	30%			$ 30,000
			Subtotal	$ 150,000
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 15,000
			Project Subtotal (Rounded)	$ 170,000
STATE SALES TAX	8.2%			$ 13,940
ENGINEERING/LEGAL/ADMIN	35%			$ 59,500
CONSTRUCTION MANAGEMENT	20%			$ 34,000
PERMITTING	10%			$ 17,000
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$ 294,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

Similk Golf Course Recommendation

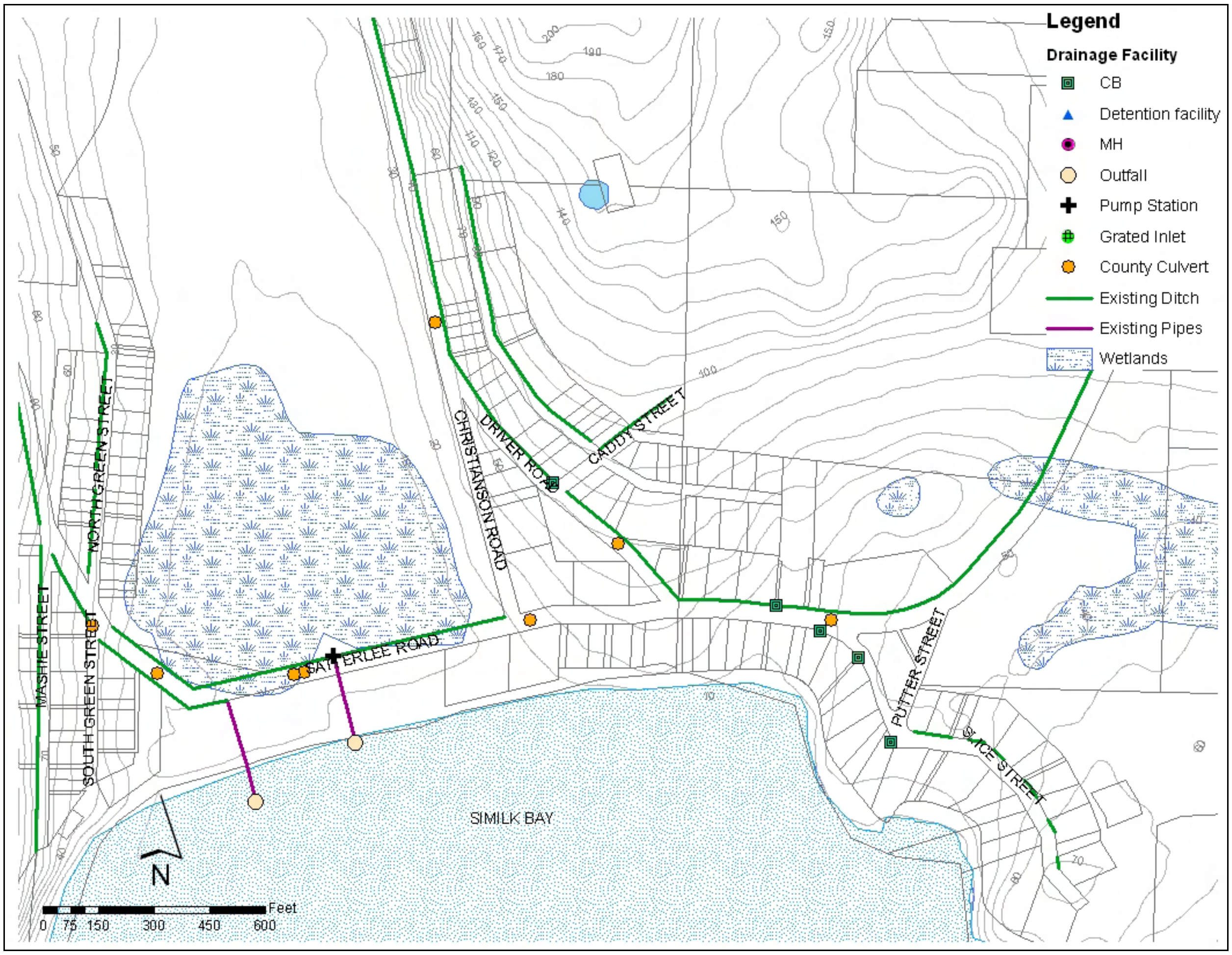


Figure 8-4. Similk Golf Course Problem and Recommendation Location Map

Problem Description

Several flooding and erosion reports have been identified in the Similk Golf Course area. Stormwater conveyance in the area is primarily in a series of roadside ditches adjacent to Caddy Street, Driver Street, Slice Street, and Satterlee Road. Infiltration of runoff within the roadside ditches may be contributing to saturated ground conditions and could interfere with septic system operation.

Several projects to improve pump station capacity and outfall efficiency as well as ditch and catch basin maintenance have been completed by Skagit County in recent years.

Recommendation

Because of the extent of the problems, the low capacity of the existing drainage system, narrow roads, and relatively flat ground, a complete drainage system retrofit is necessary to further address stormwater issues in the Similk Golf Course development. Extensive drainage system retrofits are generally only feasible in the context of complete road reconstruction. The project estimate is for over one mile of roads along Similk Bay and within the lower golf course development.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT:	**Similk Golf Course Development**		**BY:**	**smf**
DESCRIPTION:	**Roadway & Drainage Improvements**		**CHECKED BY:**	
BASIN/SUBBASIN:	**Similk Bay - SB04B-SB06**		**DATE:**	**10-Mar-10**

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
RECONSTRUCT ROADS & DRAINAGE	5,800	LF	$ 1,000.00	$ 5,800,000
			Subtotal	$ 5,800,000
DEWATERING	5%			$ 290,000
EROSION & SEDIMENTATION CONTROL	10%			$ 580,000
TRAFFIC CONTROL	5%			$ 290,000
CONTINGENCY	30%			$ 1,740,000
			Subtotal	$ 8,700,000
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 870,000
			Construction Subtotal (Rounded)	$ 9,570,000
STATE SALES TAX	8.2%			$ 784,740
ENGINEERING/LEGAL/ADMIN	25%			$ 2,392,500
CONSTRUCTION MANAGEMENT	20%			$ 1,914,000
PERMITTING	5%			$ 478,500
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$15,140,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.

2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

Day Break Lane Recommendation

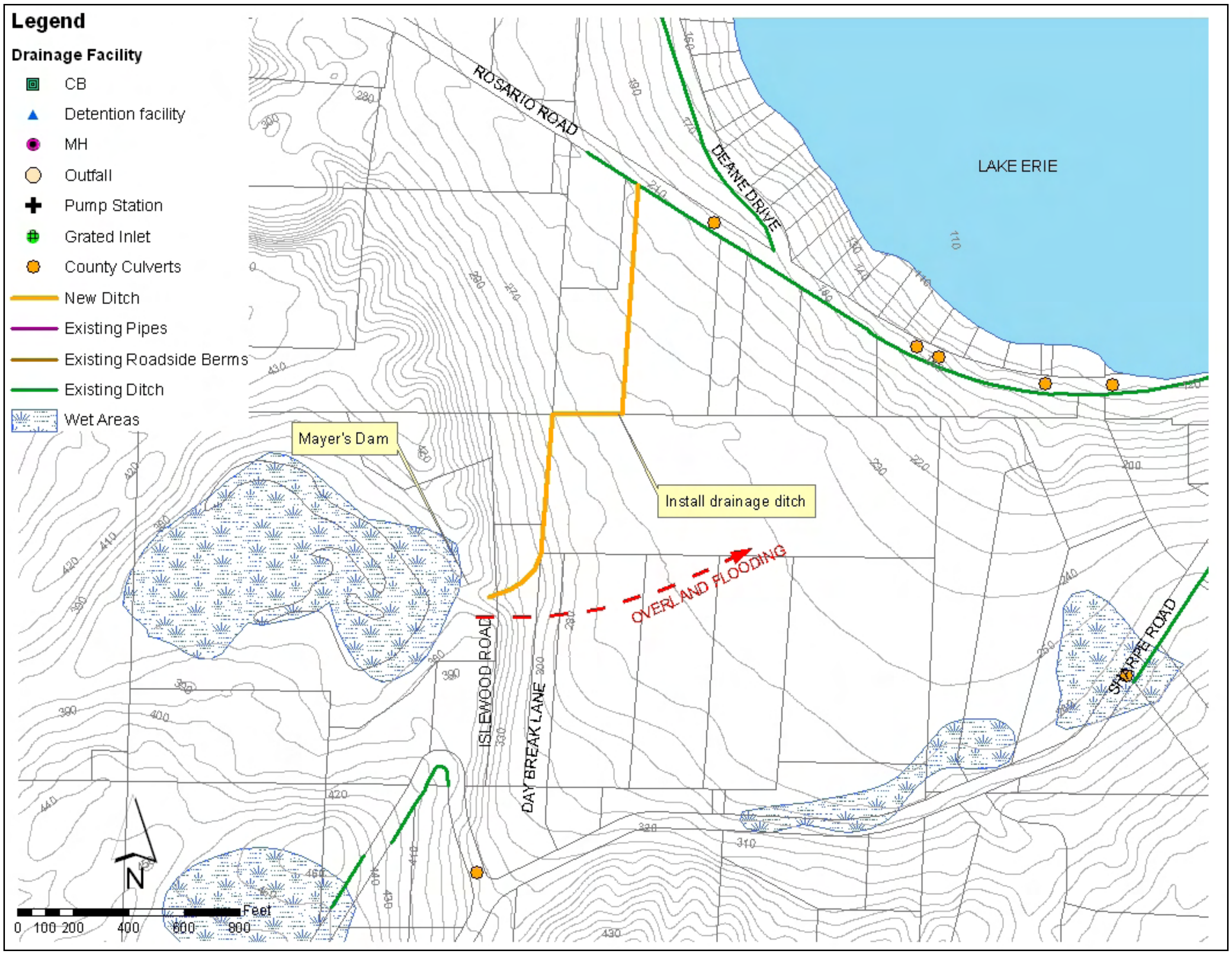


Figure 8-5. Day Break Lane Problem and Recommendation Location Map

Problem Description

Flows from a small lake impounded by Mayer's Dam periodically pond on private property downstream of Day Break Lane, flooding fields and interfering with septic system operation.

Flows from the lake pass through a culvert under Islewood Drive and through a poorly defined drainage network and eventually to a roadside ditch along Rosario Road. The roadside ditch conveys flows to culverts under Rosario Road and drains to Lake Erie.

Recommendation

The recommended solution is to construct approximately 1,800 feet of drainage ditch to convey flows from the small lake outlet to the ditch adjacent to Rosario Road. The ditch alignment would ideally be along parcel boundaries but the feasibility of this route must be assessed during design.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: Day Break Lane
DESCRIPTION: Install new ditch to Rosario Road
BASIN/SUBBASIN: Lake Erie - LE02A & LE02B

BY: JCT
CHECKED BY:
DATE: 10-Mar-10

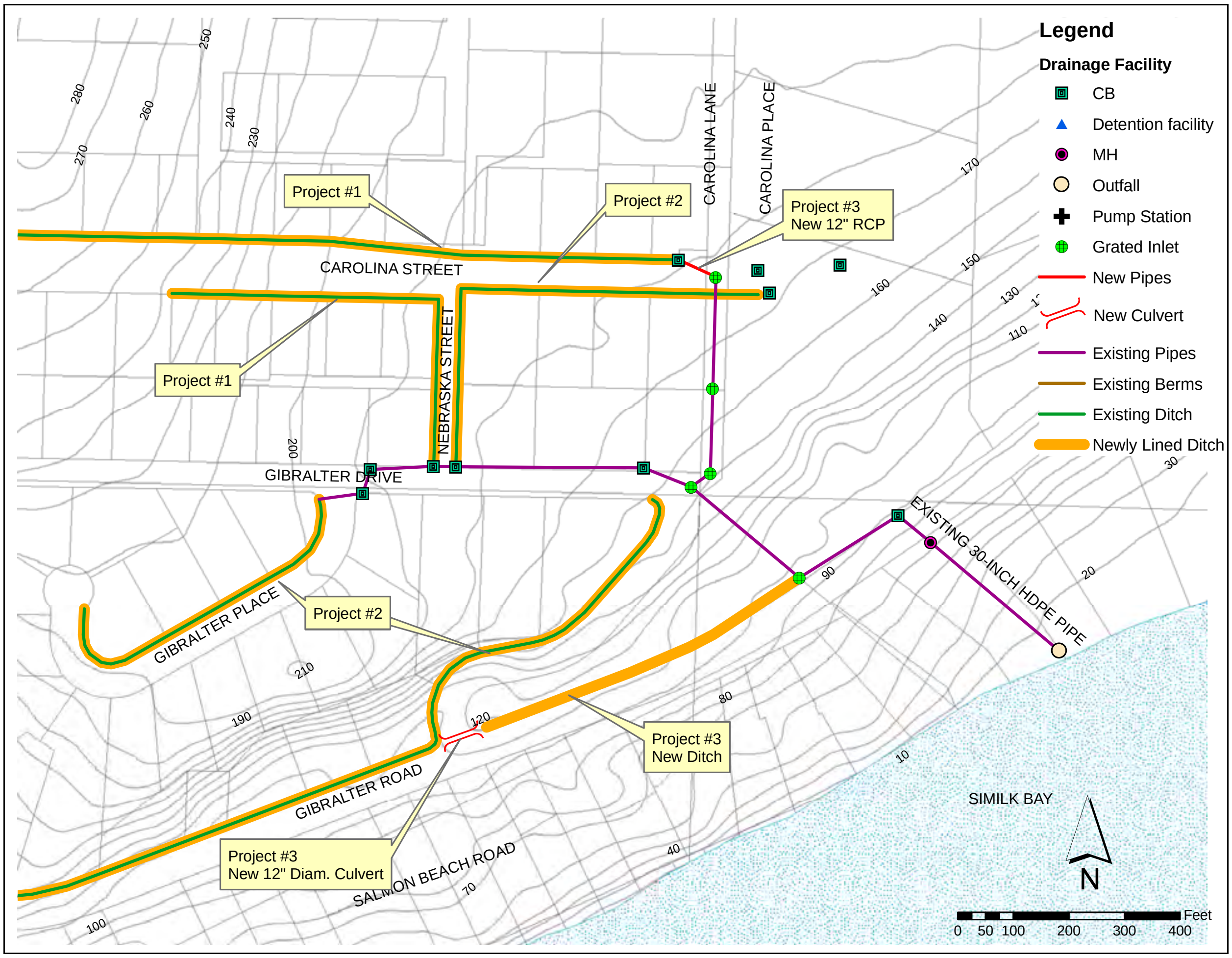
BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
DITCH EXCAVATION INCL. HAUL	930	CY	$ 15.00	$ 13,950
SEED AND MULCHING	0.4	ACRE	$ 3,000.00	$ 1,120
QUARRY SPALLS	25	TON	$ 150.00	$ 3,750
			Subtotal	$ 18,820
DEWATERING	5%			$ 941
EROSION & SEDIMENTATION CONTROL	10%			$ 1,882
TRAFFIC CONTROL	5%			$ 941
CONTINGENCY	30%			$ 5,646
			Subtotal	$ 28,230
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 2,823
			Construction Subtotal (Rounded)	$ 31,000
STATE SALES TAX	8.2%			$ 2,542
ENGINEERING/LEGAL/ADMIN	85%			$ 26,350
CONSTRUCTION MANAGEMENT	20%			$ 6,200
PERMITTING	20%			$ 6,200
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$ 72,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.

2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

Salmon Beach Recommendation



8-6. Salmon Beach Problem and Recommendation Location Map

Problem Description

Salmon Beach is an active landslide area. There are many places on and above the landslide where surface water infiltrates directly or indirectly into the ground. Although stormwater management will not eliminate the risk of additional movement of this landslide, the capture of road stormwater may reduce infiltration to the groundwater table and may reduce the frequency of damaging landslide events.

Recommendation

The recommended solution includes the following (see Figure 8-6 for problem locations):

Project #1. Roof and driveway drainage should be tightlined to roadside ditches on and above the landslide. Skagit County should coordinate this drainage upgrade with the property owners.

Project #2. All road ditches should be lined.

Project #3. A new ditch, pipeline and culvert should be installed to convey flow to the 30-inch HDPE pipe/outfall. All captured water should be delivered by tightline to the outfall at Similk Bay

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: Salmon Beach
DESCRIPTION: Roadside ditch/drainage improvements and new culvert installation
BASIN/SUBBASIN: Similk Bay - SA01, SA02 & SA04

BY: AH
CHECKED BY:
DATE: 10-Mar-10

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
RECONSTRUCT ROADSIDE DITCHES	5,820	LF	$ 25.00	$ 145,500
DITCH EXCAVATION INCL. HAUL	230	CY	$ 15.00	$ 3,450
SEED AND MULCHING	0.16	ACRE	$ 3,000.00	$ 480
QUARRY SPALLS (CULVERT END SPLASH PROTECTION)	8	TON	$ 150.00	$ 1,200
SCHEDULE A CULV. PIPE 12 IN. DIAM	125	LF	$ 25.00	$ 3,130
12-INCH DIAM RCP CLASS IV	80	LF	$ 70.00	$ 5,600
			Subtotal	$ 159,360
DEWATERING	5%			$ 7,968
EROSION & SEDIMENTATION CONTROL	10%			$ 15,936
TRAFFIC CONTROL	5%			$ 7,968
CONTINGENCY	30%			$ 47,808
			Subtotal	$ 239,040
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 23,904
			Construction Subtotal (Rounded)	$ 263,000
STATE SALES TAX	8.2%			$ 21,566
ENGINEERING/LEGAL/ADMIN	25%			$ 65,750
CONSTRUCTION MANAGEMENT	20%			$ 52,600
PERMITTING	5%			$ 13,150
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$ 416,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.

2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project w ill depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs w ill vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

Biz Point Road Recommendation

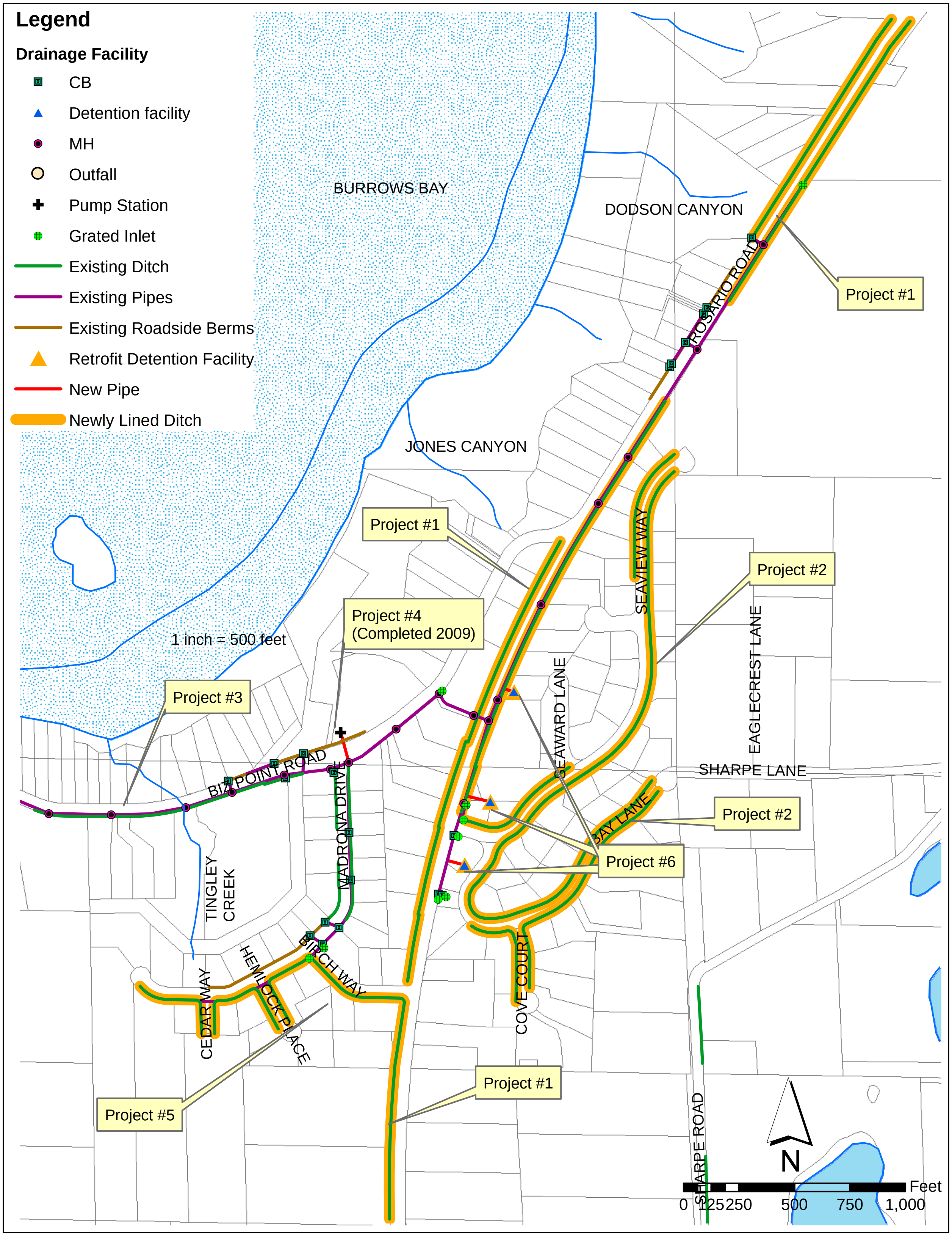


Figure 8-7. Biz Point Road Problem and Recommendation Location Map

Problem Description

Biz Point Road and the residential properties along it are affected by drainage from a large area, including Rosario Road, the subdivisions east of Rosario Road accessed from Seaview Way and Bay Lane, and the subdivisions west of Rosario Road access from Madrona Drive. Springs emerge from many places on the hillsides in the Biz Point Road/Rosario Road area. Groundwater seeps out of the roadside bank along most of the western half of Madrona Drive. A significant spring emerges from the hillside in an incised drainage to the north of the western end of Madrona Drive. This water flows as a small stream (Tingley Creek) to Biz Point Road. Seepage is also common along the eastern side of Biz Point Road between about elevations 100 and 160 feet.

The slope uphill from Biz Point Road shows many signs of instability in this area. Groundwater was pumped by the Del Mar Water Association in a wellfield on the north side of the road for many years, before recent deactivation of the well system. After the well system was deactivated, water was diverted into the Biz Point drainage system. Small seeps proliferate along Biz Point Road, just before reaching Biz Point. Lower springs also emerge from the steep shoreline bluffs to the west of Biz Point Road. A major spring flows from the hillside at about elevation 200 feet in Jones Canyon, a deeply incised landslide bowl near the eastern end of Biz Point Road. A similar spring is located in Dodson Canyon.

Recommendation

The recommended solution includes the following (see Figure 8-7 for problem locations):

Project #1. Pave or line the roadside drainage ditch along Rosario Road (both sides), so the water can be conveyed to the 30-inch diameter main collector.

Project #2. Drainage ditches in the subdivisions accessed from Seaview Way and Bay Lane should be lined and connected to the 30-inch main collector along Rosario Road.

Project #3. The quality and presence of clay trench dams along the pipeline on the steeply-graded parts of Biz Point Road has not been established. Additional records research should be performed to determine their locations and how they were installed. If they were not properly installed, additional trench dams should be constructed on steep-gradient portion of Biz Point Road.

Project #4. A pipeline can be installed to connect the wellfield pumps to the existing 42-inch diameter stormwater collector at the discretion and expense of the wellfield owners. The connection of the wellfield to the stormwater line was completed in 2009.

Project #5. Ditches along Cedar Way, Hemlock Place, and Birch Way should be lined and stormwater delivered to the manhole at the intersection of Madrona Drive and Biz Point Road, which is connected to the 42-inch collector main in Biz Point Road.

Project #6. Reconstruct the three subdivision stormwater ponds east of Rosario Road with pond lining mat and connect them to the pipeline on the east side of Rosario Road (which connects to the Biz Point drainage system) to prevent infiltration and downgradient seepage.

An evaluation should be made of the ponds' capacity for detention without infiltration of the subdivision's stormwater as well as the hydraulic capacity of the stormwater pipelines to carry the additional runoff.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT:	**Biz Point Road**
DESCRIPTION:	**Reconstruct ditch and detention ponds**
BASIN/SUBBASIN:	**Burrows Bay - BB10A, 10B, 11, 12, 13, 14A, 14B, 15A, 15B, 16 & 17**
BY:	**AH**
CHECKED BY:	
DATE:	**10-Mar-10**

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
ADDITIONAL STUDY				
GEOLOGIC INVESTIGATION ON CLAY TRENCH DAMS	1	EA	$ 5,000.00	$ 5,000
HYDRAULIC CAPACITY ANALYSIS	1	EA	$ 50,000.00	$ 50,000
			Study Subtotal	$ 55,000
CONSTRUCTION				
RECONSTRUCT ROADSIDE DITCHES	16,050	LF	$ 25.00	$ 401,250
CLEARING AND GRUBBING	0.4	AC	$ 4,000	$ 1,600
21" DIA. SMOOTH INTERIOR WALL CORRUGATED POLYETHYLENE	240	LF	$ 74.75	$ 17,940
POND LINING MAT (IMPERMEABLE MEMBRANE)	1,940	SY	$ 5	$ 9,700
TOPSOIL TYPE A	388	CY	$ 40	$ 15,520
SEEDING, FERTILIZING AND MULCHING	0.4	AC	$ 2,500	$ 1,000
TEMPORARY EROSION CONTROL BLANKET	1,940	SY	$ 5	$ 9,700
STREET CLEANING	40	HR	$ 100	$ 4,000
EROSION/WATER POLLUTION CONTROL	1	EST	$ 8,000	$ 8,000
			Construction Subtotal	$ 468,710
DEWATERING	5%			$ 23,436
EROSION & SEDIMENTATION CONTROL	10%			$ 46,871
TRAFFIC CONTROL	5%			$ 23,436
CONTINGENCY	30%			$ 140,613
			Subtotal	$ 703,065
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 70,307
			Project Subtotal (Rounded)	$ 828,000
STATE SALES TAX	8.2%			$ 67,896
ENGINEERING/LEGAL/ADMIN	25%			$ 207,000
CONSTRUCTION MANAGEMENT	20%			$ 165,600
PERMITTING	5%			$ 41,400
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$1,310,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.

2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

3. Detention ponds are assumed to have the hydraulic capacity to accommodate the flow.

South Del Mar Drive Recommendation

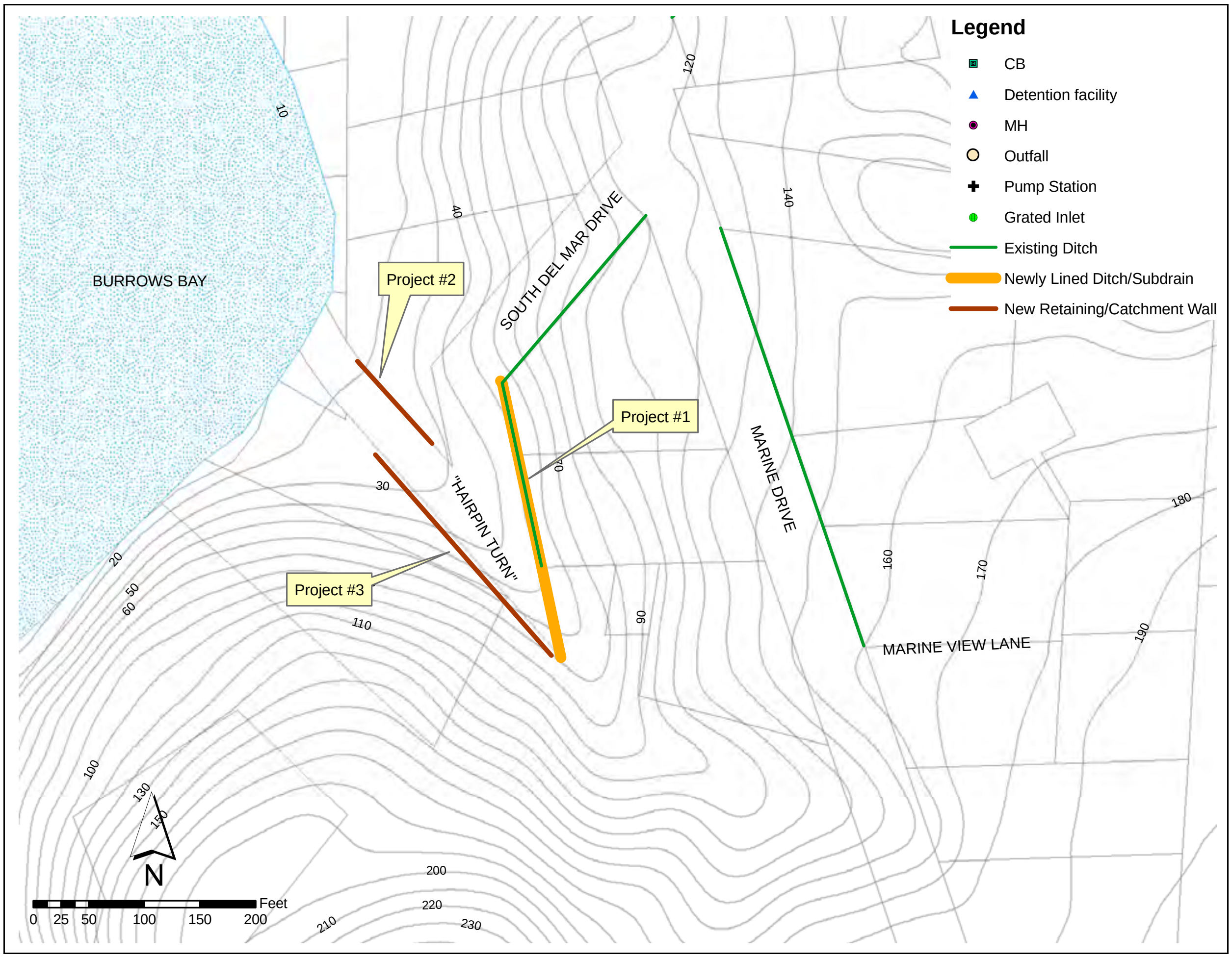


Figure 8-8. South Del Mar Drive Problem and Recommendation Location Map

Problem Description

South Del Mar Drive is at high risk of failure, owing to instability on both sides of the roadway. It appears that the road was constructed with little to no attention to drainage or stability. Continued instability on the slope above the road and upslope from the hairpin turn will block ditch drainage, causing infiltration of the seepage and diverting flows onto the road. If this water continues down the road, it will likely flow over the fill on the outside of the roadway and engender instability.

A similar condition exists on the cut slope on the section of road below the hairpin turn. On the outboard side of the road, imminent failure of the road fill and slope colluvium could land on the driveway and residence in the ravine below. Loss of this road would also cut off access to the properties along the beach.

Recommendation

The recommended solution includes the following (see Figure 8-8 for problem locations):

Project #1. On the upper part of the hairpin turn, install a trench subdrain to capture seepage and line the drainage ditch to prevent infiltration; direct stormwater to ravine to the south.

Project #2. Install a catchment wall on the inboard (uphill) side of the lower part of the hairpin turn to protect the roadway and residence below. The wall could consist of gabion baskets, ecology blocks, or other similar methods to be determined during a geotechnical study (including subsurface explorations).

Project #3. Install a retaining wall to stabilize the unstable cut slope on the lower part of the Del Mar Drive. The wall could consist of soldier piles or other similar methods to be determined during a geotechnical study.

The listed recommendations should be undertaken altogether, not individually or selectively.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT:	**South Del Mar Drive**	**BY:**	**smf**
DESCRIPTION:	**Reconstruct ditch & construct retaining walls**	**CHECKED BY:**	
BASIN/SUBBASIN:	**Del Mar Beach - BB05A & DM02A**	**DATE:**	**10-Mar-10**

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
ADDITIONAL STUDY				
GEOTECHNICAL STUDY WITH SUBSURFACE TESTING	1	EA	$ 50,000.00	$ 50,000
			Study Subtotal	$ 50,000
CONSTRUCTION				
RECONSTRUCT ROADSIDE DITCHES	150	LF	$ 25.00	$ 3,750
SOLDIER PILE RETAINING WALL	240	LF	$ 650.00	$ 156,000
CATCHMENT WALL	500	SF	$ 25.00	$ 12,500
UNDERDRAIN PIPE	100	LF	$ 20.00	$ 2,000
			Construction Subtotal	$ 174,250
DEWATERING	5%			$ 8,713
EROSION & SEDIMENTATION CONTROL	10%			$ 17,425
TRAFFIC CONTROL	5%			$ 8,713
CONTINGENCY	30%			$ 52,275
			Subtotal	$ 261,375
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 26,138
			Project Subtotal (Rounded)	$ 338,000
STATE SALES TAX	8.2%			$ 27,716
ENGINEERING/LEGAL/ADMIN	25%			$ 84,500
CONSTRUCTION MANAGEMENT	20%			$ 67,600
PERMITTING	5%			$ 16,900
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$ 535,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.

2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

RECOMMENDATION FOR FUTURE DETENTION FACILITIES

Table 6-5 identified 12 subbasins that may be expected to experience high stormwater impacts due to future development. The impacts can be mitigated by the use of detention ponds, either individually constructed with each development or built on a regional scale to provide service to large areas. An analysis was performed to estimate the size of a regional detention facility for each subbasin of interest; the size varies as a function of the size the basin and the future total impervious coverage. A general project description and cost estimate was created for a 10-acre detention pond, about the average volume of the ponds shown in Table 6-7.

Design Requirements

A detention pond manages runoff generated by urban development by detaining stormwater and releasing it at rates that protect the downstream system. Release is generally at a rate and duration matching pre-development conditions. If the discharge can be routed in a pipeline directly to a receiving water, such as Burrows Bay or Similk Bay, higher release rates and thus smaller pond volumes may be possible.

The detention pond should be located at a low point where runoff from the basin can drain to it by gravity. It is recommended that facilities be a minimum of 20 feet from any structure, property line, and vegetative buffer required by the local government. The detention pond water surface at the outlet invert elevation must be set back 100 feet from proposed or existing septic system drainfields. All facilities must be a minimum of 50 feet from the top of any slope steeper than 15 percent.

Pond bottoms should be level and be located a minimum of 1 foot below the inlet and outlet to provide sediment storage. Interior side slopes should not be steeper than 3H:1V and at least 25 percent of the pond perimeter should be a vegetated slope. Generally, detention ponds should be underlain by a liner to prevent infiltration through the bottom of the pond and potential groundwater contamination. Pond berm embankments must be designed by a professional engineer and a geotechnical engineer. A primary overflow structure, such as a riser pipe within the control structure, is required to bypass the 100-year developed peak flow over or around the restrictor system. A secondary inlet to the control structure must be provided in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. Ponds must have an emergency overflow spillway. Designs should include an access road, fencing and a gate. Exposed earth on the pond bottom and interior side slopes should be sodded or seeded with an appropriate seed mixture. All remaining areas of the pond site should be planted with grass or be landscaped and mulched with a 4-inch cover of hog fuel or shredded wood mulch. Landscaping is encouraged for most stormwater pond sites. Figures 8-9 and 8-10, taken from the 2005 Ecology manual, illustrate a typical detention pond.

Dam Safety

Any facility that impounds 10 or more acre-feet of water at the embankment crest is subject to Department of Ecology dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-020(1)). The primary dam safety requirement is in sizing the emergency spillway to accommodate the runoff from the dam safety design storm without overtopping the dam. The hydrologic computation procedures are the same as for the original pond design, except that the computations must use more extreme precipitation values and the appropriate dam safety design storm hyetographs. Other dam safety requirements include geotechnical issues, construction inspection and documentation, dam breach analysis, inundation mapping, emergency action planning, and periodic inspections by project owners and by dam safety engineers (Ecology, 2005).

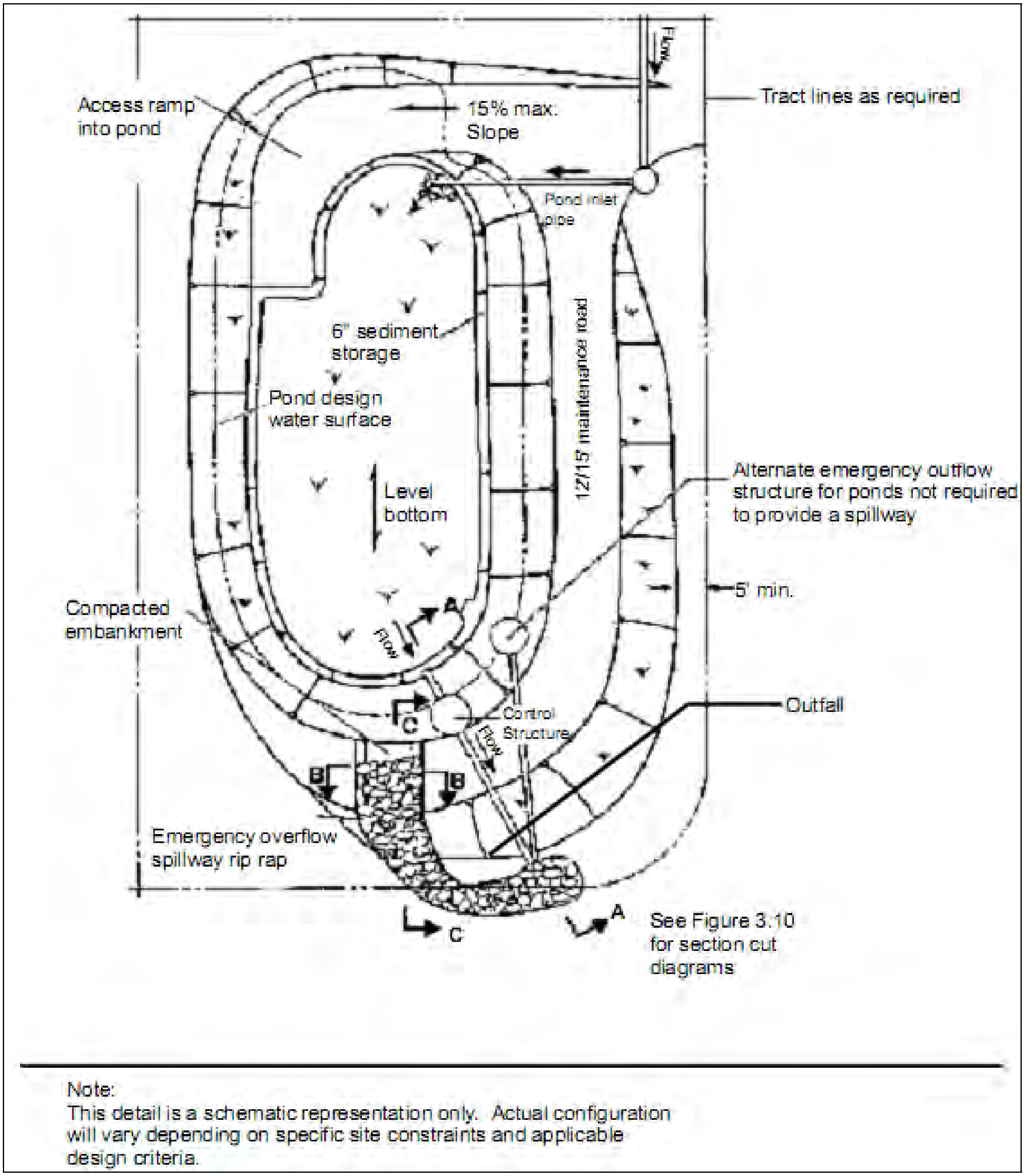


Figure 8-9. Typical Detention Pond Plan View (from 2005 Ecology Stormwater Manual, Volume III)

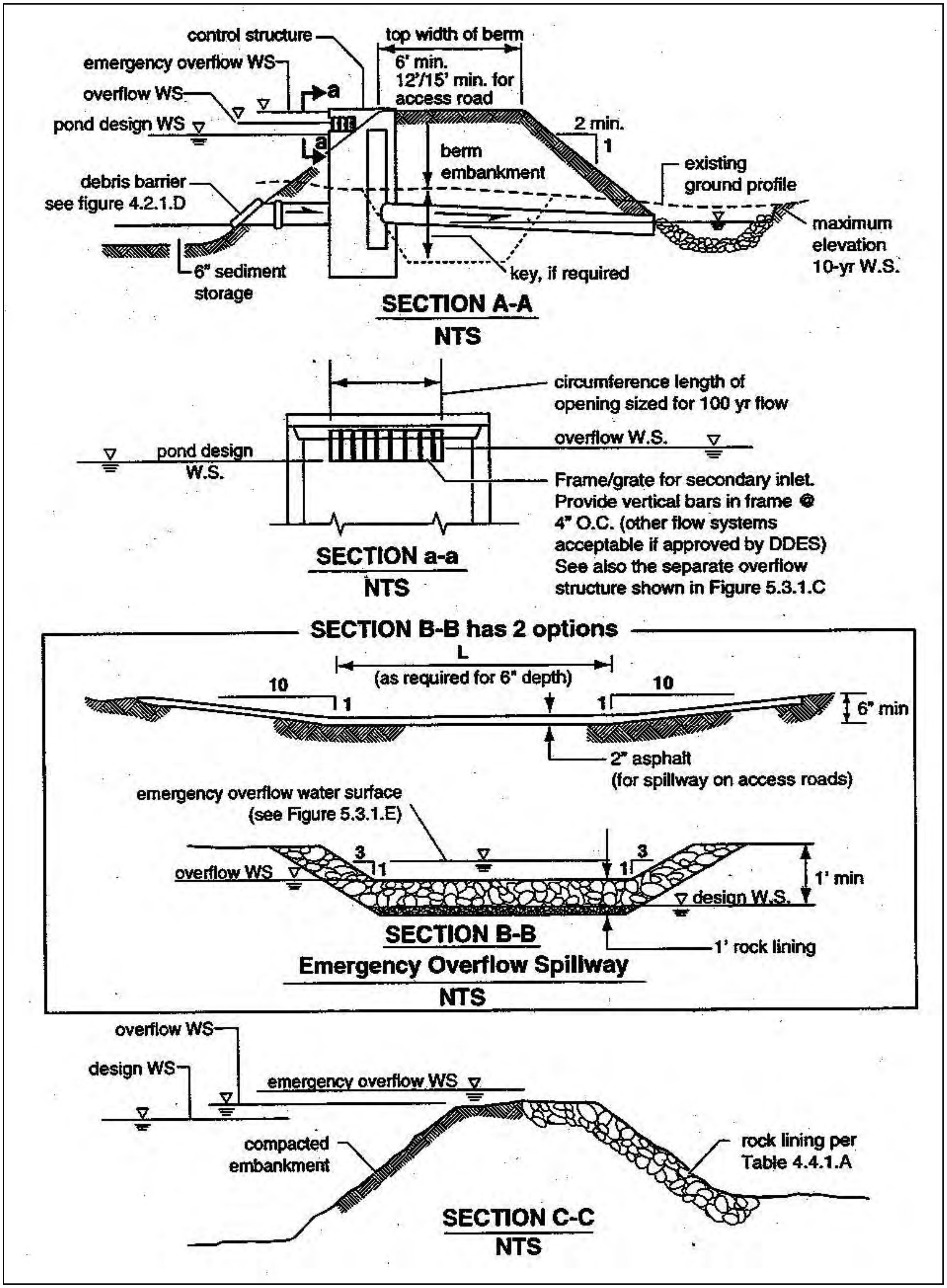


Figure 8-10. Typical Detention Pond Section Views (from 2005 Ecology Stormwater Manual, Volume III)

Cost Estimate

The following cost estimate was prepared using typical elements for a detention pond with quantities estimated for a 4-foot deep, 10-acre-foot pond with a 1,000-foot connection to a discharge location.

PLANNING LEVEL CONSTRUCTION COST OPINION

PROJECT: Regional Detention Pond | BY: smf
DESCRIPTION: | CHECKED BY:
BASIN/SUBBASIN: | DATE: 10-Mar-10

BID ITEM	QUANTITY	UNIT	UNIT PRICE	AMOUNT
PREPARATION				
CLEARING AND GRUBBING	2.5	AC	$ 4,000	$ 10,000
GRADING				
EMBANKMENT CONSTRUCTION	360	CY	$ 25	$ 9,000
EMBANKMENT EXCAVATION	16,000	CY	$ 15	$ 240,000
STORM SEWER				
CATCH BASIN TYPE 2 72 IN. DIAM.	2	EA	$ 6,000	$ 12,000
CORRUGATED POLYETHYLENE STORM SEWER PIPE 36 IN. DIAM.	1,000	LF	$ 60	$ 60,000
TRASH RACK	1	EA	$ 3,500	$ 3,500
SPLITTER STRUCTURE	1	LS	$ 10,000	$ 10,000
CONTROL STRUCTURE	1	LS	$ 10,000	$ 10,000
RIP RAP FOR SPILLWAY	60	TON	$ 60	$ 3,600
POND LINING MAT	12,500	SY	$ 5	$ 62,500
EROSION CONTROL AND PLANTING				
TOPSOIL TYPE A	1,400	CY	$ 40	$ 56,000
SEEDING, FERTILIZING AND MULCHING	2.5	AC	$ 2,500	$ 6,250
TEMPORARY EROSION CONTROL BLANKET	1,000	SY	$ 5	$ 5,000
STREET CLEANING	40	HR	$ 100	$ 4,000
EROSION/WATER POLLUTION CONTROL	1	EST	$ 8,000	$ 8,000
OTHER ITEMS				
ACCESS ROAD COMPONENT	200	TON	$ 25	$ 5,000
COATED CHAIN LINK FENCE TYPE 3	1,300	LF	$ 20	$ 26,000
END, GATE, CORNER, AND PULL POST FOR CHAIN LINK FENCE	6	EA	$ 250	$ 1,500
DOUBLE 20 FT. COATED CHAIN LINK GATE	1	EA	$ 2,000	$ 2,000
			Subtotal	$ 534,350
DEWATERING	5%			$ 26,718
EROSION & SEDIMENTATION CONTROL	10%			$ 53,435
TRAFFIC CONTROL	5%			$ 26,718
CONTINGENCY	30%			$ 160,305
			Subtotal	$ 801,525
MOBILIZATION (GENERAL REQUIREMENT)	10%			$ 80,153
			Construction Subtotal (Rounded)	$ 882,000
STATE SALES TAX	8.2%			$ 72,324
ENGINEERING/LEGAL/ADMIN	25%			$ 220,500
CONSTRUCTION MANAGEMENT	20%			$ 176,400
PERMITTING	5%			$ 44,100
2009 Dollars			**Total Estimated Project Cost (Rounded)**	**$ 1,395,000**

Notes:

1. The above cost opinion is in 2009 dollars and does not include future escalation, financing, land acquisition, or O&M costs.
2. The order-of-magnitude cost opinion has been prepared for guidance in project evaluation from the information available at the time of preparation and for the assumptions stated. The final costs of the project will depend on actual labor and material costs, actual site conditions, productivity, competitive market conditions, final project scope and schedule, and other variable factors. As a result, the final project costs will vary from those presented above. Because of these factors, funding needs for individual projects must be scrutinized prior to establishing the final project budgets.

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Skagit County

South Fidalgo Island Stormwater Management Plan

APPENDIX A.
LITERATURE REVIEWED FOR GEOTECHNICAL ANALYSIS

July 2010

Appendix A
Literature Reviewed For Geotechnical Analysis

GeoEngineers, Inc., 1991, *Summary of Skagit County Geology*

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Skagit County

South Fidalgo Island Stormwater Management Plan

APPENDIX B.
LAND USE/COVER ANALYSIS

July 2010

APPENDIX B – LAND USE/COVER ANALYSIS

Existing Land Cover/Land Use Analysis

The Existing Land Cover Layer developed in GIS is one of four layers used to characterize imperviousness on South Fidalgo Island (the Study Area). It is combined with soils, slope, and sub-basin boundaries to develop model input for HSPF. It is used for both HSPF existing and future land cover scenarios to establish loss of impervious surface and resulting needs for surface water conveyance and possible environmental hazards.

The objective in creating the land cover layer is to develop generic land cover categories for 1.) forest, 2.) pasture, 3.) lawn, 4.) open water, and 5.) impervious (rooftops, roads, parking lots, etc). In the case of this study, three notable quarries in the study area were outlined and added as a sixth category. As opposed to models that are specific to local areas of conveyance, HSPF simulates hydrologic functions over extended periods of time using local rainfall data and interpreted pervious and impervious land surfaces. As a result, the land cover layer is used to characterize gross land cover types and associated imperviousness summarized by sub-basin.

Creating the Existing Land Cover Layer

The development of land cover layers for HSPF are normally done using a.) classified imagery, b.) aerial photography, or c.) a parcel layer with polygons coded for land use. For the South Fidalgo study, Tetra Tech used an approach that was a blend of all three methods.

A. Classified Imagery

Tetra Tech used a 2006 classified satellite image as the foundation for the land cover layer. This layer contained classes that were more detailed than required by the HSPF model. Forest type distinctions (evergreen, deciduous, etc.) were distilled into a single land cover type of "forest." The classes for agricultural use and cleared forest were distilled into "pasture." The source image also included three densities of residential; however, we found these classes to be inaccurate. Manual inspection over 2006 aerial photography revealed that the unsupervised classification method did not work well in the rural suburban sectors of the study area. Furthermore, the source image's classification system did not interpret specifically for lawn and impervious as required by the model. Other data sources were integrated for residential land cover analysis.

B. Open Water

Open water are large contiguous water bodies. Polygons for open water were isolated in the County's hydrology layer and overlaid with the layer developed in Step A. Although the classified image identified most of the same water bodies, the hydrology layer polygons contained smoother shoreline edges and appeared most accurate over the aerial photo.

C. Imperviousness using Feature Extraction and Aerial Photo Interpretation

Skagit County provided a draft impervious cover layer that was generated using the ArcGIS Feature Extraction Extension on an aerial image of the study area. The layer was provided "as is" with extra caution that it was incomplete and not quality assured. Notable gaps in the coverage of imperviousness were seen where road pavement, parking areas, and rooftops are under tree canopy. Although not all impervious surfaces could be visually detected using the photos, Tetra Tech manually added impervious polygons by connecting missing sections of paved road. The resulting layer was integrated into the image source layer for forest and pasture developed in Step A.

D. Identification of Lawn

To fill large gaps in the image resulting from Step C, Tetra Tech isolated polygons from the County's parcel layer that are in the residential zones of Rural Intermediate, or RI (1 dwelling unit per 2.5 acres), Rural Reserve, or RRv (1 dwelling unit per 10 acres), and a thin section of urban parcels in the City of Anacortes at the far north section of the study area (for purposes of hydrologic connectivity of modeled basins). It should be noted that actual housing densities in the coastal portions are much closer to 1 dwelling unit per acre, likely a relic of development prior to the adoption of the current zoning ordinance.

Typical suburban interpretations of imperviousness assume no natural land cover. All surfaces are generally classified as impervious and lawn. However, the rural nature of the study area required a different approach to account for the mosaic of natural and fabricated land covers. It was noticed from the aerial photos that the RI and RRv zones contained impervious surfaces, lawns, natural forest, and to a lesser extent, pasture, thus suggesting a higher perviousness than typical suburban development. The RRv zone contains several pockets of forest and pasture that were not identified by the classified image used in Step A.

Tetra Tech used a manual process of interpreting the residential parcels in the gap areas as being predominately lawn, forest, or pasture.

The surfaces of imperviousness as identified in Step C within the residential parcels were left intact. Therefore, only the portions of parcels not identified as impervious were interpreted for cover type.

The manual interpretation of residential parcels was done at a fixed map scale of 1:4000. Parcels were not split into separate polygons by cover type. Instead they were kept intact and interpreted as to the majority cover type of lawn, forest, or pasture. Clusters of residential parcels, both developed and vacant, were identified over the photo for their predominant cover type and coded appropriately. Although a more intensive effort to outline actual cover types within residential parcels would have yielded more accurate results, the use of parcel boundaries offers a more accurate foundation for interpreting future land use (see Future Land Cover/Land Use Analysis Section).

The residential polygons were the final overlay to create the existing land cover layer. Upon overlaying the residential polygons, all underlying impervious polygons developed in Step C were retained. There were several jagged edges of forest and pasture from the satellite image source developed in Step A that overlapped the residential polygons. These edges were clipped to the residential polygon borders in favor of using the manually interpreted land cover codes in the parcel attribute table.

E. Overlay of Sub-basins

The final step in creating the land cover layer was the overlay of the digitized sub-basin boundaries. This carves the larger land cover polygons to the basin boundaries and codes each land cover polygon as to the sub-basin it resides in. This layer is later overlayed with soils and slopes to derive the model input layer.

Future Land Cover/Land Use Analysis

The development of a future land use layer for the HSPF model starts with Existing land cover and assumes full residential build-out given the variables of a.) zoning, b.) existing lot sizes, and c.) determination of developable and redevelopable land. Furthermore, opportunities for redevelopment that are likely to result in increased impervious surfaces are outlined.

Several assumptions that characterize “full build-out” are discussed below.

Zoning

In the case of South Fidalgo Island, opportunities for commercial development that would notably affect imperviousness are limited due to zoning and the lack of several services. Impervious impacts will be most in the residential zoned areas and are assessed as such. For purposes of expanding sub-basin coverage into the north area of the study area, a portion of the City of Anacortes (Zoning = “CITY”) is also assumed to be further developable and redevelopable (where appropriate).

Zones assessed for future development are as follows:
RRv – Rural Reserve. RRv is a low density rural residential zone allowing for 1 dwelling unit per 10 acres. This zone includes several developed and undeveloped lots less than ten acres because they were platted prior to the current zoning ordinance.

RI – Rural Intermediate. RI is the highest density rural residential zone allowing for 1 dwelling unit per 2.5 acres. This zone includes several developed and undeveloped lots less than 2.5 acres because they were platted prior to the current zoning ordinance.

CITY – City of Anacortes – Includes areas zoned by the city as both residential and open space. Although parcels are not able to partition further, the same unincorporated rules for new development based on vacancy and redevelopment apply.

The middle of the study area encompassed by steep forested slopes within the Anacortes City Limits is mostly conservation easement or able to convert to conservation easement. This area has been excluded as a zone for further development.

Determination of Developable Status

The first step is to identify and exclude parcels that are not developable or not considered a major potential impact to imperviousness in the study area.

Non-Developable Parcels

The following Assessor land use codes were categorically selected as Non-Developable (ND). Parcels were inspected using the 2006 aerial photography to verify the land use codes.

1. CEMETARY
2. COMMUNICATIONS
3. CULTURAL ACTIVITIES & NATURE EXHIBITS
4. EDUCATION SERVICES (SCHOOLS)
5. GOVERNMENTAL SERVICES
6. HIGHWAY & STREET RIGHT OF WAY
7. HOTELS, MOTELS
8. MINING ACTIVITIES & RELATED SERVICES
9. MISCELLANEOUS SERVICES
10. OTHER RETAIL TRADES
11. OTHER TRANSPORT/COMMUNI/UTILITIES NOT ELSEWHERE
12. PARKS
13. PUBLIC ASSEMBLY
14. RECREATIONAL ACTIVITIES
15. RETAIL TRADE, EATING & DRINKING
16. RETAIL TRADE, FOOD
17. RETAIL TRADE, GENERAL MERCHANDISE

18. UTILITIES (DIKE & DRAIN PROPERTIES)
19. WATER AREAS

The following Assessor Land Use Codes were selectively chosen as ND using the zoning and 2006 aerial photo to verify.

1. OPEN SPACE FARM & AG. Where zoning is "RMI" (rural marine industrial) – Culbertson property at east side of study area.
2. OPEN SPACE/OPEN SPACE where NBR_Code = "Golf Course" (the Similk Golf Course)
3. MOBILE HOME PARKS and MOBILE HOMES where Zoning = "RRc_NRL" (Rural Resource Natural Resource Lands)

Parcels in the following Zones are assumed to not develop further ("ND")

1. RVC (Rural Village Commercial)
2. RC (Rural Center)
3. OSRSI (Public Open Space of Regional/Statewide Importance)
4. RB (Rural Business)
5. RMI (Rural Marine Industrial)
6. RRc_NRL (Rural Resource – Natural Resource Lands)
7. SSB (Small Scale Business)

Developable/Redevelopable Parcels
The second step is categorizing each residential parcel as vacant, developed, further developable, or redevelopable. This determination is based on data provided by the County Tax Assessor as well as lot size calculations made in the GIS. The analysis focuses on residential properties that are vacant and/or large enough to partition under the current zoning. It should be noted that many of the lots in both the RI and RRv zones are smaller than allowed for under the current zoning. These smaller lots are grandfathered and may continue to develop and redevelop in densities greater than the current zoning ordinance. The small cluster of CITY parcels at the north end of the study area can develop if they are vacant and they may redevelop under the given criteria. However, the CITY lots are currently platted at their highest density and cannot partition further.

All future residential growth as calculated in the GIS is contingent upon available acreage. Available acreage is defined as total parcel acreage minus area occupied by critical areas.

Critical areas as regulated by Skagit County are as follows:
1. Wetlands (Freshwater Emergent, Freshwater Forested/Shrub, Freshwater Pond, Lake)
2. Stream Buffers (200 ft. for Types 1 & 2, 50 ft. for Types 4 & 5)
3. Geohazards (15% and greater slopes)

The following table shows the database fields and queries used to identify developable (vacant), further developable, redevelopable, and developed for residential parcels.

Definition	Criteria	Description
bldg_val	provided by Skagit County Assessor	Assessed value of structure
tot_market	provided by Skagit County Assessor	Total market value of parcel
bldg_land	bldg_val/tot_market	building value divided by total market value
Vacant for RI, RRv, and CITY	bldg_val <= 10,000	Assumes no livable home on parcel
Further Develop for RI	bldg_val > 10,000 and ac >= 4.5	Assumes livable home on parcel and further subdividable at 1 du per 2.5 acres
Further Develop for RRv	bldg_val > 10,000 and ac >= 19.5	Assumes livable home on parcel and further subdividable at 1 du per 10 acres
Redevelopable for RI, RRv, and CITY	bldg_val > 10,000 and bldg_land <= .2 and not Further Developable	Assumes existing dwelling unit is likely to be replaced with a larger unit and increased impervious area
	and SFR stick frame (not mobile) year built before 1990	
Developed	bldg_val > 10,000 and not Redevelopable and not Further Developable	Assumes full buildout on lot with redevelopment not likely
ac	ac = [calculate geometry for Acres (US)]	Total geometry acres for parcel
ca_ac	acres of critical area in each parcel	Calculated using a union of parcels with critical_areas_union.shp
Ac_availab	ac - ca_ac	Total acres minus acres from CA layer

Based on the resulting development category assigned using the above table, an approximate number of future residential building units for each parcel in the study area was assigned. Input criteria include zoning, the development category, available acreage in the parcel, and for redevelopment opportunities, a percentage of the building value versus the land value. The following table shows the assignment of future units.

Zone	Develop Category	Ac_availab	Bldg_land	Future Units
RI	Vacant	.15 < X <= 4.5	N/A	1
RI	Vacant	4.5 < X <= 7	N/A	2
RI	Vacant	7 < X <= 9.5	N/A	3
RI	Vacant	9.5 < X <= 12	N/A	4
RI	Vacant	12 < X <= 14.5	N/A	5
RI	Vacant	14.5 < X <= 17	N/A	6
RI	Vacant	17 < X <= 19.5	N/A	7
RI	Futher Develop	4.5 < X <= 7	N/A	1
RI	Futher Develop	7 < X <= 9.5	N/A	2
RRv	Vacant	.15 < X <= 19.5	N/A	1
RRv	Vacant	19.5 < X <= 29.5	N/A	2
RRv	Vacant	29.5 < X <= 49.5	N/A	3
RRv	Futher Develop	19.5 < X <= 29.5	N/A	1
RRv	Futher Develop	29.5 < X <= 49.5	N/A	2
CITY	Vacant	> .15	N/A	1
RRv/RI/CITY	Redevelopable	> .15	<= .2	1
ALL	Developed	N/A	N/A	0

Assignment of Future Land Cover

Alterations to future land cover occur only where development may occur. HSPF can model a variable level of future build-out. In the case of the South Fidalgo study, the future scenario assumes a maximum build-out of all developable and redevelopable land. All non-developable and fully developed lots do not change land cover in the future scenario.

Future land cover is assigned to developable and redevelopable parcel polygons as a percentage of total available acreage. Therefore, a parcel identified as being "further developable" within the parameters of zoning and available acreage will be assigned future percent coverage of impervious, lawn, and remnant natural land cover (either forest or pasture). Any existing cover types identified within critical areas remain unchanged in the future.

Separate analyses to develop estimated percentages of future land cover types were performed for the RI, RRv, and CITY zones. *Percent future land cover types are based on observed existing land cover types on developed parcels.* The analysis was done separately for the RI, RRv, and CITY zones because of notable differences in existing land cover types within each zone.

Tetra Tech used the source land cover image overlaid with developed parcels in each zone (RI, RRv, and CITY) to determine the average percent cover types for existing parcels. The results are in the following table.

Zone	Future % Forest	Future % Impervious	Future % Lawn	Future % Pasture
RI	30	28	40	2
RRv	45	11	34	10
CITY	0	34	66	0

The intended use of the future land cover percentages is to multiply available acreage in vacant, further developable, and redevelopable parcels to determine total future land cover. However, application of the percentages varied based on existing land cover. The table below are the rules in applying variable percentages based on zone, available vs. unavailable acreage, develop category, and existing land cover.

Zone	Acreage Type	Develop Category	Existing Land Cover	Notes	Future % Forest	Future % Impervious	Future % Lawn	Future % Pasture
All Zones	Critical Areas	ALL	ALL	Remains "as is" with no assumed conversion	N/A	N/A	N/A	N/A
All Zones	All Land	Developed/Non-Develop	ALL	Remains "as is" with no assumed conversion	N/A	N/A	N/A	N/A
All Zones	All Land	ALL	Impervious	Remains Impervious	N/A	N/A	N/A	N/A
All Zones	All Land	ALL	Water	Remains Water	N/A	N/A	N/A	N/A
All Zones	All Land	ALL	Quarry	Remains Quarry	N/A	N/A	N/A	N/A
RI	Available Land	Vacant/Further Develop/Redevelop	Forest	Based on Average Cover Types in RI Existing Developed Parcels	32	28	40	0
RI	Available Land	Vacant/Further Develop/Redevelop	Pasture	Based on Average Cover Types in RI Existing Developed Parcels	0	28	40	32
RI	Available Land	Vacant/Further Develop/Redevelop	Lawn	Based on Average Cover Types in RI Existing Developed Parcels	0	28	78	0
RRv	Available Land	Vacant/Further Develop/Redevelop	Forest	Based on Average Cover Types in RRv Existing Developed Parcels	55	11	34	0
RRv	Available Land	Vacant/Further Develop/Redevelop	Pasture	Based on Average Cover Types in RRv Existing Developed Parcels	0	11	34	55
RRv	Available Land	Vacant/Further Develop/Redevelop	Lawn	Based on Average Cover Types in RRv Existing Developed Parcels	0	11	89	0
CITY	Available Land	Vacant/Redevelop	Forest	Based on Average Cover Types in CITY Existing Developed Parcels	0	34	66	0
CITY	Available Land	Vacant/Redevelop	Pasture	Based on Average Cover Types in CITY Existing Developed Parcels	0	34	66	0
CITY	Available Land	Vacant/Redevelop	Lawn	Based on Average Cover Types in CITY Existing Developed Parcels	0	34	66	0

The above rules assume a limited retention of the existing land covers of forest and pasture under future development conditions. This is based on both average percentages in existing developed parcels and based on aerial photo and field observations. South Fidalgo Island is characteristic of rural style developments, even in the highest density development areas.

The rules assume that future residential development does not convert forest to pasture or pasture to forest. Although these circumstances can occur, our HSPF modeling assumptions generally target potential conversion to less pervious surfaces (impervious and lawn). Therefore, a forested vacant lot will only convert to the future land cover categories of lawn, impervious, and forest. In this case, the future forest cover would be the average forest AND pasture percentages added together. Similarly, a vacant lot in pasture will only convert to lawn, impervious, and pasture, with a future pasture percentage that adds together average forest and pasture percentages.

Example 1 shows existing conditions for a forested parcel in the R1 zone that is vacant.

Example 1

Parcel	Zone	Existing Cover	Develop Category	CA_Acres	Ac_Availab	Total AC
A	RI	Forest	Vacant	0	10	10

The following future percent land cover types and acreages would result for this parcel's future development.

Future Units	Per_Forest	Per_Lawn	Per_Imperv	Ac_Forest	Ac_Lawn	Ac_Imperv
4	32	40	28	3.2	4	2.8

Example 2 shows the same parcel but with a part of the polygon occupied by critical areas.

Example 2

Parcel	Zone	Existing Cover	Develop Category	CA_Acres	Ac_Availab	Total AC
A	RI	Forest	Vacant	2	8	10

The resulting future forest coverage includes the 2 acres that are in critical areas PLUS 32% of the available development acreage (2.6 acres), totaling 4.6 acres of forest under a future development scenario.

Future Units	Per_Forest	Per_Lawn	Per_Imperv	Ac_Forest	Ac_Lawn	Ac_Imperv
3	32	40	28	4.6	3.2	2.2

Example 3 shows a similar parcel in RRv zoning.

Example 3

Parcel	Zone	Existing Cover	Develop Category	CA_Acres	Ac_Availab	Total AC
B	RRv	Pasture	Vacant	2	18	20

Similar to Example 2, the existing pasture cover is converted to future coverage of lawn, impervious, and pasture.

Future Units	Per_Pasture	Per_Lawn	Per_Imperv	Ac_Pasture	Ac_Lawn	Ac_Imperv
1	55	34	11	11.9	6.1	2

Final Future Land Use/land Cover Layer

The following table summarizes changes in land cover types from Existing to Future.

Scenario	Total Acres	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)
Existing	12285.3	8486.9	1251.5	991.3	72.8	758.6	724.4
Future	12285.3	6812.3	963.4	2271.3	72.8	1441.1	724.3
Difference		-1674.6	-288.1	1280.1	0.0	682.5	0.0

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APPENDIX C. SOIL CLASSIFICATION

July 2010

APPENDIX C – SOIL CLASSIFICATION

NRCS classified most of the soils in the South Fidalgo Study Area (SFSA) in Appendix A of their Urban Hydrology Report (1986). Soils are classified by texture and infiltration potential and are summarized from the NRCS report in Table C-1.

TABLE C-1 SOIL CHARACTERISTICS		
NRCS Classification	**Texture**	**Runoff and Infiltration Characteristics**
A	Sand, loamy sand, sandy loam and coarser (gravels, cobbles)	Low runoff potential. High infiltration rates even when thoroughly wetted. Typically deep soils, well to excessively well drained with a high rate of subsurface water transmission.
B	Silt loam or loam	Moderate infiltration rates when thoroughly wetted. Typically moderately well to well-drained deep soils. Moderate rate of subsurface water transmission.
C	Sandy clay loam	Low infiltration rates when wetted. Typical profile is a soil with a subterranean layer that impedes downward movement of infiltrating water. Low rate of subsurface water transmission.
D	Clay loam, silty clay loam, sandy clay, silty clay, clay	High runoff potential with negligible infiltration rates. Chiefly clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay later at or near the nurface, or shallow soils over impervious material. These soils have a very low rate of subsurface water transmission.

Some of the soils in the SFSA are not in NRCS's Appendix A. These were classified based on their textural description (e.g., muck, silt loam, etc) and the description of their soil characteristics on the Web Soil Server (NRCS 2009). Quarries were assumed to be mostly gravels and were assigned type A.

Some soils have dual classifications, either because of differences in the drained and undrained state or because the soil is a complex of two different classes of soil. For hydrologic modeling, these needed to be simplified to one classification. This was done using the plot of soil permeability (see Figure C-1) as measured by saturated hydraulic conductivity (K_{sat}). Saturated hydraulic conductivity is a measure of a saturated soil's ability to transmit water. It can be thought of as the ease with which water moves through the soil's pores. NRCS has defined K_{sat} generally as a quantitative value to describe a soil's permeability.

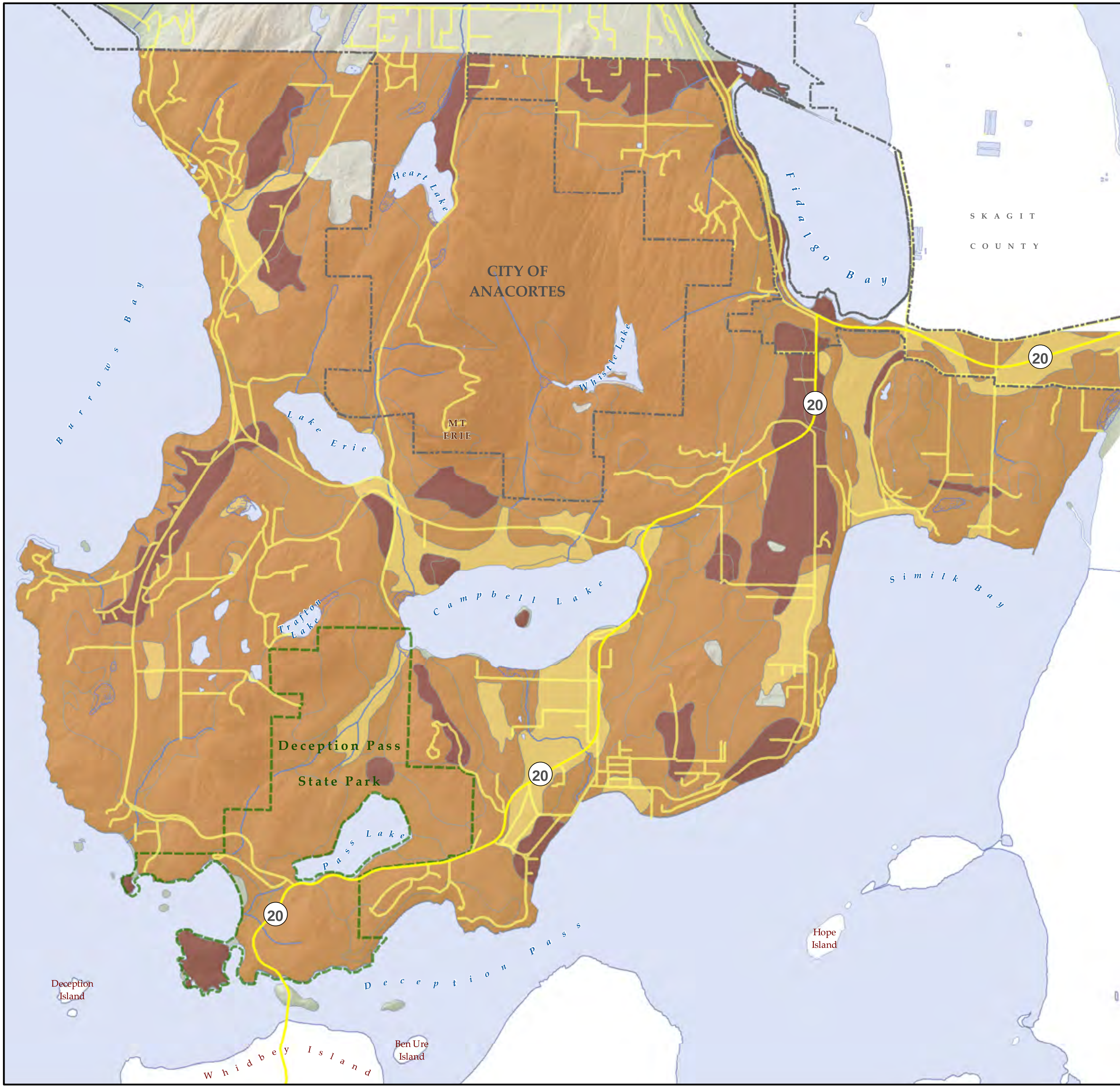
Dual classification soils located in regions with higher hydraulic conductivity rates used the more infiltrative (less runoff) classification; in lower K_{sat} rate zones, the higher runoff classification (less infiltration) was selected. Using this approach, with two exceptions, all soils fell into only one permeability zone. One soil, Coveland gravelly loam, was assigned a different soil grouping based on its slope classification. Figure C-2 shows how steeper slopes were associated with higher hydraulic conductivity; thus the steeper slopes were assigned soil type C, while flatter slopes were D.

One other soil, Whistle-Fidalgo-Rock outcrop complex, was assigned different classifications north and south of Campbell Lake. Figure C-1 demonstrates that higher K_{sat} generally occurs north of Campbell Lake, while lower K_{sat} occurs south. The Whistle-Fidalgo-Rock outcrop complex has two large distributions in the study area: north of Campbell Lake, it is assigned to soil type B; south it is classified as soil type C. This is illustrated in Figure C-3.

The resulting classifications are listed in Table C-2 for the unique soil types found in the study area with their approximate area and assigned classification letter.

TABLE C-2
SOILS IN SOUTH FIDALGO ISLAND

Soil Name	Approximate Area (acres)	NRCS Classification
Bellingham mucky silt loam	100	D
Bellingham silt loam	26	C
Bow gravelly loam, low precipitation, 0 to 8 percent slopes	390	C
Catla gravelly fine sandy loam, 0 to 15 percent slopes	1,380	D
Clallam gravelly loam, 0 to 15 percent slopes	560	B
Coveland gravelly loam, 0 to 3 percent slopes	540	D
Coveland gravelly loam, 3 to 10 percent slopes	140	C
Coveland-Bow complex, 0 to 10 percent slopes	300	D
Dystric Xerochrepts, 45 to 90 percent slopes	375	A
Fidalgo-Lithic Xerochrepts-Rock outcrop complex, 3 to 30 percent slopes	240	B
Field silt loam	4	B
Guemes variant-Rock outcrop complex, 30 to 70 percent slopes	8	A
Hydraquents, tidal	16	D
Keystone loamy sand, 0 to 30 percent slopes	250	A
Laconner very gravelly loamy sand, 0 to 15 percent slopes	690	C
Lithic Haploxerolls-Rock outcrop complex, 70 to 90 percent slopes	480	A
Mukilteo muck	8	D
Norma silt loam	65	C
Quarry Pits	100	A
Swinomish gravelly loam, 8 to 30 percent slopes	406	C
Swinomish-Fidalgo-Rock outcrop complex, 3 to 30 percent slopes	1,060	C
Tacoma silt loam, drained	31	C
Terric Medisaprists, 0 to 2 percent slopes	74	C
Tisch silty clay loam	13	D
Whistle-Fidalgo-Rock outcrop complex, 30 to 65 percent slopes (*north* of Campbell Lake)	1,285	B
Whistle-Fidalgo-Rock outcrop complex, 30 to 65 percent slopes (*south* of Campbell Lake)	2,980	C
Xerorthents, 0 to 5 percent slopes	15	A



SOUTH FIDALGO ISLAND

FIGURE C-1
SOIL PERMEABILITY

Saturated Hydraulic Conductivity (Ksat)

- Low [0.01 - 0.10) μm/s
- Moderately Low [0.10 - 1.0) μm/s
- Moderately High [1 - 10) μm/s
- High [10 - 100) μm/s

Soils Data provided by the USDA
Natural Resources Conservation Service
www.wa.nrcs.usda.gov

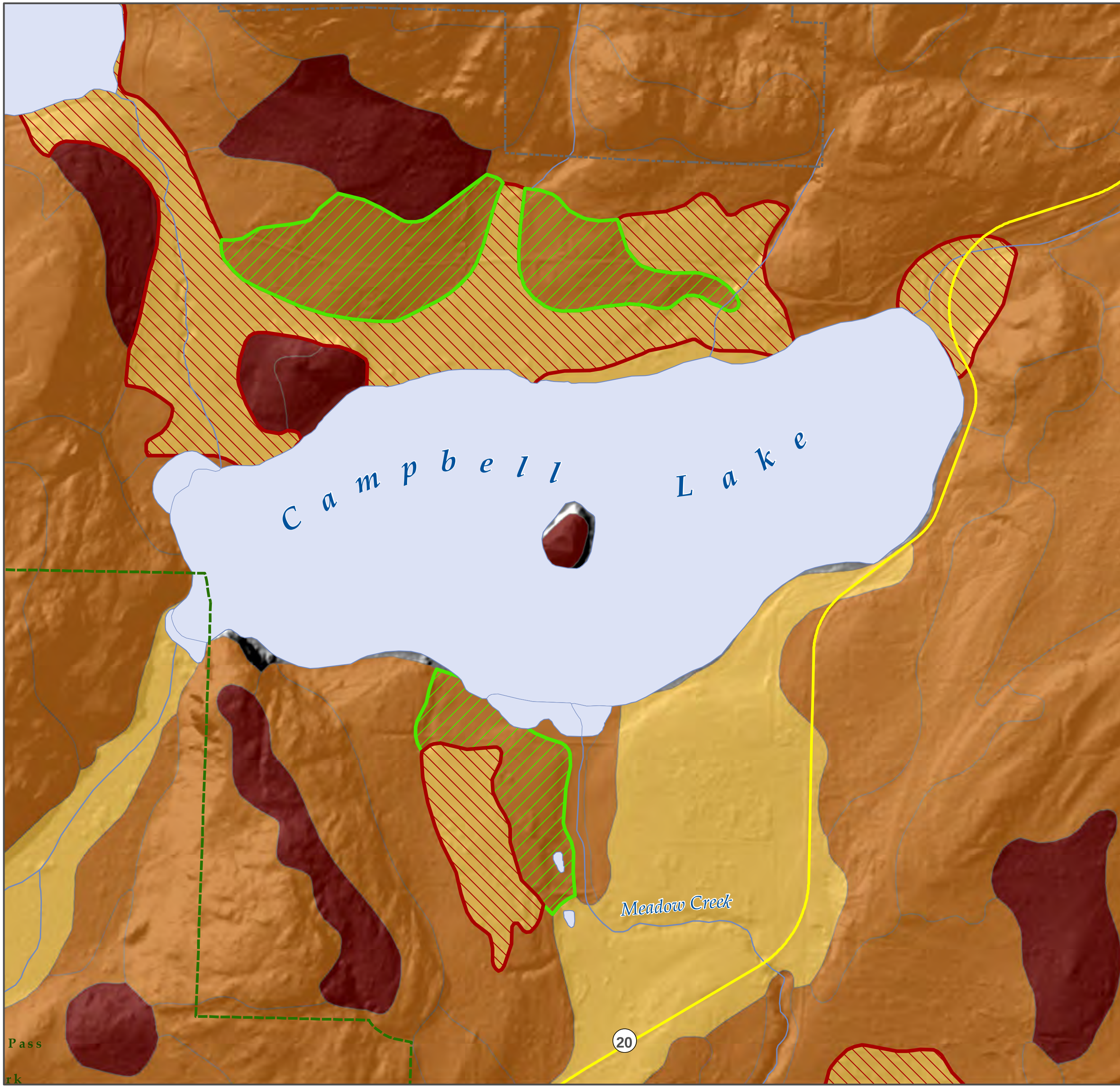
N E S W

1 inch = 4,000 feet

0 1,000 2,000 3,000 4,000 Feet

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010



SOUTH FIDALGO ISLAND

FIGURE C-2

SOIL CHARACTER AS A FUNCTION OF SLOPE & PERMEABILITY

Soil Permeability

Saturated Hydraulic Conductivity (Ksat)

- Low [0.01 - 0.10) µm/s
- Moderately Low [0.10 - 1.0) µm/s
- Moderately High [1 - 10) µm/s
- High [10 - 100) µm/s

Soil Name, Slope

- Coveland gravelly loam, 0 to 3 percent slopes
- Coveland gravelly loam, 3 to 10 percent slopes

Soils Data provided by the USDA
Natural Resources Conservation Service
www.wa.nrcs.usda.gov

N E S W

1 inch = 1,250 feet

0 625 1,250 Feet

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010

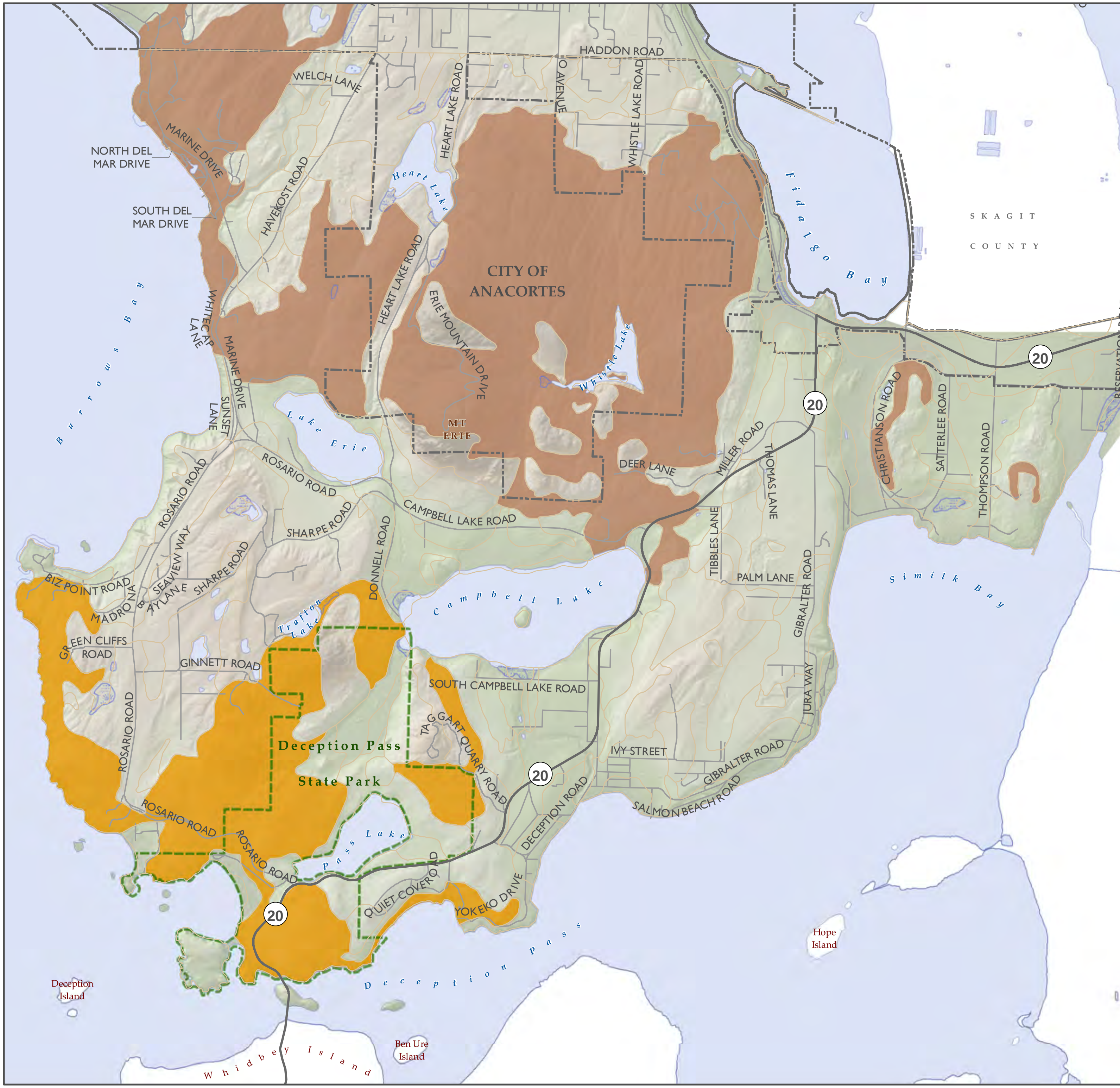
SOUTH FIDALGO ISLAND

FIGURE C-3

WHISTLE-FIDALGO-ROCK OUTCROPS, 30-65% SLOPES

For Hydrologic Model

- Whistle-Fidalgo-Rock Outcrop Complex, 30 to 65% Slopes Assigned Group B
- Whistle-Fidalgo-Rock Outcrop Complex, 30 to 65% Slopes Assigned Group C



Soils Data provided by the USDA
Natural Resources Conservation Service
www.wa.nrcs.usda.gov

N W E S

1 inch = 4,000 feet

Feet: 0, 1,000, 2,000, 3,000, 4,000

This map was created from available public records and existing map sources, and not from field surveys. Map features from all sources have been adjusted to achieve the "best fit". While great care was taken in this process, maps from different sources rarely agree as to the precise location of geographic features. This is not a substitute for field survey.

Data provided by Skagit County GIS
Cartography by Tetra Tech, Inc.
March 2010

Skagit County

South Fidalgo Island Stormwater Management Plan

APPENDIX D.
HYDROLOGIC MODELING INPUT/OUTPUT

July 2010

Table D-1
Existing Land Use by Subbasin

Subbasin	Total (acres)	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)	Percent Impervious
BB01	22.5	16.8	0.0	2.2	0.0	3.5	0.0	15.5%
BB02A	86.1	82.1	0.4	0.0	0.0	3.6	0.0	4.2%
BB02B	6.3	3.7	0.2	0.9	0.0	1.5	0.0	24.5%
BB02C	11.0	7.4	0.4	1.6	0.0	1.6	0.0	14.2%
BB03	61.8	52.6	0.5	3.0	0.0	5.7	0.0	9.2%
BB04	76.1	30.8	9.3	15.9	0.0	20.2	0.0	26.5%
BB05A	69.3	38.1	18.4	5.9	0.0	6.8	0.0	9.8%
BB05B	135.0	119.6	10.4	0.0	0.0	5.0	0.0	3.7%
BB06	20.1	13.6	4.6	0.0	0.0	2.0	0.0	9.8%
BB07	31.8	18.9	4.4	5.5	0.0	3.0	0.0	9.4%
BB08	7.4	6.8	0.0	0.0	0.0	0.6	0.0	8.3%
BB09	55.2	40.9	0.0	5.5	0.0	8.8	0.0	15.9%
BB10A	22.5	20.8	0.2	0.0	0.0	1.5	0.0	6.7%
BB10B	52.2	44.7	2.0	2.5	0.1	2.8	0.0	5.3%
BB11	18.0	16.5	0.1	0.4	0.0	1.0	0.0	5.3%
BB12	10.3	6.9	0.0	2.2	0.0	1.1	0.0	10.9%
BB13	7.7	7.2	0.0	0.0	0.0	0.4	0.0	5.6%
BB14A	8.2	6.6	0.0	1.2	0.0	0.4	0.0	5.2%
BB14B	35.2	21.3	6.7	4.6	0.0	2.6	0.0	7.3%
BB15A	23.7	13.9	0.0	6.5	0.0	3.3	0.0	14.0%
BB15B	27.2	6.3	1.4	9.9	0.0	9.6	0.0	35.2%
BB16	77.6	22.5	8.2	32.5	0.0	14.3	0.0	18.5%
BB17	100.9	84.5	1.1	7.7	0.0	7.6	0.0	7.6%
BB18	6.2	5.0	0.0	0.0	0.0	1.2	0.0	18.7%
CA01	8.4	8.2	0.1	0.0	0.0	0.1	0.0	1.5%
CA02	7.4	7.4	0.0	0.0	0.0	0.0	0.0	0.2%
CA03	43.8	8.0	0.1	19.8	0.0	5.1	10.7	11.7%
CA04A	127.4	104.0	0.2	14.7	0.0	4.2	4.3	3.3%
CA04B	50.0	41.6	1.0	1.0	6.5	0.0	0.0	0.1%
CA05	113.3	71.0	0.5	36.7	0.0	5.2	0.0	4.6%
CA06	311.1	204.7	12.2	78.0	0.0	16.2	0.0	5.2%
CL01	479.7	465.4	8.0	0.0	0.0	0.9	5.4	0.2%
CL02A	221.8	190.5	5.8	0.0	0.0	2.7	22.8	1.2%
CL02B	47.6	33.9	11.7	0.0	0.0	2.0	0.0	4.2%
CL03A	86.2	38.5	37.9	0.0	0.0	9.6	0.2	11.2%
CL03B	123.4	58.9	58.4	0.0	0.0	6.0	0.1	4.8%
CL04	431.2	197.9	105.7	0.0	0.0	10.3	117.4	2.4%
CL05	308.4	196.2	57.1	0.0	0.0	7.4	47.6	2.4%

Table D-1
Existing Land Use by Subbasin

Subbasin	Total (acres)	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)	Percent Impervious
CL06	210.4	125.0	61.6	0.4	0.0	12.5	10.9	5.9%
CL07	84.4	41.4	1.0	4.9	0.0	2.0	35.1	2.4%
CL08	73.7	56.2	0.1	3.8	0.0	1.6	11.9	2.1%
CL09	73.4	36.9	23.0	0.0	0.0	3.0	10.5	4.1%
CL10	83.7	0.7	16.4	8.2	0.0	4.1	54.2	4.9%
CL11	95.0	31.9	25.1	7.5	0.0	2.3	28.2	2.4%
CL12	60.8	26.5	0.1	1.4	0.0	0.7	32.1	1.2%
DP01	79.2	0.0	9.8	44.2	0.0	25.2	0.0	31.9%
DP02	45.4	24.2	0.2	15.1	0.0	5.9	0.0	12.9%
DP03	24.4	11.5	0.1	8.8	0.0	4.0	0.0	16.3%
DP04	19.2	17.4	0.0	0.2	0.0	1.6	0.0	8.5%
DP05	100.0	60.3	28.9	6.4	0.0	4.4	0.0	4.4%
DP06	55.5	52.1	2.6	0.6	0.0	0.2	0.0	0.4%
DP07	45.0	36.5	7.2	0.0	0.0	1.1	0.3	2.4%
DP08	21.0	20.9	0.0	0.0	0.0	0.0	0.1	0.0%
FB01	11.4	1.9	0.0	7.7	0.0	1.9	0.0	16.2%
FB02	352.4	279.1	12.3	31.1	0.0	29.8	0.0	8.5%
FB03	56.0	47.2	0.5	5.0	0.0	3.3	0.0	5.9%
FB04	130.9	123.2	0.0	0.0	0.0	7.6	0.0	5.8%
FB05	128.8	101.4	0.8	1.4	0.0	25.2	0.0	19.6%
FB06	226.2	213.2	2.2	3.9	0.0	6.9	0.0	3.0%
FB07A	127.5	107.9	2.9	5.8	8.5	2.4	0.0	1.9%
FB07B	320.3	237.9	11.5	51.1	0.0	19.9	0.0	6.2%
FB08	72.1	34.4	1.6	16.0	0.0	20.1	0.0	27.9%
FB09	162.8	68.0	1.2	85.5	0.0	8.0	0.0	4.9%
FB10	406.1	197.8	61.9	52.7	0.0	93.7	0.0	23.1%
HL01	77.7	52.7	0.0	0.0	1.4	0.0	23.6	0.0%
HL02	293.8	254.4	0.0	0.0	0.0	5.9	33.5	2.0%
LE01	174.5	60.3	52.7	0.0	0.0	8.5	53.0	4.9%
LE02A	86.4	43.2	32.8	1.8	0.0	4.9	3.8	5.7%
LE02B	73.6	44.8	20.1	2.4	0.0	2.6	3.7	3.5%
LE03A	41.3	10.7	0.0	9.7	0.0	3.7	17.2	8.9%
LE03B	62.8	40.1	9.6	0.0	9.0	4.3	0.0	6.8%
LE04	117.7	67.9	35.9	0.0	0.0	8.1	5.8	6.9%
LE05	186.2	170.8	5.2	0.0	1.1	1.4	7.7	0.7%
LE06	45.9	33.1	0.0	0.0	0.0	0.0	12.8	0.0%
LE07	335.3	329.5	0.8	0.0	0.0	3.9	1.1	1.2%
LE08	61.0	52.2	1.0	0.0	0.0	2.8	4.9	4.6%

Table D-1
Existing Land Use by Subbasin

Subbasin	Total (acres)	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)	Percent Impervious
MC01A	100.7	96.8	2.9	0.0	0.0	0.9	0.0	0.9%
MC01B	89.4	74.9	4.3	4.0	0.0	4.3	1.9	4.8%
MC02A	102.0	77.0	18.0	2.0	0.0	4.9	0.0	4.8%
MC02B	79.5	37.0	1.9	0.0	39.8	0.7	0.0	0.9%
MW01	117.3	62.2	36.1	0.0	0.0	2.2	16.8	1.9%
MW02A	130.7	98.2	19.3	8.1	0.0	5.1	0.0	3.9%
MW02B	67.7	26.5	27.9	4.8	0.0	8.5	0.0	12.6%
MW03A	28.1	8.3	0.0	12.1	0.0	7.7	0.0	27.4%
MW03B	93.2	58.9	22.7	0.0	0.0	11.6	0.0	12.5%
PL01	535.8	405.1	11.4	10.7	0.0	10.8	97.8	2.0%
RC01A	25.7	17.6	0.2	4.8	0.0	2.7	0.5	10.4%
RC01B	52.3	43.9	4.3	0.6	0.0	3.5	0.0	6.7%
RC01C	68.9	28.5	39.9	0.0	0.0	0.5	0.0	0.7%
RC01D	93.5	75.3	16.4	0.0	0.0	1.8	0.0	1.9%
RC01E	221.6	117.4	41.9	42.0	0.0	13.6	6.7	6.1%
SA01	48.6	18.9	0.6	15.0	0.0	14.1	0.0	28.9%
SA02	122.9	79.9	25.7	11.1	0.0	6.2	0.0	5.1%
SA03	66.1	37.9	12.7	7.1	0.0	8.5	0.0	12.8%
SA04	154.5	74.3	3.4	56.6	0.0	20.2	0.0	13.1%
SB01	65.3	24.6	3.8	25.4	0.0	11.5	0.0	17.6%
SB02	95.5	56.3	25.9	7.7	0.0	5.8	0.0	6.0%
SB03	141.1	76.9	51.1	0.0	6.5	6.6	0.0	4.7%
SB04A	77.9	49.9	0.7	16.1	0.1	11.1	0.0	14.3%
SB04B	192.3	95.2	2.1	77.1	0.0	18.0	0.0	9.4%
SB05	37.0	22.4	1.3	5.8	0.0	7.6	0.0	20.5%
SB06	103.0	61.6	5.5	25.0	0.0	10.8	0.0	10.5%
SB07	248.5	144.0	55.5	16.6	0.0	32.5	0.0	13.1%
SW01	21.7	19.1	0.4	0.0	0.0	2.2	0.0	10.3%
SW02	70.7	68.1	1.0	0.0	0.0	1.6	0.0	2.3%
SW03A	54.7	53.4	1.4	0.0	0.0	0.0	0.0	0.0%
SW03B	85.0	80.9	2.7	0.0	0.0	1.5	0.0	1.7%
SW04	46.3	38.5	7.6	0.0	0.0	0.2	0.0	0.4%
SW05	85.7	77.5	1.1	1.9	0.0	3.1	2.0	3.6%
SW06	18.7	15.5	2.9	0.0	0.0	0.0	0.2	0.0%
SW07	40.4	38.9	0.4	0.0	0.0	0.8	0.4	1.9%
SW08	106.6	100.5	0.2	0.0	0.0	1.9	4.1	1.8%
SW09	25.4	24.3	1.0	0.0	0.0	0.0	0.0	0.0%
WL01	423.4	404.6	0.0	0.0	0.0	0.0	18.8	0.0%

Table D-1 Existing Land Use by Subbasin								
Subbasin	Total (acres)	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)	Percent Impervious
WL02A	88.3	71.3	0.5	0.2	0.0	0.1	16.2	0.1%
WL02B	105.2	97.8	0.6	2.7	0.0	4.2	0.0	3.9%

Table D-2 Future Land Use by Subbasin								
Subbasin	Total (acres)	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)	Percent Impervious
BB01	22.5	11.4	0.0	5.3	0.0	5.7	0.0	25.5%
BB02A	86.1	35.0	0.1	29.2	0.0	21.8	0.0	25.3%
BB02B	6.3	2.9	0.1	1.3	0.0	2.0	0.0	32.3%
BB02C	11.0	6.4	0.2	2.3	0.0	2.1	0.0	19.2%
BB03	61.8	30.8	0.4	18.1	0.0	12.5	0.0	20.2%
BB04	76.1	18.6	6.0	24.6	0.0	26.9	0.0	35.3%
BB05A	69.3	19.7	7.0	23.1	0.0	19.6	0.0	28.3%
BB05B	135.0	81.1	9.7	28.0	0.0	16.3	0.0	12.1%
BB06	20.1	8.6	3.9	3.3	0.0	4.3	0.0	21.4%
BB07	31.8	12.0	2.2	10.7	0.0	6.9	0.0	21.7%
BB08	7.4	4.9	0.0	1.1	0.0	1.4	0.0	19.1%
BB09	55.2	33.8	0.0	9.4	0.0	12.0	0.0	21.8%
BB10A	22.5	13.8	0.1	4.2	0.0	4.4	0.0	19.7%
BB10B	52.2	40.1	1.9	5.4	0.1	4.7	0.0	8.9%
BB11	18.0	14.4	0.0	1.7	0.0	1.8	0.0	10.2%
BB12	10.3	6.1	0.0	2.7	0.0	1.5	0.0	14.9%
BB13	7.7	6.8	0.0	0.3	0.0	0.6	0.0	8.0%
BB14A	8.2	5.5	0.0	1.8	0.0	0.9	0.0	10.8%
BB14B	35.2	17.9	6.3	6.9	0.0	4.1	0.0	11.7%
BB15A	23.7	7.8	0.0	10.0	0.0	5.8	0.0	24.6%
BB15B	27.2	4.6	1.4	10.6	0.0	10.6	0.0	39.1%
BB16	77.6	19.5	8.0	33.8	0.0	16.4	0.0	21.1%
BB17	100.9	56.3	1.1	25.3	0.0	18.3	0.0	18.1%
BB18	6.2	4.4	0.0	0.4	0.0	1.4	0.0	23.1%
CA01	8.4	2.6	0.0	3.3	0.0	2.4	0.0	29.1%
CA02	7.4	4.1	0.0	2.5	0.0	0.8	0.0	11.2%

Table D-2
Future Land Use by Subbasin

Subbasin	Total (acres)	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)	Percent Impervious
CA03	43.8	5.2	0.1	21.2	0.0	6.6	10.7	15.1%
CA04A	127.4	98.0	0.0	19.3	0.0	5.9	4.3	4.6%
CA04B	50.0	41.6	1.0	1.0	6.5	0.0	0.0	0.1%
CA05	113.3	66.1	0.4	37.8	0.0	9.0	0.0	8.0%
CA06	311.1	154.0	4.1	105.2	0.0	47.7	0.0	15.3%
CL01	479.7	436.4	7.7	21.6	0.0	8.6	5.4	1.8%
CL02A	221.8	148.4	4.8	30.3	0.0	15.5	22.8	7.0%
CL02B	47.6	21.5	8.4	11.0	0.0	6.7	0.0	14.1%
CL03A	86.2	24.4	34.4	11.7	0.0	15.5	0.2	18.0%
CL03B	123.4	39.9	47.0	22.4	0.0	13.9	0.1	11.3%
CL04	431.2	172.6	85.8	34.1	0.0	21.3	117.4	4.9%
CL05	308.4	179.6	49.3	18.5	0.0	13.4	47.6	4.3%
CL06	210.4	86.1	48.5	39.7	0.0	25.2	10.9	12.0%
CL07	84.4	34.5	0.6	10.0	0.0	4.2	35.1	4.9%
CL08	73.7	48.4	0.1	9.6	0.0	3.7	11.9	5.0%
CL09	73.4	30.4	17.4	8.2	0.0	6.9	10.5	9.4%
CL10	83.7	0.2	6.0	13.2	0.0	10.0	54.2	11.9%
CL11	95.0	17.8	20.8	21.2	0.0	7.0	28.2	7.4%
CL12	60.8	17.2	0.1	8.4	0.0	3.0	32.1	5.0%
DP01	79.2	0.0	7.5	43.7	0.0	28.0	0.0	35.3%
DP02	45.4	11.5	0.2	21.5	0.0	12.3	0.0	27.1%
DP03	24.4	6.7	0.0	11.1	0.0	6.5	0.0	26.7%
DP04	19.2	7.5	0.0	6.0	0.0	5.7	0.0	29.6%
DP05	100.0	30.5	13.9	31.7	0.0	24.0	0.0	24.0%
DP06	55.5	52.1	2.6	0.4	0.0	0.4	0.0	0.7%
DP07	45.0	36.5	7.2	0.0	0.0	1.1	0.3	2.4%
DP08	21.0	20.9	0.0	0.0	0.0	0.0	0.1	0.0%
FB01	11.4	1.3	0.0	7.1	0.0	3.0	0.0	26.7%
FB02	352.4	231.6	5.3	59.7	0.0	55.7	0.0	15.8%
FB03	56.0	23.4	0.4	17.9	0.0	14.3	0.0	25.5%
FB04	130.9	60.2	0.0	37.1	0.0	33.6	0.0	25.7%
FB05	128.8	71.4	0.7	19.2	0.0	37.5	0.0	29.1%
FB06	226.2	188.8	1.3	21.2	0.0	14.9	0.0	6.6%
FB07A	127.5	72.2	2.5	33.1	8.5	11.2	0.0	8.8%
FB07B	320.3	127.9	6.8	133.2	0.0	52.4	0.0	16.4%
FB08	72.1	23.4	1.6	23.0	0.0	24.1	0.0	33.4%
FB09	162.8	65.8	1.2	87.0	0.0	8.7	0.0	5.4%
FB10	406.1	166.6	54.9	78.1	0.0	106.4	0.0	26.2%

Table D-2 Future Land Use by Subbasin								
Subbasin	**Total (acres)**	**Forest (acres)**	**Pasture (acres)**	**Lawn (acres)**	**Quarry (acres)**	**Impervious (acres)**	**Water (acres)**	**Percent Impervious**
HL01	77.7	52.7	0.0	0.0	1.4	0.0	23.6	0.0%
HL02	293.8	254.4	0.0	0.0	0.0	5.9	33.5	2.0%
LE01	174.5	48.0	35.8	18.3	0.0	19.4	53.0	11.1%
LE02A	86.4	33.7	27.2	11.1	0.0	10.6	3.8	12.2%
LE02B	73.6	31.1	13.5	17.2	0.0	8.1	3.7	11.0%
LE03A	41.3	6.4	0.0	11.3	0.0	6.5	17.2	15.7%
LE03B	62.8	35.3	6.8	4.6	9.0	7.2	0.0	11.4%
LE04	117.7	43.7	26.6	22.8	0.0	18.9	5.8	16.0%
LE05	186.2	118.0	3.7	40.6	1.1	15.1	7.7	8.1%
LE06	45.9	28.3	0.0	3.6	0.0	1.2	12.8	2.6%
LE07	335.3	311.1	0.7	14.0	0.0	8.4	1.1	2.5%
LE08	61.0	41.3	0.7	8.0	0.0	6.0	4.9	9.9%
MC01A	100.7	63.0	2.7	25.5	0.0	9.5	0.0	9.5%
MC01B	89.4	74.6	4.3	4.2	0.0	4.4	1.9	4.9%
MC02A	102.0	58.7	15.7	15.7	0.0	11.9	0.0	11.6%
MC02B	79.5	37.0	1.9	0.0	39.8	0.7	0.0	0.9%
MW01	117.3	45.9	32.8	14.3	0.0	7.5	16.8	6.4%
MW02A	130.7	72.4	11.0	31.7	0.0	15.6	0.0	11.9%
MW02B	67.7	12.3	19.1	17.6	0.0	18.6	0.0	27.5%
MW03A	28.1	6.1	0.0	12.6	0.0	9.4	0.0	33.6%
MW03B	93.2	24.0	17.7	23.6	0.0	27.9	0.0	29.9%
PL01	535.8	404.4	11.4	9.3	0.0	12.9	97.8	2.4%
RC01A	25.7	13.8	0.1	7.5	0.0	3.8	0.5	14.8%
RC01B	52.3	30.4	2.6	12.1	0.0	7.2	0.0	13.9%
RC01C	68.9	20.3	23.5	18.5	0.0	6.5	0.0	9.4%
RC01D	93.5	51.9	11.7	21.2	0.0	8.6	0.0	9.2%
RC01E	221.6	102.6	37.4	54.7	0.0	20.2	6.7	9.1%
SA01	48.6	13.7	0.6	18.0	0.0	16.3	0.0	33.6%
SA02	122.9	46.4	13.1	37.8	0.0	25.7	0.0	20.9%
SA03	66.1	19.5	6.6	21.0	0.0	19.0	0.0	28.7%
SA04	154.5	49.4	3.0	66.8	0.0	35.3	0.0	22.9%
SB01	65.3	15.1	1.4	31.7	0.0	17.1	0.0	26.2%
SB02	95.5	34.1	19.5	28.3	0.0	13.6	0.0	14.3%
SB03	141.1	57.8	47.4	15.9	6.5	13.5	0.0	9.6%
SB04A	77.9	37.6	0.5	25.4	0.1	14.3	0.0	18.4%
SB04B	192.3	71.4	1.6	91.1	0.0	28.2	0.0	14.7%
SB05	37.0	12.2	0.7	13.3	0.0	10.9	0.0	29.3%
SB06	103.0	38.7	4.5	40.5	0.0	19.4	0.0	18.8%

Table D-2
Future Land Use by Subbasin

Subbasin	Total (acres)	Forest (acres)	Pasture (acres)	Lawn (acres)	Quarry (acres)	Impervious (acres)	Water (acres)	Percent Impervious
SB07	248.5	89.3	47.8	60.0	0.0	51.4	0.0	20.7%
SW01	21.7	14.1	0.4	3.0	0.0	4.3	0.0	19.8%
SW02	70.7	65.1	1.0	2.3	0.0	2.3	0.0	3.3%
SW03A	54.7	52.9	1.4	0.4	0.0	0.1	0.0	0.2%
SW03B	85.0	76.9	2.2	3.4	0.0	2.6	0.0	3.0%
SW04	46.3	31.7	7.3	5.4	0.0	1.9	0.0	4.2%
SW05	85.7	62.3	1.1	13.4	0.0	6.8	2.0	8.0%
SW06	18.7	15.5	2.9	0.0	0.0	0.0	0.2	0.0%
SW07	40.4	32.6	0.4	4.8	0.0	2.3	0.4	5.7%
SW08	106.6	82.8	0.1	13.4	0.0	6.2	4.1	5.9%
SW09	25.4	24.3	1.0	0.0	0.0	0.0	0.0	0.0%
WL01	423.4	404.6	0.0	0.0	0.0	0.0	18.8	0.0%
WL02A	88.3	66.9	0.4	3.6	0.0	1.2	16.2	1.3%
WL02B	105.2	86.5	0.6	11.3	0.0	6.9	0.0	6.6%

Table D-3
Subbasin Land Use by Soil Type/Cover for WWHM

	Existing				Future			
	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)
BB01	19.0	0.0	0.0	3.5	16.8	0.0	0.0	5.7
BB02A	82.5	0.0	0.0	3.6	64.3	0.0	0.0	21.8
BB02B	4.7	0.0	0.0	1.5	4.2	0.0	0.0	2.0
BB02C	9.4	0.0	0.0	1.6	8.9	0.0	0.0	2.1
BB03	56.1	0.0	0.0	5.7	49.3	0.0	0.0	12.5
BB04	41.4	14.5	0.0	20.2	35.6	13.6	0.0	26.9
BB05A	17.3	17.3	27.8	6.8	14.6	13.1	22.1	19.6
BB05B	49.4	60.5	20.1	5.0	45.4	56.3	16.9	16.3
BB06	18.1	0.0	0.0	2.0	15.8	0.0	0.0	4.3
BB07	28.6	0.0	0.2	3.0	24.7	0.0	0.1	6.9
BB08	6.8	0.0	0.0	0.6	6.0	0.0	0.0	1.4
BB09	42.6	3.8	0.0	8.8	39.7	3.4	0.0	12.0
BB10A	21.0	0.0	0.0	1.5	18.1	0.0	0.0	4.4

Table D-3 Subbasin Land Use by Soil Type/Cover for WWHM								
	Existing				Future			
	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)
BB10B	33.9	0.0	15.5	2.8	32.4	0.0	15.1	4.7
BB11	17.0	0.0	0.0	1.0	16.2	0.0	0.0	1.8
BB12	9.2	0.0	0.0	1.1	8.8	0.0	0.0	1.5
BB13	7.2	0.0	0.0	0.4	7.1	0.0	0.0	0.6
BB14A	7.8	0.0	0.0	0.4	7.3	0.0	0.0	0.9
BB14B	2.7	0.0	29.9	2.6	2.7	0.0	28.4	4.1
BB15A	20.4	0.0	0.0	3.3	17.9	0.0	0.0	5.8
BB15B	6.5	0.0	11.1	9.6	6.3	0.0	10.2	10.6
BB16	20.4	3.2	39.6	14.3	18.8	3.1	39.3	16.4
BB17	19.1	48.1	26.1	7.6	16.4	41.0	25.3	18.3
BB18	0.0	5.0	0.0	1.2	0.0	4.8	0.0	1.4
CA01	8.3	0.0	0.0	0.1	6.0	0.0	0.0	2.4
CA02	7.4	0.0	0.0	0.0	6.6	0.0	0.0	0.8
CA03	25.1	2.6	0.2	15.8	24.0	2.3	0.1	17.3
CA04A	96.6	22.4	0.0	8.5	95.0	22.2	0.0	10.1
CA04B	50.0	0.0	0.0	0.0	50.0	0.0	0.0	0.0
CA05	45.6	62.6	0.0	5.2	44.4	59.9	0.0	9.0
CA06	260.3	34.6	0.0	16.2	235.2	28.2	0.0	47.7
CL01	149.1	291.6	32.7	6.3	147.5	285.5	32.7	14.0
CL02A	40.3	101.6	54.4	25.5	38.0	97.0	48.4	38.2
CL02B	0.0	0.0	45.6	2.0	0.0	0.0	40.9	6.7
CL03A	5.4	23.1	47.9	9.8	5.3	20.7	44.5	15.7
CL03B	15.8	64.0	37.4	6.1	15.0	58.4	36.0	14.0
CL04	181.2	79.5	42.8	127.7	177.1	74.9	40.5	138.7
CL05	193.1	22.3	38.0	55.1	189.0	21.6	36.8	61.0
CL06	146.3	15.1	25.7	23.3	136.3	13.8	24.3	36.0
CL07	12.3	8.8	26.2	37.1	11.7	8.4	25.0	39.3
CL08	12.7	18.5	29.0	13.5	12.1	17.2	28.8	15.6
CL09	48.7	2.6	8.7	13.5	45.7	2.4	7.9	17.4
CL10	5.0	0.0	20.3	58.4	3.6	0.0	15.9	64.2
CL11	6.2	44.9	13.5	30.5	5.5	41.4	13.0	35.2
CL12	7.1	21.0	0.0	32.8	6.3	19.4	0.0	35.1
DP01	0.0	21.9	32.0	25.2	0.0	21.1	30.1	28.0
DP02	0.0	39.1	0.5	5.9	0.0	32.7	0.4	12.3
DP03	0.0	20.4	0.0	4.0	0.0	17.9	0.0	6.5
DP04	0.0	17.6	0.0	1.6	0.0	13.6	0.0	5.7
DP05	0.0	89.3	6.2	4.4	0.0	70.3	5.7	24.0

Table D-3
Subbasin Land Use by Soil Type/Cover for WWHM

	Existing				Future			
	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)
DP06	0.0	39.5	15.9	0.2	0.0	39.4	15.8	0.4
DP07	0.0	43.7	0.0	1.4	0.0	43.7	0.0	1.4
DP08	20.9	0.0	0.0	0.1	20.9	0.0	0.0	0.1
FB01	9.6	0.0	0.0	1.9	8.4	0.0	0.0	3.0
FB02	322.5	0.0	0.0	29.8	296.7	0.0	0.0	55.7
FB03	52.7	0.0	0.0	3.3	41.7	0.0	0.0	14.3
FB04	123.2	0.0	0.0	7.6	97.3	0.0	0.0	33.6
FB05	95.9	7.7	0.0	25.2	84.4	6.9	0.0	37.5
FB06	203.6	15.8	0.0	6.9	196.4	14.9	0.0	14.9
FB07A	16.7	63.5	44.9	2.4	16.0	58.9	41.4	11.2
FB07B	165.8	134.6	0.0	19.9	154.4	113.5	0.0	52.4
FB08	8.3	38.9	4.9	20.1	6.9	36.8	4.3	24.1
FB09	32.1	64.0	58.6	8.0	31.9	63.9	58.2	8.7
FB10	13.1	242.7	56.6	93.7	12.8	235.6	51.3	106.4
HL01	24.3	29.8	0.0	23.6	24.3	29.8	0.0	23.6
HL02	192.8	61.6	0.0	39.4	192.8	61.6	0.0	39.4
LE01	0.0	11.9	101.2	61.5	0.0	10.6	91.6	72.3
LE02A	0.0	5.7	72.0	8.7	0.0	4.6	67.5	14.3
LE02B	0.0	8.6	58.7	6.3	0.0	7.8	54.0	11.8
LE03A	0.0	18.9	1.5	20.8	0.0	16.1	1.5	23.7
LE03B	6.2	3.3	49.0	4.3	6.2	3.3	46.1	7.2
LE04	56.1	47.1	0.6	13.9	50.3	42.2	0.5	24.7
LE05	165.8	11.3	0.0	9.1	152.9	10.4	0.0	22.8
LE06	29.3	3.8	0.0	12.8	28.3	3.6	0.0	14.0
LE07	268.1	60.8	1.4	5.0	264.3	60.0	1.4	9.5
LE08	23.2	27.4	2.6	7.8	22.4	25.0	2.5	11.0
MC01A	45.6	54.2	0.0	0.9	40.3	50.9	0.0	9.5
MC01B	59.4	17.7	6.1	6.2	59.3	17.7	6.1	6.3
MC02A	15.9	44.2	36.9	4.9	15.0	40.8	34.4	11.9
MC02B	65.3	13.5	0.0	0.7	65.3	13.5	0.0	0.7
MW01	12.1	41.6	44.7	19.0	11.3	39.0	42.7	24.3
MW02A	13.2	74.6	37.8	5.1	12.9	70.1	32.1	15.6
MW02B	0.3	0.0	58.9	8.5	0.2	0.0	48.8	18.6
MW03A	5.4	2.4	12.5	7.7	5.0	2.1	11.5	9.4
MW03B	53.7	17.1	10.9	11.6	42.3	14.0	9.1	27.9
PL01	10.7	311.5	104.9	108.6	10.7	309.4	104.9	110.7
RC01A	0.0	17.0	5.6	3.2	0.0	16.0	5.4	4.3

Table D-3
Subbasin Land Use by Soil Type/Cover for WWHM

	Existing				Future			
	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)	A/B (acres)	C (acres)	Sat (acres)	Imperv. (acres)
RC01B	0.0	22.8	26.0	3.5	0.0	20.9	24.1	7.2
RC01C	0.0	31.5	36.9	0.5	0.0	28.3	34.1	6.5
RC01D	0.0	59.9	31.8	1.8	0.0	55.0	29.8	8.6
RC01E	0.0	0.4	201.0	20.3	0.0	0.3	194.4	26.9
SA01	12.8	21.0	0.8	14.1	11.7	19.9	0.6	16.3
SA02	0.6	81.8	34.3	6.2	0.6	67.9	28.8	25.7
SA03	6.4	51.2	0.0	8.5	5.4	41.7	0.0	19.0
SA04	4.8	59.5	70.1	20.2	4.5	53.0	61.7	35.3
SB01	32.8	14.6	6.3	11.5	29.5	13.3	5.4	17.1
SB02	11.0	21.3	57.6	5.8	9.5	18.9	53.4	13.6
SB03	23.5	42.1	68.9	6.6	21.2	40.0	66.3	13.5
SB04A	0.0	66.7	0.0	11.1	0.0	63.6	0.0	14.3
SB04B	59.4	49.9	65.0	18.0	53.9	46.8	63.5	28.2
SB05	0.0	27.5	2.0	7.6	0.0	24.4	1.8	10.9
SB06	3.2	77.7	11.2	10.8	2.9	70.5	10.3	19.4
SB07	6.3	172.1	37.6	32.5	5.7	160.2	31.2	51.4
SW01	0.0	19.5	0.0	2.2	0.0	17.4	0.0	4.3
SW02	0.0	54.6	14.5	1.6	0.0	54.3	14.1	2.3
SW03A	0.0	45.5	9.3	0.0	0.0	45.3	9.3	0.1
SW03B	0.0	10.0	73.5	1.5	0.0	10.0	72.4	2.6
SW04	0.0	46.1	0.0	0.2	0.0	44.3	0.0	1.9
SW05	1.6	61.9	17.0	5.1	1.6	58.2	17.0	8.8
SW06	2.2	15.7	0.6	0.2	2.2	15.7	0.6	0.2
SW07	0.0	39.3	0.0	1.1	0.0	37.7	0.0	2.7
SW08	0.0	100.7	0.0	6.0	0.0	96.3	0.0	10.3
SW09	25.3	0.0	0.0	0.0	25.3	0.0	0.0	0.0
WL01	404.6	0.0	0.0	18.8	404.6	0.0	0.0	18.8
WL02A	72.1	0.0	0.0	16.3	71.0	0.0	0.0	17.4
WL02B	74.8	26.3	0.0	4.2	72.0	26.3	0.0	6.9

Table D-4
Hydrologic Modeling Results

Subbasin ID	Existing Conditions Peak Flow (cfs) 2-Year	10-year	100-Year	Future Conditions Peak Flow (cfs) 2-Year	10-year	100-Year
BB01	0.9	1.5	2.4	1.6	2.5	4.0
BB02A	1.0	1.6	2.5	5.9	9.7	15.2
BB02B	0.4	0.6	1.0	0.5	0.9	1.4
BB02C	0.4	0.7	1.1	0.6	0.9	1.4
BB03	1.4	2.4	3.8	3.3	5.4	8.7
BB04	5.4	9.2	15.1	7.2	12.2	20.0
BB05A	1.9	3.7	7.2	5.3	9.3	15.9
BB05B	1.8	3.8	8.1	4.9	8.9	16.1
BB06	0.5	0.8	1.3	1.2	1.9	2.9
BB07	0.8	1.3	2.1	1.8	3.0	4.9
BB08	0.2	0.3	0.4	0.4	0.6	1.0
BB09	2.2	3.7	6.0	3.0	5.1	8.2
BB10A	0.3	0.6	0.9	1.1	1.8	2.8
BB10B	0.7	1.5	3.1	1.2	2.3	4.2
BB11	0.2	0.4	0.6	0.5	0.8	1.3
BB12	0.3	0.5	0.8	0.4	0.7	1.1
BB13	0.1	0.2	0.3	0.2	0.3	0.4
BB14A	0.1	0.2	0.3	0.2	0.4	0.6
BB14B	0.7	1.6	3.6	1.1	2.2	4.3
BB15A	0.8	1.4	2.3	1.5	2.5	4.1
BB15B	2.4	4.1	6.8	2.6	4.5	7.5
BB16	3.6	6.4	11.4	4.1	7.3	12.8
BB17	2.3	4.3	8.2	5.1	9.2	16.3
BB18	0.3	0.6	1.0	0.4	0.7	1.2
CA01	0.0	0.1	0.1	0.6	1.1	1.7
CA02	0.0	0.0	0.0	0.2	0.4	0.6
CA03	3.7	6.2	10.1	4.1	6.9	11.3
CA04A	2.2	3.8	6.5	2.6	4.5	7.6
CA04B	0.0	0.0	0.1	0.0	0.0	0.1
CA05	2.3	4.9	10.4	3.3	6.4	12.5
CA06	4.2	7.5	13.4	12.2	20.7	34.2
CL01	5.1	12.9	28.7	7.0	15.3	33.6
CL02A	6.8	12.6	23.7	10.4	18.6	33.3
CL02B	0.6	1.5	3.7	1.7	3.2	6.1
CL03A	2.9	5.7	11.3	4.5	8.3	15.2
CL03B	2.3	4.8	10.3	4.6	8.7	16.9
CL04	30.2	50.8	82.6	33.4	56.2	91.9
CL05	13.0	22.1	37.1	14.6	24.9	41.6
CL06	5.8	9.9	16.7	9.2	15.8	26.6
CL07	8.7	14.8	24.8	9.3	15.8	26.4

Table D-4
Hydrologic Modeling Results

Subbasin ID	Existing Conditions Peak Flow (cfs) 2-Year	10-year	100-Year	Future Conditions Peak Flow (cfs) 2-Year	10-year	100-Year
CL08	3.4	6.0	10.8	4.0	7.1	12.8
CL09	3.2	5.4	9.1	4.3	7.2	11.7
CL10	13.5	22.7	36.8	15.0	25.1	40.6
CL11	7.5	13.0	22.0	9.0	15.6	26.6
CL12	7.7	12.9	20.9	8.4	14.2	23.1
DP01	6.9	12.6	22.8	7.6	13.6	23.8
DP02	2.0	3.8	7.3	3.6	6.6	12.0
DP03	1.4	2.7	5.0	2.1	3.8	7.0
DP04	0.5	1.0	1.9	1.6	2.9	5.0
DP05	2.4	5.1	10.7	7.6	13.8	25.0
DP06	0.6	1.8	3.8	0.6	1.8	4.1
DP07	0.8	1.9	4.2	0.8	1.9	4.2
DP08	0.0	0.0	0.0	0.0	0.0	0.0
FB01	0.4	0.8	1.3	0.8	1.3	2.1
FB02	7.2	11.9	19.3	13.9	23.1	37.1
FB03	0.8	1.4	2.2	3.8	6.2	10.0
FB04	1.9	3.1	4.9	8.6	14.0	21.8
FB05	6.2	10.3	16.5	9.4	15.6	24.9
FB06	1.8	3.1	5.3	3.9	6.6	10.7
FB07A	1.3	3.2	7.9	3.5	6.9	13.9
FB07B	6.1	11.5	21.4	15.2	27.6	49.9
FB08	5.2	9.0	15.4	6.2	10.8	18.5
FB09	3.4	7.6	17.8	3.5	7.9	18.1
FB10	24.7	43.9	78.0	28.0	49.7	88.2
HL01	5.6	9.4	15.6	5.6	9.4	15.6
HL02	9.5	16.1	26.8	9.5	16.1	26.8
LE01	13.9	23.8	40.1	16.6	28.3	47.5
LE02A	2.3	4.5	9.0	3.7	6.7	12.4
LE02B	1.7	3.5	7.3	3.0	5.7	10.7
LE03A	5.0	8.5	14.0	5.7	9.7	16.0
LE03B	1.3	2.8	6.2	2.0	3.9	7.6
LE04	3.6	6.2	10.9	6.3	10.8	18.3
LE05	2.1	3.5	5.8	5.6	9.4	15.1
LE06	2.8	4.7	7.6	3.1	5.2	8.4
LE07	1.7	3.3	6.4	2.8	5.1	9.2
LE08	2.0	3.5	6.0	2.9	5.0	8.6
MC01A	0.7	1.8	4.2	2.9	5.3	9.7
MC01B	1.5	2.6	4.5	1.5	2.6	4.6
MC02A	1.7	3.4	7.2	3.5	6.4	11.9
MC02B	0.3	0.7	1.6	0.3	0.7	1.6

Table D-4 Hydrologic Modeling Results						
	Existing Conditions Peak Flow (cfs)			Future Conditions Peak Flow (cfs)		
Subbasin ID	**2-Year**	**10-year**	**100-Year**	**2-Year**	**10-year**	**100-Year**
MW01	4.5	7.9	13.9	5.9	10.5	18.5
MW02A	2.0	4.2	9.1	4.6	8.7	16.7
MW02B	2.0	3.8	6.9	4.4	7.6	13.4
MW03A	1.9	3.4	5.8	2.3	4.0	6.9
MW03B	2.9	4.9	8.1	7.1	11.8	19.2
PL01	26.3	46.1	80.7	26.7	46.8	81.8
RC01A	1.0	1.8	3.5	1.3	2.4	4.5
RC01B	1.1	2.1	4.4	2.1	3.9	7.4
RC01C	0.6	1.7	4.9	2.1	4.1	8.2
RC01D	1.1	2.9	7.4	3.0	6.0	11.9
RC01E	5.3	11.0	23.5	6.8	13.5	27.1
SA01	3.7	6.4	10.9	4.3	7.4	12.6
SA02	2.4	5.1	10.7	7.2	13.1	23.8
SA03	2.6	4.7	8.5	5.3	9.3	16.0
SA04	5.6	10.7	20.8	9.4	17.0	30.7
SB01	3.0	5.2	9.0	4.3	7.5	12.7
SB02	1.5	3.1	6.2	3.5	6.4	11.8
SB03	2.0	4.2	8.8	3.7	7.1	13.6
SB04A	3.1	5.7	10.5	3.9	7.3	13.4
SB04B	5.0	9.6	18.8	7.6	14.0	25.7
SB05	2.0	3.6	6.4	3.0	5.3	9.2
SB06	3.4	6.6	12.9	5.7	10.5	19.4
SB07	9.1	16.5	30.0	13.9	25.1	45.2
SW01	0.7	1.3	2.4	1.2	2.2	4.0
SW02	1.0	2.5	5.6	1.2	2.7	6.1
SW03A	0.7	1.8	3.6	0.7	1.9	3.8
SW03B	0.6	2.1	7.7	0.9	2.5	7.2
SW04	0.7	1.9	3.7	1.1	2.4	5.1
SW05	1.8	3.6	7.4	2.9	5.5	10.4
SW06	0.2	0.6	1.4	0.2	0.6	1.4
SW07	0.7	1.6	3.6	1.1	2.2	4.6
SW08	2.2	4.7	10.0	3.5	6.8	13.0
SW09	0.0	0.0	0.0	0.0	0.0	0.0
WL01	4.1	6.8	10.9	4.1	6.8	10.9
WL02A	3.5	5.9	9.5	3.8	6.4	10.2
WL02B	1.2	2.1	3.7	1.8	3.2	5.5

Skagit County

South Fidalgo Island Stormwater Management Plan

APPENDIX E.
LOW IMPACT DEVELOPMENT METHODS

July 2010

APPENDIX E
LOW IMPACT DEVELOPMENT METHODS

Low impact development is a stormwater management strategy that emphasizes conservation and use of existing natural site features integrated with distributed, small-scale stormwater controls to more closely mimic natural hydrologic patterns in residential and commercial settings. Common techniques and a description of the watershed benefits are described in the following sections. This information was taken from the websites of the Low Impact Development Center (http://www.lowimpactdevelopment.org) and the Low Impact Development Urban Design Tools (http://www.lid-stormwater.net).

INTRODUCTION

The basic principle of low impact development (LID) is modeled after nature: manage rainfall at the source using uniformly distributed decentralized micro-scale controls. LID's goal is to mimic a site's predevelopment hydrology by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Techniques are based on the premise that stormwater management should not be seen as stormwater disposal. Instead of conveying and managing / treating stormwater in large, costly end-of-pipe facilities located at the bottom of drainage areas, LID addresses stormwater through small, cost-effective landscape features located at the lot level. These landscape features, known as Integrated Management Practices (IMPs), are the building blocks of LID. Almost all components of the urban environment have the potential to serve as an IMP. This includes not only open space, but also rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can be applied equally well to new development, urban retrofits, and redevelopment / revitalization projects.

In the appropriate setting, LID has benefits and advantages over conventional stormwater management approaches. It is a more environmentally sound technology and a more economically sustainable approach to addressing the adverse impacts of land use conversion. LID allows for greater development potential with less environmental impacts through the use of designs and technologies that achieve a better balance between conservation, growth, ecosystem protection, public health and quality of life. It is a comprehensive multi-systems approach that has built-in redundancy, reducing the possibility of failure. Many LID techniques have nothing to do with nor can they be significantly influenced by the behavior of a property owner. These include basic subdivision and infrastructure design features such as reducing the use of pipes, ponds, curbs and gutters; maintaining recharge areas, buffer zones, and drainage courses; using infiltration swales, grading strategies, and open drainage systems; reducing impervious surfaces and disconnecting those that must be used; and conserving open space. However, the key factor in the success of LID is to ensure that the landscape practices (such as rain gardens) are attractive and perceived by the property owner as adding value to the property. If these LID practices are viewed as assets, the primary motivation for their long-term maintenance is that of property owners protecting their vested economic interests. Additionally, experience has shown that educational efforts can successfully promote active public engagement in protecting our waters by the simple act of people maintaining their properties. In actuality, LID site source controls reduce maintenance burdens for property owners and local governments. The techniques are simple, need no special equipment or high costs to maintain, and encourage property owners to be responsible for the impacts associated with their land.

Applications

Land use on Fidalgo Island can be divided into three major land use types: residential, roads and transportation, and commercial//educational. The recommended LID methods for these areas are summarized below and described in greater detail in the subsequent sections. Most of these methods are appropriate only for regions where infiltration to groundwater will not create greater slope instability concerns.

- Residential
  - Use soil amendments in landscaping areas to improve infiltration of rainwater.
  - Landscape with a rain garden to provide on-lot detention, filtering of rainwater, and groundwater recharge.
  - Disconnect the gutters and downspouts from roofs and direct the flow to a rain garden.
  - Retain rooftop runoff in a rain barrel for later on-lot use in lawn and garden watering.
  - Combine the rain gardens with grassed swales to replace a curb-and-gutter system.
  - Use permeable pavers for walkways and parking areas.
- Roads and Transportation
  - Build narrower residential streets or restrict parking and sidewalk areas to one side of the road rather than both. Replace the space gained with pervious areas, bioretention facilities, or vegetated channels.
  - Use a linear bioretention cell in the highway median to treat runoff.
  - Disconnect sidewalks by relocating them away from the roadway or directing their runoff into a tree box filter or an open drainage system that leads to an infiltration practice.
  - Use permeable pavers for emergency stopping areas, crosswalks, sidewalks, road shoulders, on-street parking areas, vehicle crossovers and low-traffic roads.
- Commercial/Educational
  - Use bioretention cells as rain gardens in landscaped parking lot islands to reduce runoff volume and filter pollutants.
  - Disconnect the downspouts from roofs and direct the flow to permeable paver areas or other vegetated infiltration / filtration practices.
  - Use multi-functional open drainage systems in lieu of more conventional curb-and-gutter systems.
  - Use green roofs for runoff reduction, energy savings, improved air quality, and enhanced aesthetics.
  - Apply a treatment train approach to provide multiple opportunities for stormwater treatment and reduce the possibility of system failure. For example, combine a grassed swale with permeable paver overflow areas and a landscaped bioretention cell.

LID TECHNIQUES FOR URBANIZING AREAS AND THEIR WATERSHED BENEFITS

Low impact development offers a wide variety of structural and nonstructural techniques to provide for both runoff quality and quantity benefits. LID works in residential areas as well as open regions and environmentally sensitive sites.

Bioretention Cells (Rain Gardens)

Bioretention areas function as soil and plant-based filtration devices that remove pollutants through a variety of physical, biological, and chemical treatment processes. The reduction of pollutant loads to receiving waters is necessary for achieving regulatory water quality goals. Studies have generally found that properly designed and constructed bioretention cells are able to achieve excellent removal of heavy metals. Users of this technique can expect typical copper (Cu), zinc (Zn), and lead (Pb) reductions of greater than 90%. Phosphorus removal is dependent on depth of the bioretention and can reach a maximum of approximately 80% removal. Average removal efficiency for TKN (nitrogen) is around 60% and 70 to 80% for ammonia. Nitrate removal appears to be quite variable.

One of the primary objectives of LID site design is to minimize, detain, and retain post development runoff uniformly throughout a site so as to mimic the site's predevelopment hydrologic functions. By infiltrating and temporarily storing runoff water, bioretention cells reduce a site's overall runoff volume and help to maintain the predevelopment peak discharge rate and timing: the ponding capability of the cell reduces the immediate volume load on the storm drain system and reduce the peak discharge rate. An additional hydrologic benefit of the bioretention cell is the reduction of thermal pollution. Heated runoff from impervious surfaces is filtered through the bioretention facility and cooled. This function of the bioretention cell is especially useful in areas such as the Pacific Northwest where cold water fisheries are important.

Residential Applications

In residential developments, rain gardens are a natural stormwater management solution. Planted in low-lying areas, the gardens contain specific layers of soil, sand, and organic mulch. These layers naturally filter the site's runoff, substantially reducing common homeowner pollutants such as lawn fertilizers and driveway oils and providing protection for the receiving waterways.

Designing with rain gardens in residential areas can establish a unique sense of place by featuring plants native to the area, encourage environmental stewardship and community pride, provide a host of additional environmental benefits (habitat for wildlife and native plant varieties, improved air quality, mitigation of urban climates), and increase real estate values by the use of aesthetically pleasing landscape. Vegetated swales can be used to redirect stormwater from a residential street to a bioretention cell. A rain garden can be designed to treat all of the runoff from the 24-hour storm, while overflow from larger storms discharges to the stormwater conveyance system. Capturing all or most of the first flush from the impervious drainage area helps to remove oil and grease, heavy metals, nutrients, and sediment from the runoff water. Additional elements could include redirecting the runoff from building roofs into the grass swales as well.

Roadway Applications

A linear rain garden can also be installed along a street median. Usually designed as raised curb sections, the median can redesigned as a landscaped infiltration/bioretention swale. Designs such as this one make multifunctional use of the roadway for stormwater controls.

Seattle Public Utilities has enacted a pilot project called SEA Streets (the Street Edge Alternatives project), which aims to reduce the impact that streetscapes have on local stream watersheds and salmon habitat. SEA Streets is a comprehensive approach that manages stormwater, minimizes impervious surfaces, and eases traffic. The alternative streetscape is intended to change the paradigm that the traditional curb and gutter system is necessary. Vegetated swales, bioretention areas, and infiltration trenches are used in conjunction with traditional drainage infrastructure to collect and treat runoff close to its source. Bioretention areas were integrated into existing grades to achieve a functional transition between public and private property.

Instead of curb and gutter systems in older neighborhoods in Maplewood, Minnesota, neighborhood rain gardens (bioretention cells) are used to decrease the runoff volume, improve runoff water quality, reduce construction costs, and maintain the character of the neighborhood. To assist in the acceptance and construction of the neighborhood rain gardens, the City provides prototype layouts with such appealing themes as easy daylily garden, prairie garden, butterflies and friends garden, etc. Maplewood is able to recycle street material for the base aggregate of the gardens, obtain reasonably priced landscape plants from the County Correctional Facility’s greenhouse, and engage neighborhood residents in the cell construction through a block-wide planting day/block party. Besides saving money and bringing the neighborhood together, the projects are also a hydrologic success; runoff is contained entirely within the neighborhoods.

Commercial/Educational Applications

Traditional commercial or educational lot design involves a lot of pavement. LID practices can be included in these settings either through initial design or site retrofit. Rain gardens can be easily integrated into existing infrastructure (roads, parking areas, buildings etc.) and use only a small amount of land on any given site. Bioretention techniques have been successfully applied to retrofits of ultra-urban areas as the Naval District Washington, DC. As part of an overall initiative to help maintain and restore the water quality, bioretention areas were installed along parking lot perimeters and between the parking stalls in various lots. Bioretention strips require minimal disturbance and maintained parking spaces at existing numbers. All of the bioretention areas were designed to intercept preferential stormwater pathways and to treat, at a minimum, the first one-half inch of rain from approximately half acre segments of impervious parking surface. Pollutants are filtered and runoff volume and timing are controlled before discharge of the water to the adjacent river occurs through the existing storm sewers. Bioretention strips between parking stalls have also been successfully implemented as part of a stormwater control plan for an 11.5 acre asphalt and concrete parking area that serves 700,000 visitors per year at The Florida Aquarium in Tampa, Florida.

Landscaped islands retrofit to become bioretention cells have an additional benefit. In one parking lot project in Maryland a drought occurred after planting. Many of the other plants in the parking lot died or experienced severe stress, but the plants in the bioretention facility survived, because of the retained water supply.

Green Roofs

Green roofs, also known as vegetated roof covers, eco-roofs or nature roofs, are multi-beneficial structural components that help to mitigate the effects of urbanization on water quality by filtering, absorbing or detaining rainfall. They are constructed of a lightweight soil media, underlain by a drainage layer, and a high quality impermeable membrane that protects the building structure. The soil is planted with a specialized mix of plants that can thrive in the harsh, dry, high temperature conditions of the roof and tolerate short periods of inundation from storm events.

Green roofs provide stormwater management benefits by utilizing the biological, physical, and chemical processes found in the plant and soil complex to prevent airborne pollutants from entering the storm drain system and by reducing the runoff volume and peak discharge rate by holding back and slowing down the water that would otherwise flow quickly into the storm drain system.

Using green roofs can also reduce city "heat island" effect, CO2 impact, summer air conditioning cost and winter heat demand. Green roofs potentially lengthen roof life 2 to 3 times, treat nitrogen pollution in rain and help reduce volume and peak rates of stormwater. The hydrologic processes that can be influenced by design choices and aid in the management of stormwater include interception of rainfall by foliage and subsequent evaporation; reduction in the velocity of runoff; infiltration, percolation, and shallow subterranean flow through the soil; and root zone moisture uptake and evapotranspiration.

Through the variety of physical, biological and chemical treatment processes that filter pollutants and reduce the volume of precipitation runoff, green roofs reduce the amount of pollution delivered to the local drainage system and, ultimately, to receiving waters. Green roofs contribute to improved water quality not only by retaining and filtering the rainwater through the soil and root uptake zone, but also through the vegetation, which slows down the water through friction and root absorption; the foliage in particular, which collects dust, transpires moisture and provides shade; and the binding of potential pollutants to clay and organic matter in the roof top soil matrix.

The storage provided by green roofs helps to reduce the volume of runoff that would otherwise need to be controlled elsewhere in order to replicate natural watershed conditions and attenuate peak flows. The quantity of rainfall retained or detained by a green roof can vary, but for small rainfall events little or no runoff will occur and the majority of the precipitation will return to the atmosphere through evapotranspiration. For storms of greater intensity and duration a vegetated roof can significantly delay and reduce the runoff peak flow that would otherwise occur using conventional roof design. This helps to reduce the risk of flash flooding and the frequency of combined sewage overflow events.

As with natural soil/plant systems, green rooftops reduce runoff problems by a variety of means, including storage of water in the substrate, absorption of water in the root zone, and capture of precipitation in the plant foliage where it is returned to the atmosphere through transpiration and evaporation.

Greater grass & plant diversity provides better plant uptake and increased friction, creating less erosion and more water retained on the green roof surface. The characteristics of the soil substrate have a major influence on the effectiveness of a green roof as a whole. The soil layer traps sediments, leaves and other particles, thereby treating the runoff before reaching an outlet. The water retention capacity of the soil is dependent upon both the properties of the soil substrate and the vegetative cover.

Residential Applications

Green roofs are appropriate mostly for larger settings such as educational or office buildings. They are generally not feasible in residential settings.

Commercial/Educational Applications

Green roofs can be integrated into a proposed or existing project to help meet stormwater management requirements. Beyond stormwater management concerns, many green roofs in urban areas have been designed with multiple benefits in mind, such as aesthetic enhancement, improvements in air quality, and habitat re-creation.

Components of multi-benefit rooftop can include a native butterfly and bird habitat, urban agricultural plots with perennials and annuals, semi-intensive plots featuring a variety of flowering plants, shrubs and small trees, or plots featuring a variety of sedum or alpine perennials.

A retrofit application in Chicago was created as a demonstration project to showcase the benefits of green roofs in moderating summer temperatures within ultra-urban environments. The landscape design followed a formal garden plan as opposed to a meadow-like environment. The project included a wide range of roof landscape environments, from a 3.5-inch deep 'extensive' system to 24-inch deep 'intensive' landscape islands. Approximately 14,000 cubic feet of polystyrene was used to create the illusion of a rolling terrain. A drip irrigation system fed partially by water collected from the adjacent penthouse roof was also incorporated into the roof design.

An green rooftop with a meadow-like setting of perennial sedum varieties was installed in Philadelphia as a retrofit design with the performance objective being the restoration of the pre-development hydrology for the 2-year return-frequency storm.

Once the vegetated cover has reached a mature stage of development, a meadow-like setting of perennial sedum varieties selected to withstand the range of typical seasonal conditions typical without the need for irrigation or regular maintenance will be created. The appearance of the roof will change with the seasons. In the spring fescue grass and sedge, along with allium, burnet and dianthus dominate species. During the summer and fall months flowering sedum varieties will dominate.

Permeable Pavers

Most of the 'paving over' in developed areas is due to common roads and parking lots, which play a major role in transporting increased stormwater runoff and contaminant loads to receiving waters. Alternative paving materials can be used to locally infiltrate rainwater and reduce the runoff leaving a site. This can help to decrease downstream flooding, the frequency of combined sewer overflow (CSO) events, and the thermal pollution of sensitive waters. Use of these materials can also eliminate problems with standing water, provide for groundwater recharge, control erosion of streambeds and riverbanks, facilitate pollutant removal, and provide for a more aesthetically pleasing site. The effective imperviousness of any given project is reduced while land use is maximized. Alternative pavers can even eliminate the requirement for underground sewer pipes and conventional stormwater retention / detention systems. The drainage of paved areas and traffic surfaces by means of permeable systems is an important building block within an overall Low impact development scheme that seeks to achieve a stormwater management system close to natural conditions.

In several ongoing studies, pollutant loads from concrete or permeable pavers are lower than from asphalt surfaces. One study found that with permeable pavers made up of interlocking concrete blocks can significantly reduce the surface runoff loads of such contaminants as nitrite, nitrate, phosphate, phosphorus, metals, biochemical oxygen demand (BOD), and ammonium. Additionally, since the permeable pavers also increase infiltration, the total heat content of runoff leaving a site is reduced substantially.

Studies have also examined the influence of permeable pavers on runoff volume, tending to show a marked reduction in the surface runoff that leaves a permeable paver site due to increased infiltration, though the greatest influence on runoff is during small storms. For high intensity rainfalls or when soil conditions are saturated, runoff is not reduced as substantially.

Residential Applications

Permeable pavers are being used in a residential subdivision in Connecticut. The subdivision was developed in one part using a traditional lot style and typical construction practices, while the other part used a cluster approach and employed a wide variety of best management practices (BMPs). These practices include shared pervious driveways and a reduced-width access road, which is also constructed of permeable pavers (transportation permeable pavers). Over 20,000 square feet of interlocking concrete pavers were used in the project. The permeable driveways and roads will contribute to the project's water quality objectives of reducing nitrogen, bacteria and phosphorus export from the site, maintaining the pre-development peak runoff rate and volume, and maintaining pre-development suspended sediment loads.

The City of Olympia, Washington, replaced 1,500 feet of traditional pavement with porous concrete on a busy sidewalk in a residential neighborhood near a local school system. Users were surveyed as to their feelings about the newly installed porous pavement sidewalk. The majority of users traveled the sidewalk daily, and while most did notice that it differed from traditional pavements, approximately half of those surveyed liked its appearance and even felt that the sidewalk was less slippery when wet. Increased tripping risks did not seem to be a major concern for users, and most felt that if the costs of installation were the same or less than traditional pavements, they would consider using porous cement for the sidewalks and driveways of their homes.

Another example is a permeable paver system used to further advantage by under-sealing it so that stormwater can be retained for reuse in non-potable services. The sub-base of a permeable footpath, driveway or parking lot can be easily reconstructed with an impermeable membrane so that the desired storage volume is contained, yet the surface still exists as available land within its intended purpose.

Roadway Applications

There are a number of transportation scenarios that can make effective use of permeable paving materials, including roadways, driveways, and parking areas.

One residential subdivision in Connecticut made substantial use of permeable pavers in developing their transportation infrastructure. The subdivision, which incorporates a number of Best Management Practices (BMPs), boasts a permeable, reduced-width access road from which permeable driveways extend.

Another type of permeable paver that has proven successful in transportation applications is that of grass and soil-filled plastic cells. This type of paving provides the drainage and natural beauty of grass, while still easily supporting light or infrequent traffic loads. Manufacturers have even demonstrated the successful use of these systems in locations where heavy vehicular loads are occasionally expected, such as for fire access lanes.

Commercial/Educational Applications

Permeable pavers are well suited for use in commercial areas, such as parking lots, storage yards, and loading dock areas. They are also very effective for paved surfaces that serve primarily pedestrian traffic - for example, building entryways, plazas and patios.

The environmental benefits of these permeable pavers include increased water conservation and improved water quality. For example, a water agency in southern California used permeable interlocking concrete pavers when building the light-duty parking areas of their new water treatment plant. Existing concrete from the site was crushed and recycled to create the parking lot's base, and the permeable paver system was designed to allow infiltration into the existing soils and drainage towards landscaped islands. In this way, the parking lot also functioned as an effective component of a drought-tolerant landscape.

During an LID retrofit in D.C., permeable interlocking concrete paving blocks were installed between the central rows of the parking lot to help maintain and restore the water quality of the Chesapeake Bay and adjacent rivers. The permeable paver strip required minimal disturbance and maintained parking spaces at existing numbers. It was designed to intercept preferential stormwater pathways and to treat, at a minimum, the first one-half inch of rain from the surrounding impervious parking surfaces. Pollutants are filtered and runoff volume and timing are controlled before discharge of the water to the adjacent river occurs through the existing storm sewers. LID retrofits such as this are crucial in impervious areas that abut directly to the waterways.

A combination roadway and parking area in Florida was retrofit with over 9,000 square feet of porous concrete and two 150-foot underdrains. Before the retrofit, stormwater runoff flowed directly into a single storm sewer, carrying its full load of nonpoint source pollutants directly to the receiving bay. Besides maximizing the infiltration of stormwater runoff, the project also demonstrated an innovative way to improve the quality of stormwater runoff in highly urbanized areas where conventional stormwater treatment practices, such as detention ponds, are often prohibitively expensive due the high cost of land.

In institutional settings, grass and soil-filled permeable pavers can provide an aesthetic and functional alternative to traditional pavement. During part of a renovation of a historic building in Kansas, a large driveway leading up to the building's main entrance was removed. It was replaced with a system of interlocking plastic cells, which are made up of 98% post consumer recycled materials and filled with topsoil and vegetation. The result was a permeable surface with a lawn appearance, yet one that is capable of bearing heavy emergency or maintenance vehicle loads and providing protection against soil compaction and rutting.

In general, parking lots serve as one of the primary examples for the application of permeable pavers. A mall in Connecticut has made use of a four-acre reinforced grass parking lot with a submerged tank to store stormwater and reuse it in turf irrigation. In Georgia, numerous parking lot locations - from libraries and doctor's offices to local businesses - have chosen to apply pervious paving. Gravel-filled or soil and grass-filled plastic cells, interlocking concrete paver blocks, and porous concrete are all suitable for parking areas depending on frequency of use and traffic loads. Some creative designs include a combination of gravel-filled cells or interlocking blocks applied to the parking aisles and turf in the parking stalls.

Rain Barrels and Cisterns

Rain barrels and cisterns are low-cost water conservation devices that can be used to reduce runoff volume and, for smaller storm events, delay and reduce the peak runoff flow rates. By storing and diverting runoff from impervious areas such as roofs, these devices reduce the undesirable impacts of runoff that would otherwise flow swiftly into receiving waters and contribute to flooding and erosion problems.

TABLE E-1.
SITE CONSIDERATIONS FOR RAIN BARRELS AND CISTERNS

	Rain Barrel	Cistern
Space Needed	Not a factor	Usually not a factor with proper design
Soils	Not a factor	Not a factor
Slopes	Usually not a factor with proper design	Not a factor
Depth To Water Table	Generally not a factor	A factor in high water table areas for in, or on-ground placement
Depth To Bedrock	Not a factor	Usually not a factor with proper design
Proximity To Foundations	Not a factor	Usually not a factor with proper design away from foundation
Max. Depth	N/A	N/A
Distance To Septic Tanks	N/A	Recommend a minimum of 100 ft.
Maintenance	Generally low, only routine inspection required of all components	Low to moderate requirements

Although most commonly used as a secondary source of water for gardening in residential areas, larger sized cisterns can be adapted for use to supplement potable water systems. Many municipalities are promoting the use of cisterns for potable water use as well as for commercial applications. Both rain barrels and cisterns can provide a source of chemically untreated ‘soft water’ for gardens and compost, free of most sediment and dissolved salts. Because residential irrigation can account for up to 40% of domestic water consumption, water conservation measures such as rain barrels can be used to reduce the demand on the municipal water system, especially during the hot summer months. Table E-1 lists some of the site considerations of rain barrels and cisterns.

For residential applications a typical rain barrel design will include a hole at the top to allow for flow from a downspout, a sealed lid, an overflow pipe and a spigot at or near the bottom of the barrel. The spigot can be left partially open to detain water or closed to fill the barrel. A screen is often included to control mosquitoes and other insects. The water can then be used for lawn and garden watering or other uses such as supplemental domestic water supply. Rain barrels can be connected to provide larger volumes of storage. Larger systems for commercial use can include pumps and filtration devices.

Stormwater runoff cisterns are roof water management devices that provide retention storage volume in above or underground storage tanks. They are typically used for water supply. Cisterns are generally larger than rain barrels, with some underground cisterns having the capacity of 10,000 gallons. On-lot storage with later reuse of stormwater also provides an opportunity for water conservation and the possibility of reducing water utility costs.

Soil Amendments

Soil amendments increase the spacing between soil particles so that the soil can absorb and hold more moisture. This in turn reduces runoff and the damaging effects of excessive runoff on local streams. The amendment of soils changes various other physical, chemical and biological characteristics so that the soils become more effective in maintaining water quality.

Soil amendments help to provide water quality benefits, not only by increasing the infiltration capacity of the soil, but also by filtering and breaking down potential pollutants; immobilizing and degrading pollutants by holding potential pollutants in place so that soil microbes can decompose them; reducing the need for fertilizers, pesticides and irrigation by supplying more nutrients and a slow-release of them to plants; holding more rainwater on-site, decreasing runoff, and providing increased soil moisture and infiltration capacity; increasing soil stability, leading to less potential erosion; providing added protection to groundwater resources, especially from heavy metal contamination; and reducing thermal pollution by maintaining runoff in the soil and on-site longer.

By restoring or improving the physical and therefore hydrological characteristics of a soil, that soil can then best be utilized for stormwater management purposes. Compared to compacted, unamended soils, amended soils provide greater infiltration and subsurface storage and thereby help to reduce a site's overall runoff volume, helping to maintain the predevelopment peak discharge rate and timing..

Soil amendments provide stormwater management, quantity control, benefits by holding more rainwater on-site, attenuating peak flows and decreasing runoff; helping to maintain base flow to local waterways, especially during dry periods; providing increased groundwater recharge through better infiltration and by maintaining the water on-site longer; improving soil structure and stability, while increasing infiltration capacity and available storage within the soil; reducing paving and compaction of highly permeable or problem soils through a site fingerprinting approach; and increasing soil stability, leading to less runoff and erosion through improved cover conditions.

Site preparation prior to the construction of residential units typically involves removing or stock piling the existing vegetation and topsoil. This has an immediate hydrologic impact because of the reduction in soil structure, pore space, organic content and biological activity. After construction, a thin layer of topsoil is usually spread on the now very compacted subsoil and then the area is seeded or sodded.

The combination of soil compaction and loss of organic matter has several undesirable consequences:

- With the infiltration capacity of the site significantly reduced, rainwater more quickly runs off into local streams. This, in turn, tends to increase erosion, scouring and the sediment load.
- The rate of groundwater recharge decreases.
- Due to the soil compaction and the loss of organic matter, the availability of subsurface water to plants is reduced.
- The increased volume and frequency of runoff carries pollutants with it that include pesticides, fertilizers, animal wastes and chemicals such as phosphorous and nitrogen.

Homeowners now have to apply pesticides, fertilizers and irrigation water in increasing amounts in order to maintain their landscapes.

Soil additives, or amendments, can be used to minimize development impacts on native soils by restoring their infiltration capacity and chemical characteristics. After soils have been amended their improved physical, biological and hydrological characteristics will make them more effective agents of stormwater management.

Soil amendments can include not only compost and mulch but also top soil, lime and gypsum. These additional components help offset any nutritional deficiencies and control acidity. A thorough soil analysis of the native soil is required to determine the optimum quantity for each component in order to obtain the maximum benefit from compost amending. Soil amendment components should generally be mixed and applied as shown in Table E-2.

TABLE E-2.
APPLICATION OF SOIL AMENDMENT COMPONENTS

Amendment	Application
Compost	The amount of compost to be applied depends upon the organic content of the existing soil as well as the targeted amount of the proposed soil amendment. Compost typically has an organic content of 45-60% and is often used as the sole means of providing organic material to the soil profile. In soils that have organic contents of less than one percent, 8 to 13 percent by soil weight is a typical target of a proposed soil amendment with compost. As a general rule, a 2-to-1 ratio of existing soil to compost, by loose volume, will achieve the desired organics level. Locally available compost may be utilized if it is of high enough quality and available at a cost effective price.
Nutrients and Lime	If the soil pH is below 6.0 the addition of pelletized dolomite is recommended, with application rates in the range of 50 to 100 pounds per 1000 square feet. Nitrogen requirements usually range from 2 to 8 pounds per 1000 square feet, with slow release water-insoluble forms being the preferred method. Other soil additions may include sulfur and boron with the amount needed determined by soil analysis.
Gypsum	Hydrated calcium sulfate ($CaSO_4 \bullet 2H_2O$) is sometimes applied to a soil in order to increase calcium and sulfur without affecting the pH, as well as to enhance a soil's structure in high clay content soils.

Tree Box Filters

Tree box filters are mini bioretention areas installed beneath trees that can be very effective at controlling runoff, especially when distributed throughout the site. Runoff is directed to the tree box, where it is cleaned by vegetation and soil before entering a catch basin. The runoff collected in the tree-boxes helps irrigate the trees.

Tree box filters are based on an effective and widely used “bioretention or rain garden” technology with improvements to enhance pollutant removal, increase performance reliability, increase ease of construction, reduce maintenance costs and improve aesthetics. Typical landscape plants (shrubs, ornamental grasses, trees and flowers) are used as an integral part of the bioretention / filtration system. They can fit into any landscape scheme increasing the quality of life in urban areas by adding beauty, habitat value, and reducing urban heat island effects.

The system consists of a container filled with a soil mixture, a mulch layer, under-drain system and a shrub or tree. Stormwater runoff drains directly from impervious surfaces through a filter media. Treated water flows out of the system through an under drain connected to a storm drainpipe / inlet or into the surrounding soil. Tree box filters can also be used to control runoff volumes / flows by adding storage volume beneath the filter box with an outlet control device.

Tree box filters can be used to meet many stormwater management goals, meet regulatory requirements for new development, protect and restore streams, control combined sewer overflows, retrofit existing urban areas and protect reservoir watersheds. By emphasizing natural processes and micro-scale management practices, tree box filters are often less costly than conventional stormwater controls. Working at a small scale allows volume and water quality control to be tailored to specific site characteristics. Pollutants vary across land uses and from site to site, therefore the ability to customize stormwater management techniques using tree box filters is a considerable advantage over conventional management methods.