# CHAPTER 3: HYDROLOGY

This chapter summarizes and discusses the results of the basin hydrologic analysis. Separate final reports on the existing and future hydrology are in Appendix E.

The "basin hydrology" describes the behavior of the lakes, streams and wetlands in response to precipitation. Rain falling on the basin either evaporates, infiltrates into the ground, or drains to a surface feature such as a stream or pond. Land cover, soil characteristics, and ground water interactions determine how the water bodies absorb and store precipitation, and convey it to receiving waters. The basin hydrology influences flooding, erosion, habitat loss and water quality degradation.

## 3.1 METHODS

The basin hydrological analysis was conducted in four steps. First, a simulated model of the existing basin was developed and calibrated. Second, the basin was modeled for future, fully developed conditions. Third, the Grass Lake area of the model was revised to incorporate new data provided by the City of Olympia. Finally, several management alternatives to reduce future flows were modeled, which are discussed in the chapter on analysis of alternatives.

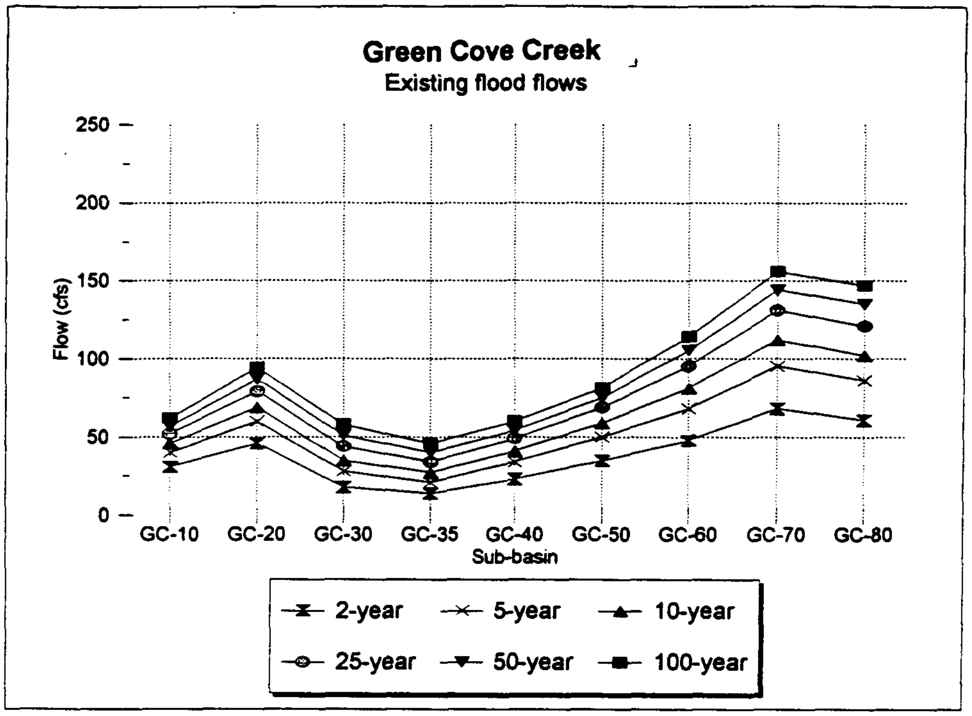
A computer simulation model of the entire Green Cove basin was constructed using a state-of-the-art computer model called "Hydrologic Simulation Program-Fortran" (HSPF), developed by the EPA. The computer model simulates continuous stream flows over time through the full length of the creek, as a function of rainfall, landcover, soil, and slope. The continuous simulation method gives a better picture of the basin hydrology than more common, event-based simulations, because it accounts for pre-existing soil moisture conditions which influence stream flow.

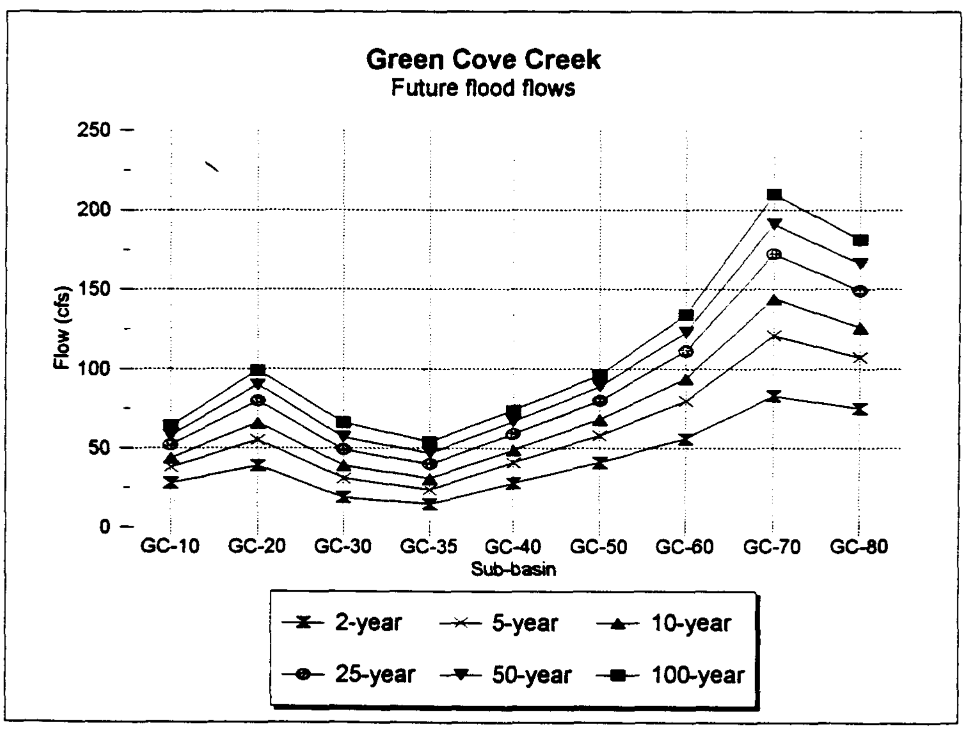
The rainfall data used for the simulation was actual daily rainfall from October 1, 1990 through September 30, 1994, recorded in the basin at 36th Avenue NW. The basin's land cover and slopes were interpreted from 1989 aerial photographs. Soil characteristics were derived from the *Soil Survey of Thurston County, Washington* (US Department of Agriculture 1990).

The basin was divided into nine sub-basins, based on soils, vegetation and slope. Each sub-basin shares similar hydrologic characteristics. Appendix E contains the estimated runoff storage volumes and stage-discharge relationships for each sub-basin, used by the model.

The computer simulation was calibrated to match recorded flows from 1990 through 1994, logged every 15 minutes by a gauge on Green Cove Creek at 36th Avenue NW. The calibration was improved by adjusting the soil characteristics to better depict groundwater levels and subsurface flows. The soil characteristics largely determine how the rainfall behaves when it falls on the ground. According to the model calibration report:

Figure 3-2 Green Cove Creek existing and future peak flows



Current and future water levels and durations in the basin's wetlands, predicted by the initial modeling, were compared to criteria developed by the Puget Sound Wetlands and Stormwater Management Research Program (King County Environmental Division 1995) and adapted for the HSPF model (King County Surface Water Management 1996). The criteria were designed to prevent future development from degrading wetland ecosystems, based on current research into Puget Sound wetland flora and fauna. The criteria included:

G1. Post development annual high water levels will increase by no more than one foot over pre-development levels for return periods from the 1.01 to the 100 year return interval.

G2. A wetland with a pre-development average monthly range (AMR) greater than or equal to 0.5 foot shall not have the AMR increase more than 0.2 foot. Wetlands with an AMR less than 0.5 foot shall not increase above 0.7 foot.

SP1. The aggregate duration of Spring 0.25 foot excursions from the pre-developed stage versus time curve shall not exceed 24 hours in any 30 day period.

SU1. The aggregate duration of Summer 0.5 foot excursions from the pre-developed stage versus time curve shall not exceed 72 hours.

SU2. The aggregate duration of post-development Summer dry periods shall not exceed or drop below the pre-development period by more than two weeks.

Revising the model resulted in more accurate hydrologic predictions for Grass Lake wetlands. The City of Olympia contracted with Cooke Scientific Services to analyze the hydrologic output of the revised basin model. Cooke scientific performed a new analysis using an additional hydrologic criterion. Analysis of the revised modeling indicated that future development would not cause any of the wetlands to exceed the hydrologic criterion (Aqua-Terra 1997; Cooke 1997).

## 3.3 DISCUSSION

The discussion of basin hydrology is organized into three geographic areas with distinct physical and hydrologic characteristics. Southern Green Cove basin contains no streams, but includes several suburban residential drainage systems and extensive, broadly dispersed wetlands that flow into an artificial lake at the head of Green Cove Creek. Central Green Cove basin contains the flat-slow moving upper reach of Green Cove Creek and two large, contiguous wetlands adjacent to the creek. Northern Green Cove basin contains the fast-moving lower reach of Green Cove Creek, with relatively few, isolated wetlands.

### 3.3.1 Hydrology Of Southern Green Cove Basin

Southern Green Cove basin includes sub-basins GC-10 through GC-40. The southern basin contains no natural streams (other than small seasonal drainages and remnants of drainages), and runoff drains through ditches and stormwater pipes to the Grass Lake wetland and Louise Lake. Roads encircle most of this area, containing the runoff. Surface water drains from the southern basin into the head of Green Cove Creek at the culvert where Louise Lake drains under Kaiser Road.

The extensive wetlands in the southern basin have the capacity to store large quantities of runoff because the roads that surround them form a barrier that contains the runoff (except when Kaiser Road floods). The estimated surface storage capacity of the delineated wetlands in the southern basin is approximately 509 acre-feet of water. Smaller depressions and channels store additional runoff.

The soil also stores large quantities of rainfall, but the soil's capacity to store runoff depends on the condition of the groundwater in the soil. The depth to groundwater in the southern basin changes as the water table rises in the winter and recedes in the summer. The soil can store large quantities of runoff when the water table is low. As the water table rises, less surface water infiltrates and more becomes runoff. When the water table rises to the surface, completely inundating the ground, virtually all surface water becomes runoff, or evaporates.

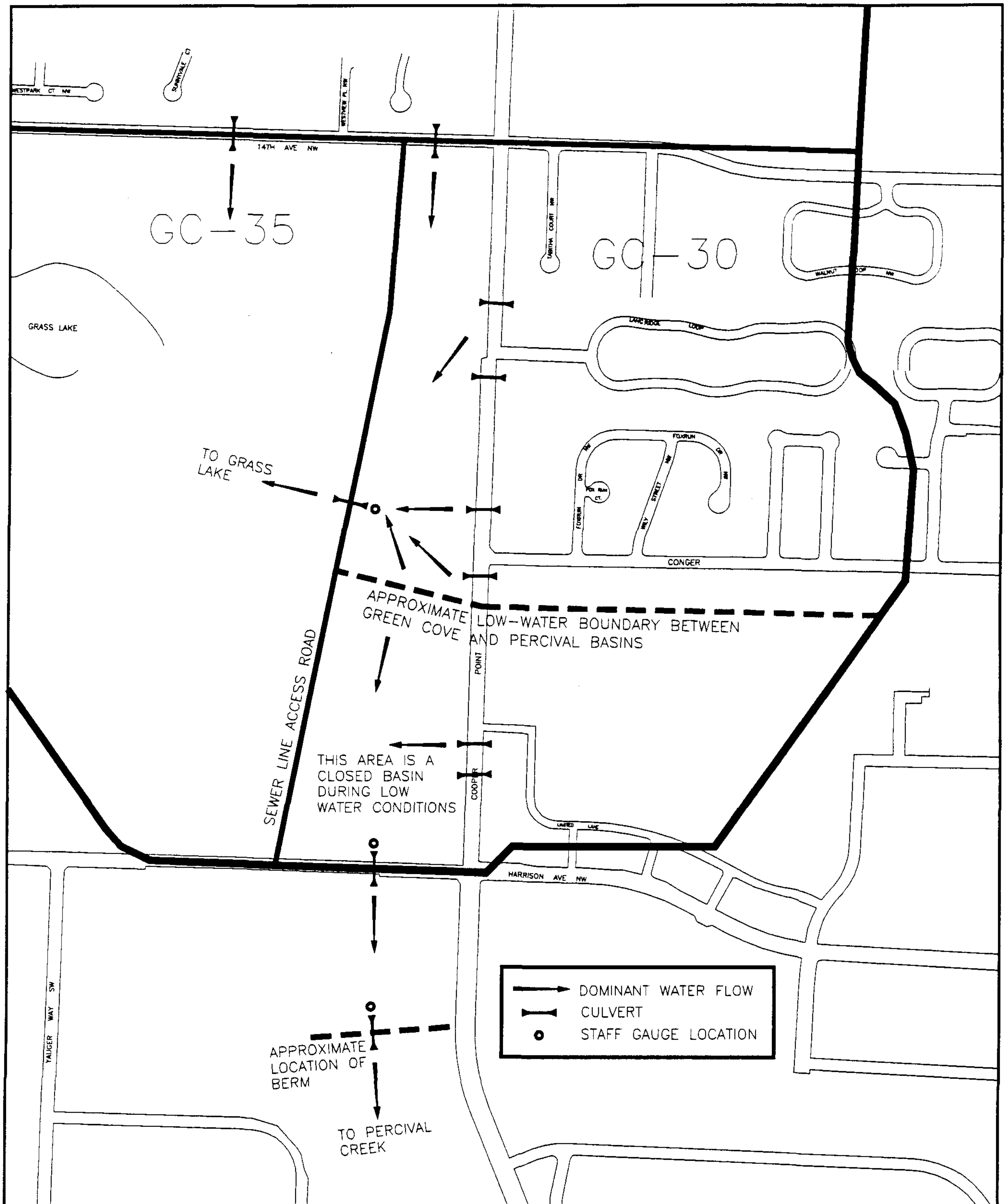
Peak flows from the southern basin remain low for all flood events because of the basin's storage capacity. The existing peak discharge into the head of Green Cove Creek from the southern basin's outlet at Louise Lake is estimated to be only 60 cfs for the 100-year flood, even while two contributing upstream sub-basins (GC-10 & 20) peak at 62 cfs and 94 cfs. The future peak discharge for the 100-year event is predicted to increase 23% over existing conditions.

*Hydrologic relationship of Green Cove basin and Percival basin*

Southern Green Cove basin shares an indistinct boundary with Percival Creek basin, that shifts according to the water level conditions (see figure 3-3). Sub-basin GC30 flows into Grass Lake, but the southwest corner of the sub-basin contains a wetland area that also drains south through a culvert under Mud Bay Road to Yauger Park and contributes to Percival Creek. A culvert in a berm that parallels Mud Bay Road just north of Yauger Park controls the water level south of Mud Bay Road. Theoretically, water can flow north under Mud Bay Road from Percival basin to Green Cove basin when the water is higher on the south side of the road than the north. Considerable effort went into determining the hydrologic significance of this interaction.

Field surveys were conducted to determine whether a topographic divide separates the areas of GC30 that drain to Percival Creek and to Grass Lake Wetland. Staff gauges were installed at the Mud Bay Road culvert, the culvert in the berm south of Mud Bay Road, and the culvert under the sewer access road at the outlet to GC30. The gauges were observed daily. Frequent trips were made to observe the flows and behavior of runoff during storms. All of the culvert elevations were surveyed, and stage-discharge curves were developed for each culvert.

Figure 3-3 Drainage patterns in southern Grass Lake wetlands area



Field observations indicated that water flowed north under Mud Bay Road only once during 1995-96, in October of 1996. During the winter months, only southerly flow was observed, even during extreme flood conditions. Northerly flow under Mud Bay Road causes water to temporarily build in GC30. Olympia recently installed a larger culvert in the berm to drain the area south of Mud Bay Road, which reduced back flows into Green Cove basin. The dominant southerly water flow under Mud Bay Road returns when the water level to the south drops down, which occurs rapidly now, due to the larger culvert.

The results indicate that the hydrologic interaction between Green Cove basin and Percival basin is not significant. The culvert under Mud Bay Road that connects the two basins is partially crushed, so flow is highly restricted. Rare backflows from Percival basin into Green Cove basin do not cause flows to increase at the sewer road culvert. Under low water conditions, the southeast corner of GC30 is a closed depressional wetland. As the water level rises, runoff flows predominantly south through the Mud Bay Road culvert, because the culverts south of Mud Bay Road lie at a lower elevation. Backflows to GC30 from south of Mud Bay Road are insignificant compared to the other inflows along Cooper Point Road and 14th Avenue.

*Grass Lake Park Wetlands Hydrology*

The following discussion of Grass Lake Park wetlands hydrology is summarized from the report prepared by Cooke Scientific Services for the City of Olympia (Cooke 1997).

Drainage subbasins GC10, GC20 & GC30 contribute to the Grass Lake Park wetlands through five culvert inlets around the park perimeter. There are two outlets but the dominant outlet is the culvert from Louise Lake under Kaiser Road. Stormwater from developed areas east of Cooper Point Road and north of 14th Avenue flows directly into three wetland areas in or near the park.

The wetlands in GC30, east of the sewer access road, detain stormwater during the rainy season. The access road culvert limits outflows and increases drawdown times following storms. Substantial inflows from GC10 and GC20 are probably stored through infiltration, because the flows entering Louise Lake are much lower than the flows at the inflow culverts on 14th Avenue.

The modeling indicated that future peak water levels in the wetlands will increase less than 0.5 feet above existing conditions during the growing season of March 1 through August 31. The winter (non-growing season) base elevations may increase. If the base flows dissipate by early spring they would probably not affect the wetlands. Peak flows at the inlets would increase only slightly (1-4 cfs), which would not affect water levels in the wetlands.

According to the Cooke report, "the limited water level fluctuations estimated to occur at Grass Lake park after build-out conditions have been achieved (growing season excursions of less then 0.5 feet) will most likely not result in visible impacts to the existing vegetation communities." The vegetation most likely to be affected by hydrologic effects of development are isolated areas near the culverts, where the plant communities "are already altered as a result of human activities, and the plants growing in them are more resistant to hydrologic change than are the plants found in the internal wetlands."

In fact, the Cooke report found that the future hydrology could actually prove beneficial to the wetlands near the culverts. In one wetland dominated by non-native reed canarygrass, "it would be a benefit to the wetland community if water depths increase after buildout conditions are realized. The reed canarygrass community might be replaced by a native species which better tolerates winter inundation." Another narrow drainage channel would be expected to overtop in the future, which "could result in increased wetland area if flows persisted through at least the early growing season (March and April)."

The forested wetland area on the west side of Cooper Point Road near 14th Avenue was found to be the most sensitive to hydrologic changes. An existing community of flood-tolerant native species near the inlet culvert act as buffers to the forested wetland plant community. The Cooke report recommended monitoring the vegetation in this area to watch for future changes, and install flow controls there if needed.

Plant communities in the other wetland areas are predicted to have a low risk of impacts from hydrologic changes. Also, the bird and mammal populations are unlikely to show any negative effects because "the increased volumes and [water level fluctuations] within the Grass Lake park wetland system is sufficiently small that mobile organisms would simply evade areas where inundation was a problem." The Cooke report suggested that the impacts to amphibians might be larger, and recommends additional analysis after collecting data on the existing amphibian populations.

*Louise Lake Hydrology*

Surface water enters the Louise Lake sub-basin as stormwater runoff from culverts under 14th Avenue and from Grass Lake wetland to the east, and discharges to Green Cove Creek through a culvert at the northwest corner of the lake. Surface water sometimes enters the lake through the outlet culvert, when the water table to the west of the lake is high and the depth of Louise Lake is less than 7'.

Shallow till soils cover most of the Louise Lake sub-basin and force groundwater to the surface. When the water table drops, the surface water level of Louise Lake falls and 100% of rainfall infiltrates into the ground or evaporates. The outlet culvert elevation controls discharge to Green Cove Creek; no water discharges to the creek from Louise Lake until the lake depth reaches 7'. As the lake level rises, progressively smaller portions of runoff infiltrate, and only 2% of runoff infiltrates when Louise Lake is full. Figure 3-4 illustrates the relationship between water depth in Louise Lake and discharge to ground and surface water.

Figure 3-4 Louise Lake stage-discharge relationship

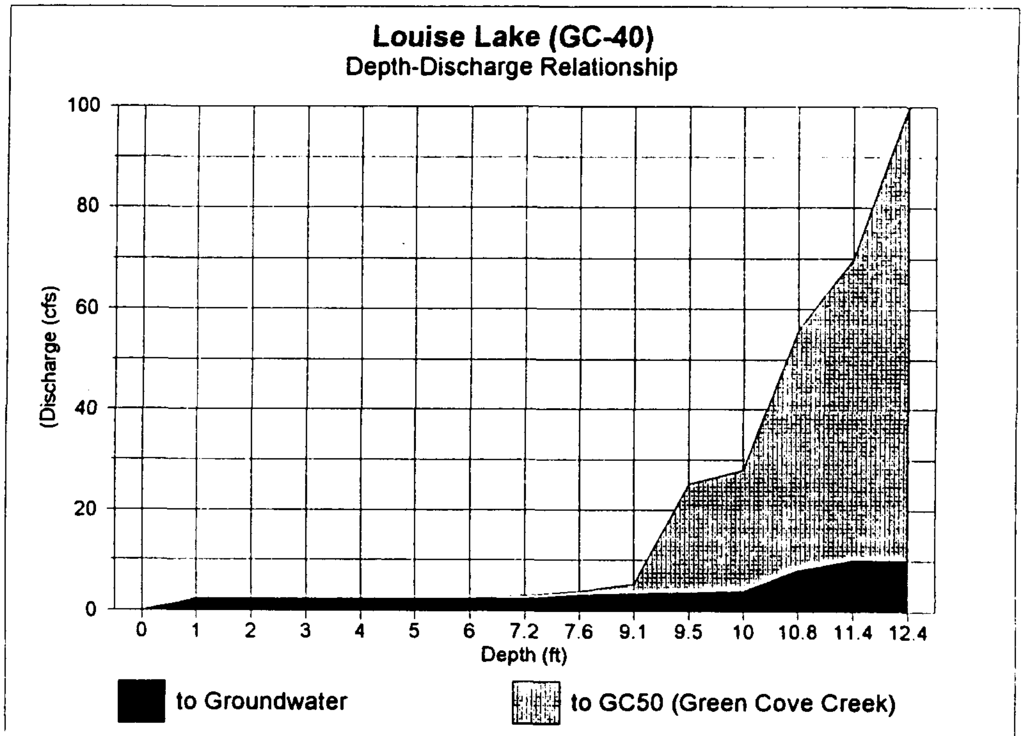
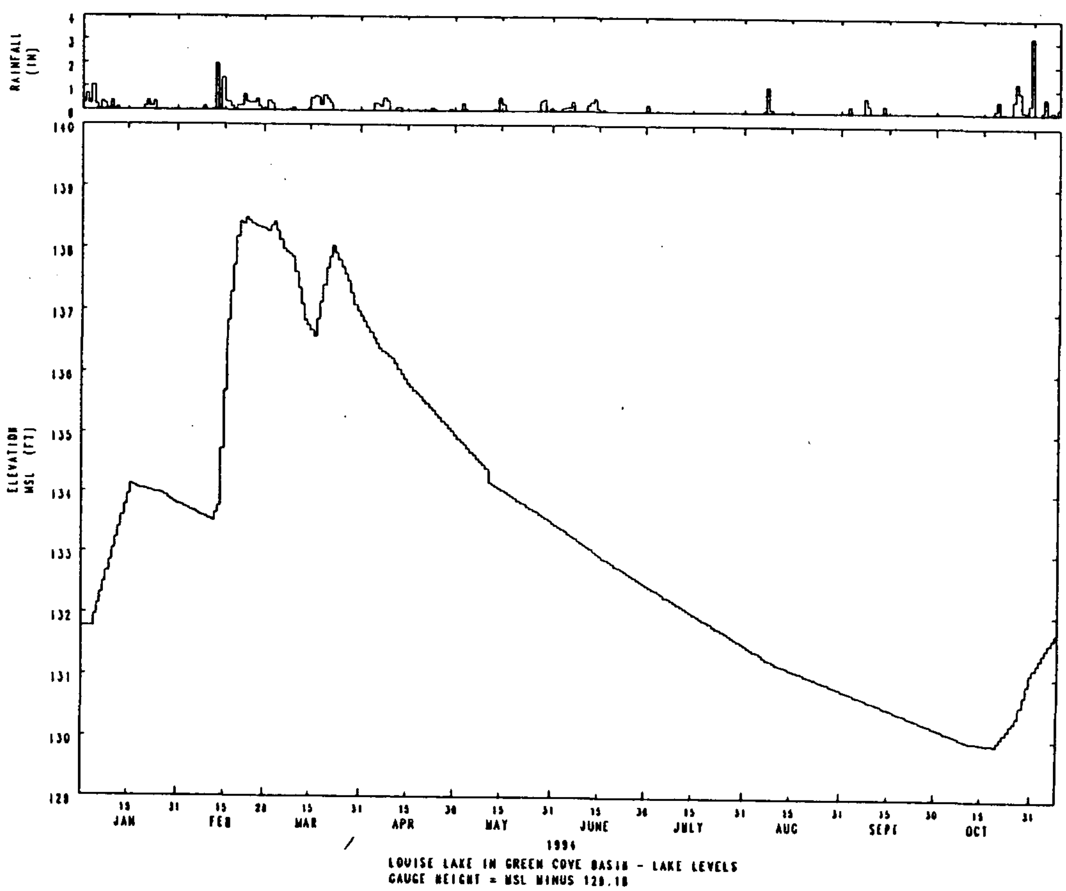



Figure 3-5 Louise Lake daily water surface elevation and precipitation, 1994



Fluctuating groundwater exerts significant influence on Louise Lake's response to rainfall. The lake level rises quickly following rainfall when the ground is saturated, but shows little or no response to rainfall when the groundwater level is low. Figure 3-5 illustrates Louise Lake's water level and rainfall for 10 months in 1994. Each water level peak immediately followed a rain event during the rainy season (October-March) when the ground was saturated. The lake level rose 7' in 50 days during the period. The water level declined steadily from April through September as the groundwater dropped, and rainfalls during that time did not effect the dropping lake level.

### 3.3.2 HYDROLOGY OF CENTRAL GREEN COVE BASIN

Central Green Cove basin includes sub-basins GC-50 and GC-60. The central basin contains Kaiser Road wetland, Evergreen Parkway wetland, and the uppermost reaches of Green Cove Creek, some of which has been ditched. Runoff reaches the creek primarily as subsurface flow. No culverts discharge directly to the creek and wetland, although road ditches drain into the creek where it crosses under Kaiser Road. The central basin discharges into a steeper segment of Green Cove Creek at the northernmost culvert under Evergreen Parkway.

*Kaiser Road wetland (GC-50)*

The Kaiser Road wetland covers 109 acres, or 21% of the sub-basin. This is the most wetland-dominated area in Green Cove basin. The estimated surface storage capacity of the Kaiser Road wetland is approximately 294 acre-feet of water. Surface water enters the wetland from Louise Lake when the lake level is high. Runoff flows into the wetland subsurface from the uplands along Kaiser Road on the east and Overhulse Road on the west. Groundwater also feeds the wetland.

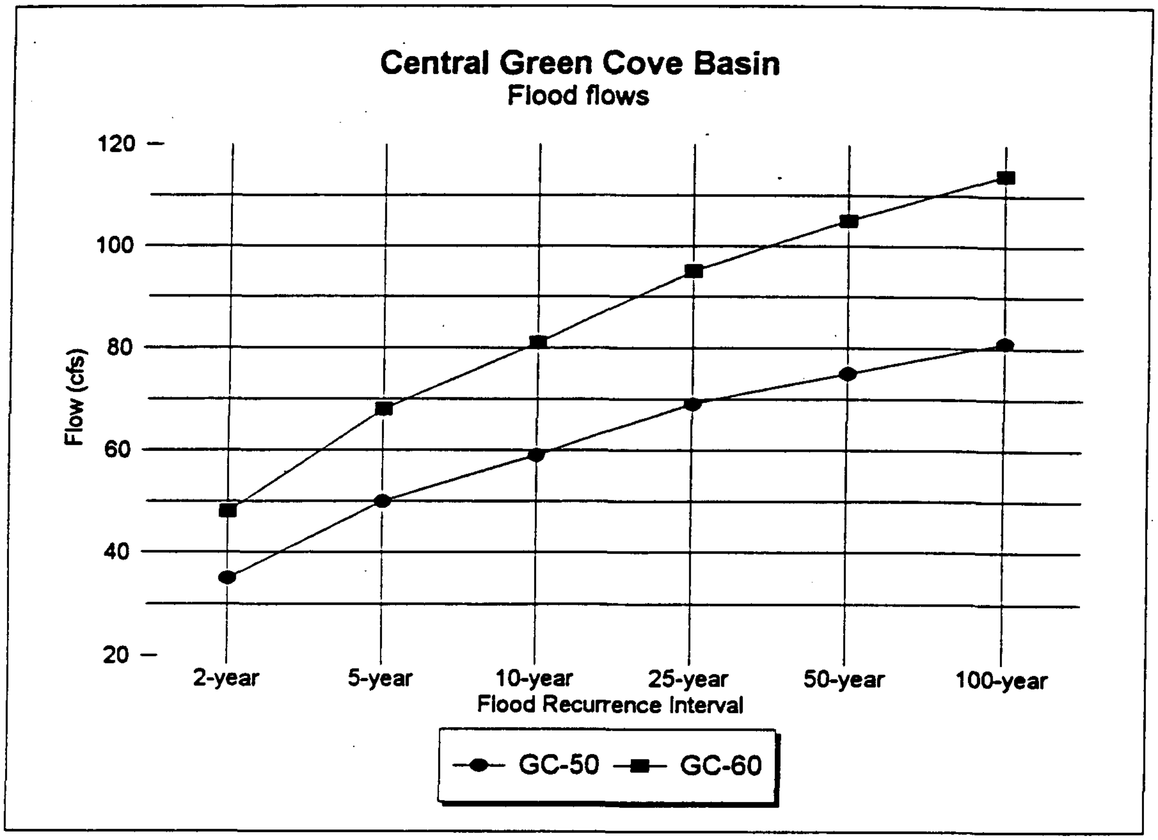
Kaiser Road wetland mitigates downstream flows in Green Cove Creek because it stores so much runoff. The maximum outflow from the wetland is only 81 cfs from the hundred year storm event. Figure 3-7 illustrates the range of flood flows that discharge from the wetland. The 100-year flood flow is only slightly more than twice the 2-year flood flow because the wetland effectively stores runoff.

*Evergreen Parkway wetland (GC-60)*

The Evergreen Parkway wetland covers 53 acres, or 15% of the sub-basin. The estimated surface storage capacity of the wetland and surrounding sub-basin is 185 acre-feet of water. Surface water enters the sub-basin from the creek upstream, and from a seasonal stream that drains a small residential neighborhood at the west end of 20th Avenue.

Evergreen Parkway wetland stores most of the runoff from 2-year and smaller events. Figure 3-6 illustrates the range of flood flows that discharge from the wetland. The 2-year flood discharge

Figure 3-6 Central Green Cove basin peak flows




for the wetland is only slightly higher than the next basin upstream, indicating that the sub-basin is storing most of the additional runoff. Larger events produce progressively higher flow increases through GC-60. The wetlands appear to reach capacity from the 2-year flood, and do not mitigate downstream flows for larger flood events.

The apparent failure of the Evergreen Parkway wetlands to mitigate major flood flows could be due partially to the fact that the wetland follows a fairly narrow corridor immediately adjacent to the creek, where it has the least mitigating effect. Also, the wetland may discharge groundwater or sub-surface flow from the wetlands farther upstream, during the rainy season. A soil study of an area north of Evergreen Parkway observed similar behavior in another wetland adjacent to the creek. The study found that rainfall in the Grass Lake area recharged shallow groundwater, which discharged in the Evergreen Parkway wetland (RZA AGRA, Inc. 1993). A study of the Kaiser wetlands also found that shallow hardpan could cause subsurface flow to seep out at the bottom of slopes (Earth Consultants. Inc. 1992). That would explain the increasing discharge from GC-60 during higher floods. A small wetland at the base of a hillside drainage in a residential subdivision feeds the creek just south of Evergreen Parkway. This wetland is also likely to be a surface discharge point for sub-surface flows that move down fairly rapidly from the developed hill slopes above, which consist primarily of till soils.

### 3.3.3 Hydrology Of Northern Green Cove Basin

Northern Green Cove basin includes sub-basins GC70 and GC80. The northern basin contains the steepest, fastest flowing reaches of Green Cove Creek, and a few isolated wetlands. The creek flows through a ravine in this area. Road drainage systems discharge to the creek at Evergreen Parkway, 36th Avenue and Green Cove Street. A few culverts also discharge to the creek from residential neighborhoods west of the creek on Green Cove Street. The northern basin empties into Green Cove in a small estuary.

The upstream wetlands exert a major influence on flood flows in the northern basin. Sub-basins GC-50 & 60 both absorb much of the rainfall during small, frequent flood events, unless the pre-existing water level is high. The mitigating effect of the upstream basins declines during high water events. The portion of downstream flows at the creek mouth which originates in sub-basin GC-60 rises from 21% of the 2-year flood event to 28% of the 100-year flood.

Peak flows increase significantly north of Evergreen Parkway. Peak flows at the mouth are consistently 75-80% higher than flows at Evergreen Parkway for all events from the 2-year through the 100-year flood. The greatest increases occur in sub-basin GC-70, where peak flows increase an average of 72% between Evergreen Parkway and 36th Avenue for all flood events.

Several factors could cause the northern creek flows to increase sharply with higher magnitude flood events. The northern sub-basins lack the extensive wetland storage capacity found farther south. A tributary that joins the creek south of Evergreen Parkway increases the total flow in the creek. The steeper slopes and hillier topography cause relatively more rainfall to run off instead of infiltrating. The soils in the northern peninsula areas have poor infiltration characteristics.

The lack of wetland storage capacity compared with the central and southern basin clearly influences the stream flow. Wetlands occupy only 50.3 acres, or 6% of the northern basin, compared to 162 acres or 18% of the central basin. Most of the wetlands occur right by the mouth of the creek, where they have the least effect on stream flow. Consequently, more runoff reaches the creek without being detained by wetlands.

The poorly drained till soils that dominate the northern basin generate large amounts of runoff that reaches the creek quickly and increases stream flows. The limited outwash soil in the basin consists mainly of Yelm fine sandy loam, which has poor infiltration for an outwash soil. In addition, the soil maps probably overstate the extent and depth of outwash. Well logs from the basin indicate that thick layers of till occur in areas mapped as outwash. For instance, the City of Olympia's Well No. 1 lies in an area inventoried as outwash, yet the well driller's log indicates clay from 6' to 19' deep and cemented gravel below that to 54' deep. The log for a well farther north, in an outwash-mapped site near the creek, indicates clay from 0 to 17' deep, clay and gravel from 17' to 38' deep, and a water-bearing layer below that.

The soil study for the Cedrona subdivision confirms the inaccuracies in the soil inventory. The Cedrona site spans the area mapped as outwash soil south of 36th Avenue. Soil test pits exhibited wide variations, but many pits in the heart of the outwash-mapped area contained shallow layers of dense sand and compacted clay, and showed signs of seepage at depths of 5' to 9'. The study also found that the shallow groundwater table existed at an elevation of 140', or only 5' below the surface (RZA AGRA, Inc. 1993).

## 3.4 CONCLUSIONS

The primary hydrologic impacts of development in Green Cove Basin are altered wetland hydrology in Grass Lake wetlands and increased peak flows in lower Green Cove Creek.

The current hydrologic fluctuations in the Grass Lake wetlands sub-basins fall within typical hydrology for large Puget Sound wetlands. The altered hydrology does not appear to have impaired the wetland functions. Most hydrologic impacts have occurred near the main inlets to the wetlands, where the plants have already adapted to the hydrology (Cooke 1997). The model of future development did not cause any of the wetlands to exceed the recommended hydrology standards for wetlands. Winter base flows could increase, but they would be unlikely to affect the wetlands (Aqua-Terra 1997; Cooke 1997). The wetlands are extensive enough to absorb significant quantities of runoff without detectable changes to hydrology.

Hydrologic modeling indicates that future peak flows in Green Cove Creek will increase by an average of 30% for all flows at 36th Avenue, and 23% at the mouth. The peak flow increases are high enough in magnitude to decrease channel stability.

### 3.4.1 Summary of Hydrologic Analysis Results

1. Shallow till soils underlie most of Green Cove basin and limit the basin's ability to infiltrate rainfall.
2. The wetlands in southern Green Cove basin help compensate for the southern basin's poor infiltration by storing large quantities of runoff from the most developed portion of the basin, which substantially mitigates downstream peak flows.
3. Backflow into sub-basin GC30 from Percival basin causes no measurable effect on flows in Green Cove Creek.
4. The water level in Louise Lake responds quickly to rainfall when the groundwater level is high, and does not respond to rainfall when the groundwater level is low.
5. The wetlands in central Green Cove basin (GC50 & GC60) help mitigate peak flows in Green Cove Creek, but have less effect than the southern Green Cove wetlands.
6. The soil inventory of sub-basin GC60 overstates the soil's capacity to infiltrate rainfall.

7. Flows in Green Cove Creek respond quickly to rainfall because the poorly drained soil saturates rapidly and the northern basin contains few natural surface features to detain stormwater.
8. Peak flows in lower Green Cove Creek will increase significantly due to future development.
9. Future development will not cause wetlands in the basin to exceed hydrology criteria.

# CHAPTER 4: WATER QUALITY

This chapter summarizes the results of a two-year water quality study of Green Cove Creek and the stormwater discharges in the basin. A separate final report on the study, the *Green Cove Creek Basin Comprehensive Drainage Basin Plan Water Quality Assessment* (Thurston County 1995), is available from the Thurston County Department of Water and Waste Management, and contains the supporting data.

Water quality concerns are a major focus of the basin plan because water quality affects human health, natural resources, recreational opportunities and the economic health of the basin. This chapter begins with a general overview of water quality concerns, before covering the basin water quality study. Readers who are familiar with water quality parameters may want to skip to the study summary, beginning in section 4.2. Chapter 6 discusses specific problem sites and chapters 7 and 8 contain follow-up recommendations.

## 4.1 OVERVIEW OF WATER QUALITY CONCERNS

The water quality assessment of Green Cove basin evaluated "conventional" parameters, sediments, and benthic macroinvertebrates. Conventional parameters indicate the general water quality with respect to human health and natural resources. Sediment analysis provides additional indications of specific contaminants contained in stormwater runoff. Benthic macroinvertebrates indicate the impact of water quality on fish habitat.

Washington State has established stream water quality standards for several conventional parameters which are tied to the stream classification as defined in state law (WAC 173-201A). The state classifies Green Cove Creek as water quality Class A. The state has not established standards for sediment, but the EPA and the state have developed recommended criteria for some of the pollutants found in sediments. The EPA has developed indices that relate macroinvertebrate species to overall stream conditions. Table 4-1 summarizes surface water quality standards.

### 4.1.1 CONVENTIONAL WATER QUALITY PARAMETERS

*Fecal Coliform.* Fecal coliform is bacteria contained in human and warm-blooded animal feces. Certain types of fecal coliform bacteria can cause severe illnesses, and, in extreme cases, death. Fecal coliform can also indicate the possible presence of other pathogens and nutrients. Stream water quality standards include a two-part standard for fecal coliform. The first part sets the maximum geometric mean value (GMV) allowed for all samples, expressed as the number of organisms per 100 milliliters of water (for example, maximum GMV=100/100 ml). The second part of the standard sets the maximum number of samples allowed to exceed a higher threshold, defined as a percentage of the total number of samples (for example, maximum 10% > 200/100 ml).

Table 4-1: Overview of water quality parameters

| Parameter | Sources | Class A Standards | Primary issues and concerns |
|---|---|---|---|
| Fecal coliform | Human and animal waste; failing septic systems, pet waste, manure, wildlife | Max. GMV 100/100ml Max. 10% of samples exceed 200/100 ml | Some fecal coliform bacteria pose human health hazards. Fecal coliform bacteria accumulate in shellfish. |
| Temperature | Vegetation clearing that reduces shade, channel alterations that reduce flow, warm water inputs from roads, ponds, other outfalls | Max. 18 0C | High temperatures can kill fish directly, and can stress fish and other aquatic organisms by reducing the dissolved oxygen levels. |
| Dissolved oxygen (DO) | Photosynthesis, aeration | Min. 8 mg/l | Aquatic organisms, including fish, need dissolved oxygen to survive. Slow moving water found in many wetlands is naturally low in dissolved oxygen. |
| pH | Soil, vegetation, rain and wind deposition, and water hardness influence pH | 6.5- 8.5, max. human-caused variation 0.5 | Acidic (low pH) water can damage plants and aquatic animals. Wetlands and many local forests have naturally low pH. |
| Turbidity | Sediment, decaying plants, algae, tannins | Max. 5.0 NTU over background | Turbidity is usually due to sediments that can damage fish habitat. Background turbidity is difficult to measure. |
| Total suspended solids (TSS) | Streets, parking lots, catch basins, construction sites, logging sites, pastures, eroding stream banks | No standard | Suspended solids accumulate in stream beds and shellfish areas. They often contain water quality contaminants and they impede successful fish spawning. |
| Nitrogen | Manure, fertilizers, septic effluent, decomposing organic matter | Max. 10mg/l in drinking water | Elevated nitrogen in drinking water poses health hazards for infants. Nitrogen often occurs in association with other pollutants. |
| Phosphorous | Manure, fertilizer, detergents | No standard | Phosphorous causes algae blooms and aquatic weed growth in streams and lakes, which in turn depletes dissolved oxygen. |
| Conductivity | Sediment and inorganic pollutants | No standard | High conductivity often indicates a recent pollution event such as a spill, or an ongoing source such as an illegal discharge pipe. |
| Metals | Vehicle traffic, air deposition, soil | No standards | Metals persist in the environment and may endanger human health. Metals of concern include lead, copper, mercury and arsenic. Metals accumulate in sediment deposition areas and in certain animal tissues. |
| Organic compounds | Petroleum products, manufacturing processes, road wear, pesticides | No standards | Some organic compounds pose extreme health hazards to humans and animals, including cancer and reproductive damage. |

*Temperature.* Water temperature regulates the metabolism, growth rate, and internal chemical reactions of aquatic plants and animals, and directly affects the ability of fish species to survive. Anadromous fish such as salmon generally require colder water than resident species such as perch and bass. Temperature limits the amount of dissolved oxygen in water, which fish require to survive; colder water can hold more oxygen. Stream water quality standards include a maximum temperature not to be exceeded due to human activities.

*Dissolved Oxygen (DO).* Aquatic plants and animals rely on oxygen dissolved in water. Plants add dissolved oxygen to water during the daytime and deplete it at night, and aquatic organisms breathe dissolved oxygen. Water contains less than 1% oxygen, so small changes in oxygen levels have a profound impact on aquatic life. Three factors control the amount of dissolved oxygen in water: *temperature* limits the total amount of oxygen; *respiration and decay* of aquatic organisms remove oxygen; and *aeration and photosynthesis* add oxygen. Stream water quality standards include a minimum for dissolved oxygen, expressed in milligrams per liter (mg/l).

*pH.* pH measures the amount of free hydrogen in the water and indicates its acidity. pH affects the solubility of several nutrients and toxic chemicals, which influences their impact on aquatic plants and animals. Acidic water can damage the metabolism of aquatic organisms, and alkaline water can absorb, or "buffer" acidic runoff. Streams in our area tend to be slightly acidic, due to the soil of the surrounding coniferous forests. pH is expressed as a number from 0 to 14; 0 is totally acidic, 7 is neutral, and 14 is totally alkaline. Stream water quality standards include an allowable range of pH values.

*Turbidity.* Turbidity is a measure of cloudiness in water. Fine soil and sediment particles and staining by algae or plants cause turbidity. Sediment harms fish gills and eggs, and aquatic insects. Sediment often contains water quality contaminants, including phosphorous which can increase aquatic plant growth. Stream water quality standards set a maximum allowable turbidity, expressed as an amount of NTUs (nepthlometric turbidity units) above background turbidity.

*Total Suspended Solids (TSS).* TSS is a measure of sediment in water which can help to differentiate between turbidity caused by water stained with algae or root tannins and water clouded by sediment. There is no TSS water quality standard.

*Nutrients.* Nutrients refer to the substances required for plant growth, especially nitrogen, phosphorous, and potassium. Chemical fertilizers, human and animal feces, sediments, and decomposing organic material such as leaves and grass contain nutrients.

Nitrogen occurs in several forms, dissolves into water, and is not readily absorbed, filtered, or degraded, so it usually ends up in receiving waters. The nitrogen forms available to plants are nitrate, nitrite, and ammonia. Most common fertilizers contain nitrates or ammonia. Fertilizers are often applied in agriculture and residential areas in combination with other potential contaminants such as pesticides. Consequently, high nitrogen levels may indicate the presence of other pollutants that were not monitored. Stream water quality standards do not include nitrogen, but drinking water standards set a maximum nitrate nitrogen concentration of 10 mg/l.

Phosphorous is critical to plant growth; phosphorous levels are often the limiting factor in aquatic plant growth. "Total phosphorous" consists of all forms of the element, including phosphorous contained in plant tissue and sediments. "Ortho phosphorous" is that fraction of total phosphorous which is available for plant growth. There is no water quality standard for phosphorous, but the EPA recommends a maximum of 0.10 mg/l to prevent weed growth.

*Conductivity.* Conductivity is a measure of water's ability to conduct an electrical charge. Conductivity can be used to trace inorganic pollutant sources, because inorganic pollutants often raise conductivity. There is no water quality standard for conductivity.

### 4.1.2 SEDIMENT

Sediment often contains metals and organic pollutants, which "adsorb" or attach themselves to the sediment particles. Sediment from streets, parking lots and construction sites collects in storm drains and subsequently washes into receiving waters during storms, if it is not periodically removed.

*Metals.* Metals include copper, lead, zinc, cadmium, chromium, arsenic, and other trace metals. Metals in stormwater sediment come mainly from vehicle traffic, but they also occur naturally in soil and water, and differentiating between natural and human-caused sources of metals can be difficult. Metals attach to sediment and accumulate in stream and runoff deposits. Metals present health threats to humans, fish and wildlife. The Washington Department of Ecology (DOE) has established background levels for metals in soil and fresh water. There are currently no water quality standards for metals in sediment, although the DOE has compiled guidelines for metals and organics in the *Summary of Criteria and Guidelines for Contaminated Freshwater Sediments*.

*Organics.* Chemically, organic compounds are defined as compounds which contain carbon. Several organic pollutants are known to cause health problems. Organic compounds include polynuclear aromatic hydrocarbons (PAH) and phthalates. PAHs are found in fossil fuels, and enter streams and lakes through petroleum spills, atmospheric fallout, and road wear. Phthalates are found in plastics, industrial oils, cosmetics, fragrances and pesticides, and are used in several manufacturing processes.

### 4.1.3 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are the aquatic insects which live in lake and stream beds and form the basis for the aquatic food chain. Benthic macroinvertebrates are sensitive to water quality changes. The EPA has developed protocols for assessing macroinvertebrates, which look at the structure, variety, and population of aquatic insect communities. In general, streams and lakes with good water quality have diverse and plentiful aquatic insect population. Certain families of aquatic insects cannot thrive in poor quality water, so their absence can indicate a water quality problem. Benthic macroinvertebrate populations in streams help provide an overall index of habitat quality.

## 4.2 WATER QUALITY STUDY METHODS

Environmental Health Department staff characterized the water quality in Green Cove basin for this basin plan. The *Green Cove Creek Basin Comprehensive Drainage Basin Plan Water Quality Assessment* (Thurston County 1995) contains the complete results of the water quality study. Map 10A & B show the sampling locations.

Water quality sampling occurred in 1994. The sampling program included:

*1) Monitor conventional water quality parameters in Green Cove Creek.*

Monitoring was conducted from the headwaters of Green Cove Creek at the Louise Lake outlet to the mouth, to provide an overall picture of water quality in the basin. Monitoring occurred twice monthly from January through April 1994 to represent wet season conditions, and twice monthly in August and September 1994 to represent low flow conditions. Parameters included conductivity, dissolved oxygen, flow, pH, temperature, fecal coliform bacteria, total phosphorous, nitrate+nitrite, ammonia, chlorides, total suspended solids and turbidity.

Samples for laboratory analysis were collected at each station, at approximately mid-channel, by submersing the bottle in the water. Field instruments were used to measure temperature, pH, dissolved oxygen and conductivity. The final study report explains the analytic procedures, measurement methods, and quality assurance/quality control methods.

The results were compared with state water quality standards. Daily loading levels of stream pollutants were calculated. Phosphorous concentrations were compared with EPA recommended limits. Chloride concentrations were compared with typical groundwater ambient levels.

*2) Assess benthic macroinvertebrates in Green Cove Creek.*

Benthic macroinvertebrate samples were collected from three sites in Green Cove Creek, in April 1994. The sampling method was based on the EPA's *Rapid Bioassessment Protocols for use in Rivers and Streams* (U.S. Environmental Protection Agency 1989). The samples were analyzed for species diversity and abundance, and scored and ranked using EPA protocol II metrics.

*3) Analyze total petroleum hydrocarbons, copper, metal and zinc in water at the creek mouth.*

Grab samples of stream water were collected at the mouth of the creek in January, March, July and August of 1994, and analyzed for total petroleum hydrocarbons (TPH), copper, lead and zinc. TPH and metals were compared to Washington State acute toxicity standards.

*4) Monitor stormwater quality at storm drain outfalls during three major storms.*

Water samples were collected from each of seven stormwater outfalls during three rain events in February and March 1994. The samples were analyzed for fecal coliform bacteria, total phosphorous, nitrate+nitrite, ammonia, chloride, total suspended solids and turbidity. Conductivity, temperature and flow were measured in the field. Rainfall was measured at the gauging station on 36th Avenue NW.

Sample results were compared to state water quality standards for streams. Daily loading levels of stormwater pollutants were calculated. Phosphorous concentrations were compared to EPA recommended limits to prevent nuisance weed growth. Chloride concentrations were compared to typical groundwater ambient levels.

*5) Analyze metals and total petroleum hydrocarbons in sediment from storm drains.*

Sediment samples were collected in June 1994 from five of the seven outfalls that were sampled for stormwater (the two other outfalls were sampled for sediment in 1990). Sediment samples were analyzed for chromium, copper, lead, mercury, nickel, zinc, and TPH.

Metals concentrations in sediment were compared with background concentrations in Washington soils. Metals and organic compounds concentrations were compared with various North American criteria summarized by the Washington Department of Ecology. TPH concentrations were compared with a variety of state and local standards.

*6) Conduct follow-up investigation of areas where water quality problems were discovered.*

Additional sampling was conducted for fecal coliform in stormwater at Evergreen Parkway (GCS5) and 36th Avenue NW (GCS4) after initial sample results indicated high fecal coliform concentrations at those locations. Stormwater samples were collected from 7 additional outfalls that drain to Grass Lake wetland, and analyzed for fecal coliform, turbidity and settleable solids.

## 4.3 RESULTS

### 4.3.1 GREEN COVE CREEK WATER QUALITY

Table 4-2 summarizes the results of the creek monitoring. Fecal coliform bacteria concentrations met both parts of the state standards at all stations except the mouth station (GC7), which failed the second part of the standard. The first two stations downstream of Louise Lake (GC1 & 2) had the lowest concentrations and daily loading levels. The sites at 36th Avenue NW and Green Cove Street (GC5 & 6) had the highest concentrations and daily loading levels.
Temperature did not exceed the state standard at any site. The highest temperature was observed at the Evergreen Parkway site (GC3) in August.

Dissolved oxygen concentrations fell below state standards on most occasions at two sites (GC2 & 3). The average and minimum concentrations at both sites were roughly equal; GC3 registered the lowest minimum, but GC2 averaged slightly lower concentrations overall.

All sites but GC2 & 3 met the state standards for pH most of the time. All samples from GC2 registered acidic pH that failed the state standard, and 82% of the samples from GC3 failed the standard. Also, two of twelve samples from GC5 failed the standard.

When using the mean turbidity from each sampling site as the background, no sites failed the state standard for turbidity, and turbidity in the stream registered at consistently low levels. Total suspended solids concentrations and daily loading levels increased steadily from headwaters to mouth, but remained relatively low overall.

Phosphorous concentrations were highest at the Evergreen Parkway site (GC3), but they did not exceed the EPA recommended limits. Overall phosphorous concentrations were higher in summer than winter. Nitrate+nitrite concentrations increased from Evergreen Parkway to the mouth. Chloride concentrations ranged from 2.32 to 4.75 mg/L, close to the median groundwater concentration for Thurston County of 3.4 mg/L.

TPH at the mouth was detected in January, but was not detected during other sampling dates. Lead in samples from the mouth exceeded Washington state chronic and acute toxicity standards in January, but was not detected during other dates. The chronic and acute standards are not directly applicable because they are based on four day and one-hour averages, not on a grab sample. Copper and zinc were detected in some samples, but they did not exceeded state standards.

Bioassessment site #3 off Biscay Street scored the highest overall habitat assessment, a score of 100 out of a possible 135. Site #2 at Evergreen Parkway scored moderate, and site #1 above Kaiser Road scored low-to-moderate.

### 4.3.2 Green Cove Basin Stormwater Quality

Table 4-3 summarizes the results of stormwater sampling. Temperatures never exceeded state water quality standards for streams. The highest stormwater temperature, 10.0 0C, was measured at 36th Avenue NW (GCS4) and Evergreen Parkway (GCS5 & 6). The highest conductivity was measured at Sunset Beach Drive (GCS1), which flows directly into Green Cove. Conductivity readings were generally low during monitoring.

## Table 4-2: Summary of Sampling Results from Green Cove Creek, 1994

| STATION | GC1 | GC2 | GC3 | GC4 | GC5 | GC6 | GC7 | GC8 |
|---|---|---|---|---|---|---|---|---|
| **# Data Sets*** | #3 | #8 | #11 | #1 | #12 | #12 | #13 | #5 |
| **FLOW** (cfs) | | | | too | | | | |
| Average | 1.51 | 2.37 | 2.32 | slow | 2.91 | 2.81 | 3.10 | 0.31 |
| Minimum | 1.24 | 0.40 | 0.01 | to | 0.01 | 0.06 | 0.11 | 0.17 |
| Maximum | 1.95 | 6.95 | 7.00 | measure | 10.25 | 10.46 | 11.39 | 0.42 |
| **OXYGEN** (mg/L) | | | | | | | | |
| Average | 9.49 | 5.39 | 5.74 | | 10.26 | 10.90 | 10.80 | 9.12 |
| Minimum | 9.35 | 3.66 | 2.65 | 9.92 | 8.28 | 8.56 | 9.02 | 7.51 |
| Maximum | 9.64 | 8.76 | 8.97 | | 11.70 | 12.91 | 12.80 | 10.30 |
| **pH** (scale from 0-14) | | | | | | | | |
| Median | 6.64 | 5.83 | 6.28 | | 6.82 | 7.07 | 6.65 | 6.53 |
| Minimum | 6.62 | 5.65 | 5.67 | 6.52 | 6.25 | 6.68 | 7.28 | 6.50 |
| Maximum | 7.30 | 6.07 | 6.58 | | 7.16 | 7.38 | 7.42 | 6.92 |
| **TEMPERATURE** (0C) | | | | | | | | |
| Minimum | 8.63 | 2.36 | 2.81 | 6.41 | 2.94 | 3.53 | 3.70 | 7.50 |
| Maximum | 9.28 | 10.85 | 16.15 | | 15.02 | 15.37 | 14.92 | 9.69 |
| **CONDUCTIVITY** (umhos/cm) | | | | | | | | |
| Average | 53 | 46 | 69 | | 75 | 94 | 101 | 61 |
| Minimum | 47 | 32 | 38 | 44 | 38 | 40 | 43 | 51 |
| Maximum | 57 | 58 | 109 | | 116 | 157 | 169 | 70 |
| **FECAL COLIFORM BACTERIA** (#/100ml) | | | | | | | | |
| Geometric Mean | 2 | 11 | 55 | | 60 | 59 | 52 | 27 |
| Minimum | 0 | 0 | 20 | 0 | 5 | 15 | 5 | 10 |
| Maximum | 10 | 25 | 140 | | 280 | 320 | 395 | 110 |
| % of samples >200/100mL | 0% | 0% | 0% | | 8.33% | 8.33% | 15.38 | 0% |
| **TURBIDITY** (NTU) | | | | | | | | |
| Average | 1.62 | 0.88 | 2.20 | | 1.35 | 1.36 | 1.82 | 0.90 |
| Minimum | 1.08 | 0.55 | 0.85 | 0.90 | 0.70 | 0.65 | 0.84 | 0.45 |
| Maximum | 2.28 | 1.25 | 5.70 | | 2.00 | 2.90 | 3.50 | 1.15 |
| **TOTAL SUSPENDED SOLIDS** (mg/L) | | | | | | | | |
| Average | 0.25** | 0.46** | 1.63** | | 1.90** | 1.97** | 2.35 | 0.74** |
| Minimum | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | <0.50 | 0.50 | <0.50 |
| Maximum | <0.50 | 1.50 | 6.50 | | 12.00 | 5.60 | 4.30 | 2.20 |
| **TOTAL PHOSPHORUS** (mg/L) | | | | | | | | |
| Average | 0.014 | 0.025 | 0.045 | | 0.038 | 0.034 | 0.035 | 0.017 |
| Minimum | 0.013 | 0.013 | 0.013 | 0.009 | 0.017 | 0.017 | 0.018 | 0.011 |
| Maximum | 0.016 | 0.033 | 0.121 | | 0.127 | 0.061 | 0.059 | 0.027 |
| **CHLORIDE** (mg/L) | | | | | | | | |
| Average | 3.10 | 3.22 | 4.04 | | 3.18 | 4.75 | 4.45 | 2.32 |
| Minimum | 2.94 | 1.83 | 0.83 | 2.49 | 1.83 | 1.33 | 1.08 | 0.33 |
| Maximum | 3.39 | 3.82 | 12.90 | | 4.70 | 7.63 | 6.84 | 3.27 |
| **NITRATE+NITRITE** (mg/L) | | | | | | | | |
| Average | 0.306 | 0.048 | 0.216 | | 0.388 | 0.442 | 0.601 | 0.353 |
| Minimum | 0.201 | 0.014 | 0.051 | 0.258 | 0.164 | 0.233 | 0.267 | 0.055 |
| Maximum | 0.378 | 0.086 | 0.758 | | 0.741 | 0.615 | 1.020 | 0.508 |
| **AMMONIA** (mg/L) | | | | | | | | |
| Average | 0.034 | 0.035 | 0.097** | | 0.027** | 0.019** | 0.017** | 0.027** |
| Minimum | 0.026 | 0.017 | <0.010 | 0.031 | <0.010 | <0.010 | <0.010 | <0.010 |
| Maximum | 0.044 | 0.053 | 0.362 | | 0.052 | 0.051 | 0.046 | 0.037 |

Station # and location:

GC1 - Grass Lake Outlet
GC2 - Green Cove Creek at Kaiser Rd. Sewer Lift Station
GC3 - Green Cove Creek at Evergreen Parkway
GC4 - Tributary to Green cove Creek from TESC
GC5 - Green cove Creek at 36th NW
GC6 - Green Cove Creek in Country Club Estates
GC7 - Green Cove Creek Mouth Station
GC8 - Tributary to Green Cove Creek at 28th NW

* Total number of data sets that average is based on
** Averages were calculated using 1/2 the detection limit when the reported value was less than the detection limit.
< = less than detection limit
Shading means parameter failed water quality standard

Fecal coliform concentrations were highest at Evergreen Parkway (GCS5), where the highest sample measured 11,650/100 ml. Fecal coliform concentration at GCS5 measured 9,100/100 ml at a later sampling date. The next highest concentration, 3,450/100 ml, occurred at Sunset Beach Drive (GCS1). Both sites exceeded the state standards for stream water quality, but the standards are not directly applicable to stormwater. These two sites also had the highest daily loading levels. The daily loading at Sunset Beach Drive was somewhat higher than Evergreen Parkway, because the flow at Sunset Beach Drive was significantly higher.

Fecal coliform concentrations were also high at 36th Avenue NW (GCS4) and 14th Avenue NW (GCS7). Follow-up investigation identified a failing septic system as the source of contamination.

Average total phosphorous at 14th Avenue and Road 65 (GCS7) and Evergreen Parkway (GCS5 & 6) exceeded EPA recommended limits for preventing nuisance weed growth. Total suspended solids and/or turbidity was also highest at these three sites, and site GCS7 had markedly higher total suspended solids and turbidity than any other sites. When using the average of all sites for the background level, all samples from site GCS7 failed the state standard for turbidity.

Average nitrate+nitrite concentrations were highest at Sunset Beach Drive (GCS1) and 36th Avenue NW (GCS4). Ammonia concentration was highest at Evergreen Parkway (GCS5). Chloride concentrations were below average ambient groundwater levels at all sites.

### 4.3.3 Stormwater Sediment Quality

Copper concentrations in sediment exceeded background soil levels for Washington State at Evergreen Parkway (GCS5 & 6), and slightly exceeded background freshwater sediment levels. However, they fell well below severe effects criteria for aquatic organisms from the *Provincial Sediment Quality Guidelines.* The state background levels for copper in soil and freshwater sediment exceed the provincial guidelines for lowest levels which affect aquatic organisms.

Chromium levels also exceeded background levels for freshwater sediments at Evergreen Parkway (no background levels are available for soil). As with copper, chromium concentrations fell below the provincial guidelines for severe effects, and state background levels exceed the provincial guidelines for lowest effects.

Lead concentrations exceeded background levels for Washington soils, but measured below background levels for freshwater sediments, at all locations. No locations exceeded the provincial severe effects guidelines. Mercury concentrations fell below the level of detection for all sites except Sunset Beach Drive (GCS1), which exceeded state marine sediment standards as well as provincial lowest effects guidelines.

Table 4-3: Summary of Results from Green Cove Basin Stormwater Monitoring February 15, March 3 & 17, 1994.

| STATION | GCS1 | GCS2 | GCS3 | GCS4 | GCS5 | GCS6 | GCS7 |
|---|---|---|---|---|---|---|---|
| **FLOW** (cfs) | | | | | | | |
| **Average** | **0.71** | **0.024** | **0.04** | **0.054** | **0.05** | **0.057** | **1.56** |
| 2/15/94 | 2.06 | 0.001 | 0.06 | 0.100 | 0.04 | 0.07 | 2.84 |
| 3/3/94 | 0.067 | 0.027 | 0.04 | 0.134 | 0.04 | -- | 1.60 |
| 3/17/94 | 0.016 | 0.045 | 0.03 | 0.027 | 0.07 | 0.043 | 0.25 |
| **TEMPERATURE** (0C) | | | | | | | |
| 2/15/94 | 8.0 | 7.8 | 8.5 | 7.5 | 8.0 | 9.0 | 7.5 |
| 3/3/94 | 9.7 | 9.8 | 9.2 | 9.3 | 9.2 | -- | 8.2 |
| 3/17/94 | 8.0 | 9.8 | 9.5 | 10.0 | 10.0 | 10.0 | 8.2 |
| **CONDUCTIVITY** (umhos/cm.) | | | | | | | |
| **Average** | **105** | **28** | **98** | **85** | **60** | **46** | **55** |
| 2/15/94 | 33 | 26 | 116 | 110 | 95 | 49 | 73 |
| 3/3/94 | 130 | 52 | 108 | 72 | 42 | -- | 39 |
| 3/17/94 | 151 | 7 | 69 | 73 | 43 | 43 | 53 |
| **FECAL COLIFORM BACTERIA** (#/100mL) | | | | | | | |
| **Geometric Mean** | **8.92** | **33** | **13** | **650** | **9771** | **49** | **638** |
| 2/15/94 | 3450 | 140 | 20 | 600 | 11650 | 40 | 610 |
| 3/3/94 | 500 / 730 | 5/10 | 5/5 | 2050 / 1950 | -- | -- | 600 / 495 |
| 3/17/94 | 785 / 570 | 70 / 85 | 25 / 30 | 220 / 220 | 8800 / 9100 | 45 / 65 | 625 / 930 |
| % of samples >200/100mL | **100%** | 0% | 0% | **100%** | **100%** | 0% | **100%** |
| **TURBIDITY** (NTU) | | | | | | | |
| **Average** | **15.7** | **4.5** | **3.6** | **8.9** | **24.0** | **22.0** | **82.3** |
| 2/15/94 | 22.5 | 9.0 | 4.2 | 14.0 | **32.0** | 27.0 | **150** |
| 3/3/94 | 12.5 | 2.5 | 1.95 | 5.3 | -- | -- | **63** |
| 3/17/94 | 12.0 | 2.1 | 4.5 | 7.4 | 16.0 | 17.0 | **34** |
| **TOTAL SUSPENDED SOLIDS** (mg/L) | | | | | | | |
| **Average** | **19.7** | **4.8** | **2.0** | **3.6** | **11.7** | **29.5** | **77.5** |
| 2/15/94 | 42 | 12.0 | 4.2 | 5.6 | 16.0 | 48.0 | 164.0 |
| 3/3/94 | 6.2 | 1.3 | 0.5 | 2.0 | 9.1 | -- | 45.0 |
| 3/17/94 | 11 | 1.0 | 1.3 | 3.3 | 10.0 | 11.0 | 23.5 |
| **TOTAL PHOSPHORUS** (mg/L) | | | | | | | |
| **Average** | **0.096** | **0.039** | **0.023** | **0.090** | **0.125** | **0.138** | **0.277** |
| 2/15/94 | 0.139 | 0.056 | 0.029 | 0.098 | 0.134 | 0.067 | 0.346 |
| 3/3/94 | 0.103 | 0.020 | 0.011 | 0.077 | 0.083 | -- | 0.119 |
| 3/17/94 | 0.045 | 0.040 | 0.030 | 0.096 | 0.157 | 0.209 | 0.365 |
| **CHLORIDE** (mg/L) | | | | | | | |
| **Average** | **4.11** | **2.65** | **3.80** | **2.59** | **2.00** | **1.35** | **1.87** |
| 2/15/94 | 1.52 | 1.20 | 1.94 | 1.84 | 1.52 | 0.35 | 2.26 |
| 3/3/94 | 5.04 | 3.69 | 5.77 | 3.80 | 1.73 | -- | 1.10 |
| 3/17/94 | 5.76 | 3.07 | 3.69 | 2.14 | 2.76 | 2.35 | 2.24 |
| **NITRATE+ITE** (mg/L) | | | | | | | |
| **Average** | **1.29** | **0.433** | **0.224** | **1.003** | **0.361** | **0.166** | **0.589** |
| 2/15/94 | 0.275 | 0.248 | 0.302 | 0.534 | 0.503 | 0.122 | 0.732 |
| 3/3/94 | 1.53 | 1.020 | 0.172 | 1.750 | 0.398 | -- | 0.669 |
| 3/17/94 | 2.07 | 0.032 | 0.197 | 0.191 | 0.182 | 0.209 | 0.365 |
| **AMMONIA** (mg/L) | | | | | | | |
| **Average** | **0.088** | **0.047** | **0.034** | **0.098** | **0.742** | **0.101** | **0.047** |
| 2/15/94 | 0.087 | 0.033 | 0.037 | 0.130 | 0.724 | 0.090 | 0.064 |
| 3/3/94 | 0.133 | 0.023 | 0.009 | 0.108 | 0.403 | -- | 0.024 |
| 3/17/94 | 0.043 | 0.084 | 0.055 | 0.055 | 1.100 | 0.112 | 0.052 |

Station # and location:
GCS1 - Sunset Beach Drive - pipe to Green Cove
GCS2 - Green Cove St. - pipe to Green Cove Creek from north
GCS3 - Green Cove St. - pipe to Green Cove Creek from south
GCS4 - 36th Ave. NW - pipe from east
GCS5 - Evergreen Parkway - pipe to Green Cove Creek from west
GCS6 - Evergreen Parkway - pipe to Green Cove Creek from east
GCS7 - 14th Ave. NW at Road 65 - ditch to wetlands
Shading means parameter failed water quality standard

Nickel concentrations slightly exceeded provincial lowest effects guidelines at all sites, but fell below severe effects guidelines. Nickel concentrations were highest at Evergreen Parkway (GCS5 &6) and 14th Avenue (GCS7). No background levels for nickel in soils or freshwater sediments are available.

Zinc exceeded background levels for Washington soils at all sites except Green Cove Street (GCS3), but exceeded background levels for freshwater sediments only at 36th Avenue NW (GCS4). Zinc concentrations exceeded provincial lowest effects criteria at three sites: 36th Avenue (GCS4), Evergreen Parkway (GCS5 &6), and Sunset Beach Drive (GCS1). However, background freshwater sediment levels also exceed the provincial lowest effects guidelines. No sites exceeded the provincial severe effects guidelines.

Total petroleum hydrocarbons in stormwater sediments ranged from 790 to 1,100 mg/L, with the highest concentration at 14th Avenue NW (GCS7). There are no standards for TPH in sediment, but Thurston County uses 200 mg/L as the limit for landfilling soil, and the Washington State Model Toxics Control act uses 200 mg/L as the cleanup level threshold.

## 4.4 DISCUSSION

The purpose of the state water quality standards is to help insure the "public health and public enjoyment" of Washington State waters and the "propagation and protection of fish, shellfish and wildlife." The state has established an "antidegradation policy" which states that "existing beneficial uses shall be maintained and protected and no further degradation which would interfere with or become injurious to existing beneficial uses shall be allowed" (WAC 173-201A). This section discusses the implications of the water quality study results for three primary existing beneficial uses of water in Green Cove basin: shellfish harvesting in Green Cove, salmon habitat in Green Cove Creek, and ecosystem diversity in Grass Lake

### 4.4.1 WATER QUALITY IMPACTS TO SHELLFISH HARVESTING IN GREEN COVE

Commercial shellfish harvesting in Green Cove is currently unrestricted, but declining water quality has forced restrictions on commercial shellfish harvesting farther south in Eld Inlet. Unrestricted shellfish harvesting in Green Cove is protected by the state water quality standards. The primary water quality parameter of concern for shellfish harvesting is fecal coliform bacteria, which accumulate in shellfish. Fecal coliform can indicate the presence of viruses and pathogens that can cause diseases in humans. Rainfall is the main factor in shellfish harvesting restrictions, because stormwater runoff to streams and inlets elevates fecal coliform levels in shellfish growing areas. Stormwater systems that discharge to Green Cove Creek or directly to Green Cove are the largest sources of runoff to shellfish beds in the cove.

The water quality study found that Green Cove Creek met the state standard for fecal coliform concentrations at all the sampling stations except the mouth, where the samples failed the second part of the standard (15% of the samples exceeded 200 organisms/100 ml). Generally, the fecal coliform concentrations were relatively low throughout the stream.

Fecal coliform concentrations in stormwater runoff were much higher than in the stream itself, which is typical for stormwater. Several stormwater samples were high enough to raise concern and suspicion of a land-use related source, including samples measuring 11,650/100 ml and 9,100/100 ml at Evergreen Parkway (GCS5), and 3,450/100 ml at Sunset Beach Drive (GCS1). Stormwater runoff clearly contributes significant pulses of fecal coliform to the stream and inlet.

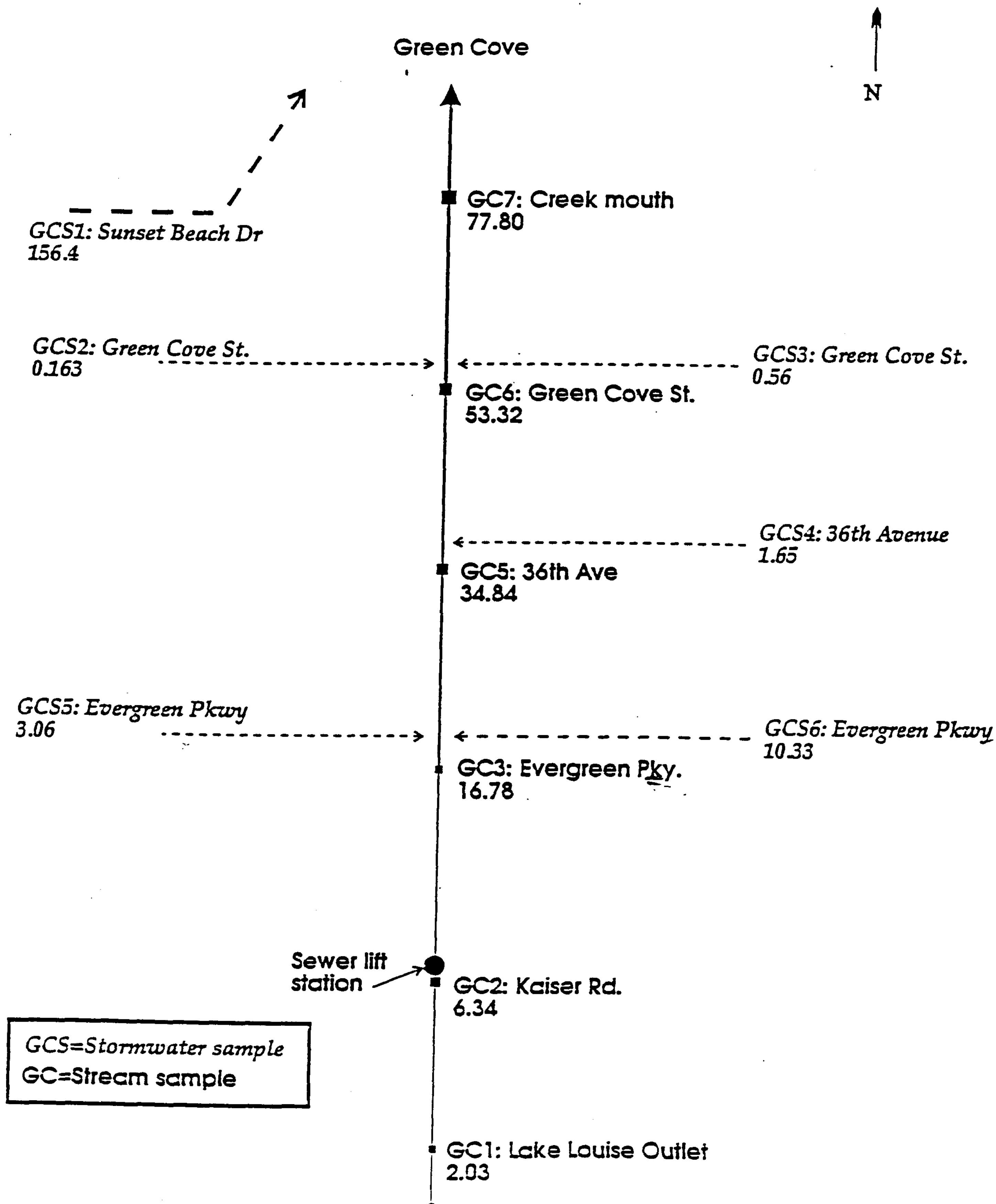
The fecal coliform *concentrations* indicate the relative contamination per unit of water, not the total quantity of contaminant delivered to the receiving waters. A low flow with a high concentration of pollutants will not contribute much total contamination to a large stream. The fecal coliform *loading* indicates the total amount of bacteria delivered, in organisms per day. The fecal coliform loading levels provide a better picture of which sources deliver the most non-point pollution.

Figure 4-1 depicts a schematic diagram of the fecal coliform loading levels in Green Cove Creek and the stormwater discharges in the basin. The thickest lines represent the segment of creek or stormwater system with the highest loading levels. Stormwater loading levels have a higher magnitude than stream loading levels, because the stormwater samples include only major rainfalls, but the stream samples include both wet and dry seasons. The stream loadings indicate where the greatest increases in fecal coliform occur along the creek. The stormwater loadings indicate which stormwater systems contribute the most fecal coliform contamination. Other sources contribute to fecal coliform in the creek, where high creek loadings cannot be traced to stormwater system discharges.

The loading analysis indicates:

- The largest increase in fecal coliform loading in Green Cove Creek occurs between Kaiser Road just upstream of the sewer lift station (GC2) and Evergreen Parkway just upstream of the stormwater outfalls (GC3). No significant stormwater source was identified on this segment of the creek.
- The next largest increase occurs between the Evergreen Parkway site (GC3) and 36th Avenue just upstream from the stormwater outfall (GC5).
- The highest loading levels in stormwater runoff come from the stormwater system discharging to the creek from the west on Evergreen Parkway (GCS5), and from the system discharging directly to Green Cove from Sunset Beach Drive (GCS1). These discharges contained fecal coliform loading levels several orders of magnitude higher than any of the other stormwater systems tested.
- The second largest stormwater contributor to stream fecal coliform is the stormwater system discharging from the east at 36th Avenue NW (GCS4).

Figure 4-1 Fecal coliform loading levels in Green Cove Creek and adjacent stormwater outfalls



The TSS loading level at the site on Sunset Beach Drive (GCS1) was fairly high, indicating that the stormwater system is discharging sediments into Green Cove. High TSS is often associated with high fecal coliform because sediments contain fecal coliform. The occurrence of high TSS at the Sunset Beach Drive site provides another indication that the stormwater system contributes nonpoint pollution to the cove.

### 4.4.2 WATER QUALITY IMPACTS TO SALMONIDS IN GREEN COVE CREEK

Coho, Chum and Sea-run Cuththroat currently use Green Cove Creek for both spawning and rearing habitat. The state water quality standards protect salmon use of Green Cove Creek. The primary water quality parameters of concern for salmon habitat include benthic macroinvertebrates, dissolved oxygen, temperature, turbidity, and total suspended solids.

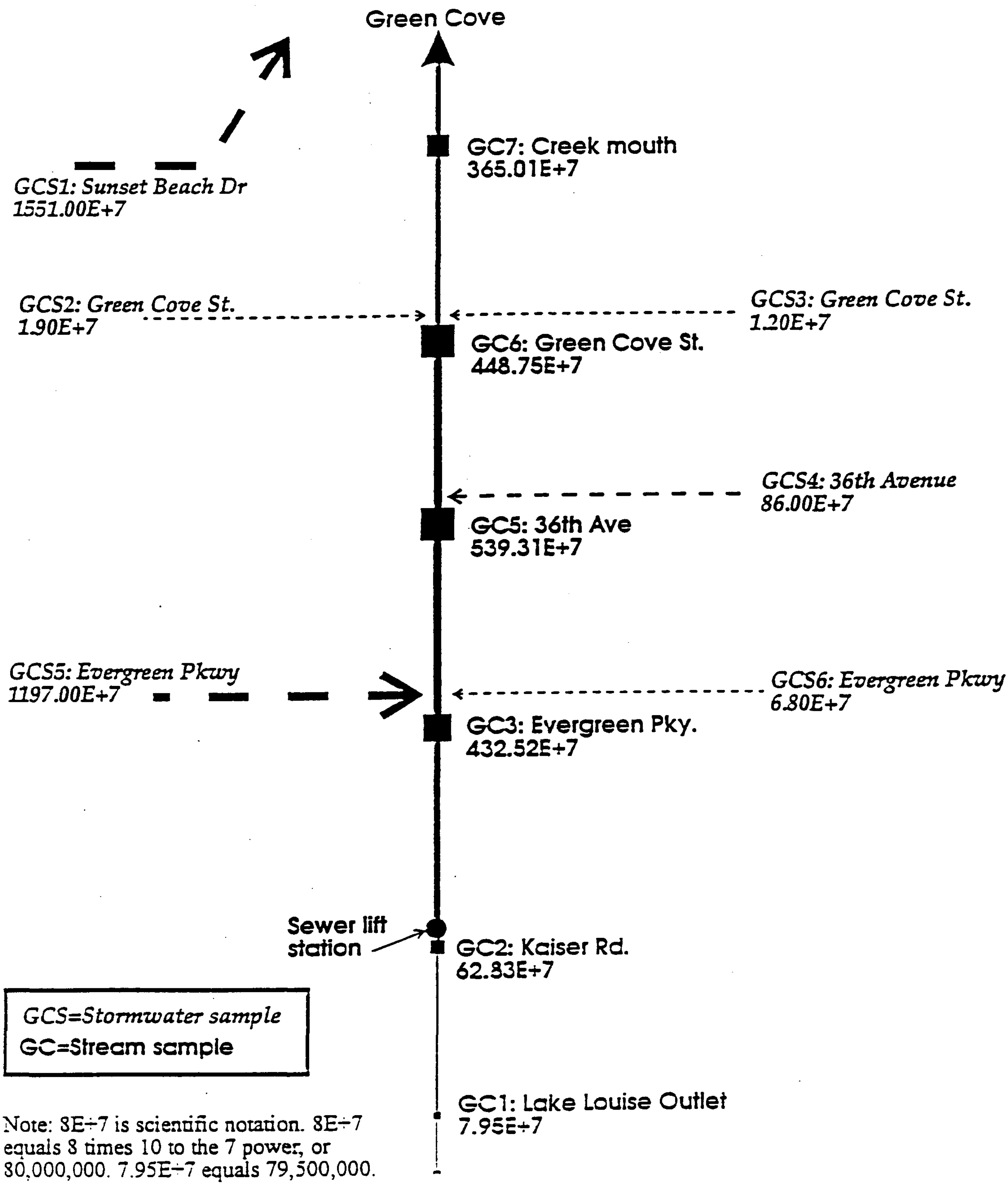
Dissolved oxygen levels complied with state standards at all sites except stations GC2 and GC3, where large wetlands produce naturally low dissolved oxygen levels, because decomposing plant matter depletes dissolved oxygen. The naturally low DO in the wetland areas does not pose a threat to salmon in the creek. The DO levels were good below 36th Avenue where most of the fish use occurs. Dissolved oxygen was high at the head of the creek despite extensive wetlands there, perhaps because the Louise Lake outlet structure creates high turbulence that oxygenates the water. Temperatures stayed within state standards at all sites, and there are no indications that high stream temperatures pose problems for salmon.

Macroinvertebrate conditions were excellent at Green Cove Street in the lower segment with the highest fish use, which agrees with the overall high water quality found in the study. Macroinvertebrates are used to indicate changing water quality conditions because they respond quickly to water quality degradation. Macroinvertebrate conditions were only fair at Evergreen Parkway and above Kaiser Road, but this is probably due to natural wetland conditions. The macroinvertebrate index used to assess habitat is designed for streams, and is not intended to portray wetland conditions.

Turbidity was generally low and never exceeded standards. Total suspended solids (TSS) were low throughout the system, with gradually increasing levels downstream, probably due to a combination of natural streambank erosion and some stormwater input. TSS naturally increases toward the mouths of streams because they receive the accumulated sediment from all upstream sources. The daily load of TSS at the mouth measured 77.8 lbs. per day, which is quite low.

The primary water quality impact of stormwater runoff on fish habitat is likely to be sediment deposition, which can inhibit spawning and deposit heavy metals in the creek. Road runoff often contains high levels of suspended sediments, especially from high volume arterials and highways. However, investigation of the stormwater systems discharging to Green Cove Creek indicated that the stormwater is generally low in total suspended solids. The stormwater system at Evergreen Parkway had moderately high TSS concentrations.

Figure 4-2 Total suspended solids loading levels in Green Cove Vreek and adjacent stormwater outfalls




Note: 8E+7 is scientific notation. 8E+7 equals 8 times 10 to the 7 power, or 80,000,000. 7.95E+7 equals 79,500,000.

Overall, there are no indications that stormwater systems cause significant sediment deposition in the stream. Also, stormwater sediments were relatively clean, consistent with low-volume road runoff in other areas of the state. Most heavy metals hovered somewhere between the natural background levels for soil and the natural background levels for freshwater sediment, and none exceeded the provincial guidelines for severe effects on aquatic organisms.

Figure 4-2 depicts the TSS loading levels in the creek and stormwater. The loading levels show that the creek has generally low sediment levels, and none of the stormwater systems contribute large loads of TSS to the stream, although the Evergreen Parkway site is somewhat higher in TSS loads than the other sites.

### 4.4.3 Water Quality Impacts to Grass Lake Wetland Ecosystem Integrity

Several indicators provide evidence that the Grass Lake wetland is currently a highly complex and diverse urban ecosystem. Grass Lake wetland comprises one of the highest quality wildlife habitats in the Olympia area, and supports several aquatic and terrestrial vegetation communities. The wetland provides a home for the Olympic mud minnow, a state-listed species, and supplies priority habitat for breeding waterfowl. Most of the wetland area is protected as a city park with walking trails and educational opportunities. The state water quality standards protect the beneficial uses of Grass Lake wetland. The primary water quality parameters of concern for maintaining the integrity of Grass Lake wetland include nutrients, turbidity, and total suspended solids.

Little data exists on the water quality of Grass Lake wetland. The stream monitoring station included one site at the outlet of Louise Lake. Nutrient levels were quite low at this site, as were turbidity and total suspended solids. Dissolved oxygen was surprisingly high. This site had good overall water quality.

The original water quality study included only one outfall to Grass Lake wetland (GCS7), which drains from a residential neighborhood at the intersection of 14th Ave. NW and Rd. 65. Hansen Elementary School and Marshall Middle School, which drain directly to this outfall, were under construction at the time of the study. The sampling results indicated high turbidity, TSS and phosphorous at the site, probably because of the construction upstream. The results indicate that human impacts to the wetland have occurred, and continued sediment deposition could be harmful to the wetland in the deposition area. Fecal coliform was somewhat high as well, possible because of wildlife using the wetlands that drain to the outfall or pet waste from pets in the residential area. Other water quality parameters were normal.

Eight stormwater outfalls that drain to Grass Lake wetland were sampled once in March 1995 for fecal coliform, turbidity and settleable solids. The outfall at 14th Avenue and Rd 65 again exhibited high fecal coliform levels, although turbidity was low. An outfall that drains from Capitol High School also exhibited high fecal coliform and high turbidity.

## 4.5 CONCLUSIONS

- Fecal coliform concentrations at the mouth of Green Cove Creek exceed state standards, and overall fecal coliform loading levels in stormwater may be high enough to affect shellfish beds in Green Cove. TSS loading levels from the stormwater system on Sunset Beach Drive also indicate potential stormwater impacts to the cove.

- The highest fecal coliform loading in Green Cove Creek occurs in the area between Evergreen Parkway and Kaiser Road, and stormwater does not appear to be the source.

- The stormwater systems that contribute the highest fecal coliform loads to Green Cove are the drainage systems at Sunset Beach Drive, the west side of Evergreen Parkway, and the east side of 36th Avenue NW.

- Water quality does not appear to limit fish runs in Green Cove Creek. Dissolved oxygen, temperature, macroinvertebrates and total suspended solids all indicate good to excellent conditions for fish. Sediment from Evergreen Parkway could be contributing slightly to TSS in the creek. The water quality goals for sustaining salmon runs in the creek currently appear to be met.

- Existing water quality data for Grass Lake wetland is not adequate for drawing conclusions about the current conditions or the impact of stormwater runoff. Preliminary results indicate that human-caused water quality impacts probably have occurred, and fecal coliform and turbidity could be a problem at two stormwater outfalls.