CHAPTER 3: PROBLEM IDENTIFICATION

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This chapter begins by describing and analyzing the general processes which cause surface water-related problems throughout the McAllister/Eaton Creek basin. These problems are closely related to each other and must be regarded together. Site-specific problem descriptions follow the overall analysis, grouped into three geographic areas: Eaton Creek basin; McAllister Creek basin; and McAllister GSA. Readers interested in a specific area or problem site may want to skip ahead to their area of interest. Maps 9 and 10 in Appendix A show the locations of problem sites described in this chapter.

3.1 PROBLEM DESCRIPTION AND ANALYSIS

This section describes the processes which cause:

- Flooding
- Erosion
- Water quality degradation
- Fish and wildlife habitat loss

Existing problems in the McAllister/Eaton Creek basin were identified through field reconnaissance and detailed research. Field investigations included inventorying and evaluating all stormwater facilities in the basin, and examining all natural drainages for impacts. Research efforts included thoroughly reviewing existing literature, examining all drainage complaints and service records received by the Thurston County and Lacey Road Maintenance crews, and studying and verifying the stormwater facilities inventory and evaluation.

Thurston County contracted with Brown and Caldwell in association with Adolfson Associates and Sweet Edwards/EMCON to analyze current and future drainage problems and assess risks to ground water, based on population growth and development projections from the Thurston Regional Planning Council. Future risks to ground water were projected using a computer model that analyzes land use, soil type, surface and ground water flow patterns, traffic densities, railway transportation, background pollutant loading, and contaminant characteristics. Future drainage scenarios were projected using both Hydrologic Simulation Program Fortran (HSPF) and HYDRA computer models.

The problem identification process revealed major risks of ground water contamination and severe erosion on upper Little McAllister Creek. Flooding is a local problem in a number of areas in McAllister basin and at one site in Eaton basin.

3.1.1 Flooding

Flooding occurs naturally when major storms cause rivers and streams to overflow their banks. Forests and natural vegetation intercept and absorb significant amounts of rainfall, preventing the rain from running off rapidly and flooding streams. Repeated flooding creates floodplains which absorb overflow waters and slow down the flows. Floodplains have evolved unique ecosystems adapted to these conditions. Evergreen Valley's floor is the floodplain for Eaton Creek, and McAllister Creek is surrounded by extensive floodplains.

Flooding in developed areas results from several factors, including:

- __Increased Impervious Area__ Land development reduces the landscape's natural capacity to moderate flooding because buildings and pavement cover the soil with surfaces that are impervious to water. Development in highly water-permeable soil causes large increases in runoff because it greatly reduces the soil's ability to infiltrate water. Flooding problems are consequently likely to increase with development, especially in areas with permeable soils such as those around Lake St. Clair.

- __Pothole Area Soils__ Complex soils and drainage patterns in the pothole areas create the potential for numerous localized flooding problems associated with development. Rainfall in these closed basins drains into potholes and eventually evaporates or infiltrates to ground water. The water level in potholes following storms depends on the rate and quantity of runoff entering the potholes, and the rate at which the water leaves the potholes through infiltration and evaporation. The pothole bottoms contain muck soils and collected sediments that drain extremely slowly. In contrast, the surrounding sand-and-gravel soils rapidly infiltrate rainfall and reduce runoff into the potholes. As development reduces infiltration and increases runoff into potholes, higher water levels can flood adjacent homes.

- __Clogged Stormwater Facilities__ In McAllister/Eaton Creek basin, about 85% of the stormwater runoff collected by artificial stormwater systems drains into the ground through infiltration facilities such as dry wells and retention ponds. Facilities designed to infiltrate stormwater directly into the ground fail occasionally, usually because fine sediments contained in runoff clog them. Clogged stormwater facilities cause localized flooding, often in residential neighborhoods, when the runoff backs up and spills out into streets and parking lots. Many infiltration facilities have never been cleaned out or maintained, so they no longer function properly.

- __Perched Water Tables__ Layers of impermeable, clay-cemented till near the soil surface prevent water from infiltrating in numerous locations around the basin. These deposits create "perched" high water tables when the soil becomes saturated during the rainy season, which can flood stormwater facilities. Well logs from western McAllister basin indicate a high likelihood that failing facilities in some of these areas are located over perched till deposits.

__McAllister/Eaton Creek Flooding Problems__ Existing flooding problems in the McAllister and Eaton Creek basins are limited to suburban developments in the northern part of the basin and one site in Evergreen Valley. Most flooding problems can be traced to a combination of three factors: facility design and/or construction deficiencies; seasonally high water tables; and lack of maintenance.

The creeks themselves do not appear to have any major flooding problems, because the basin is still largely undeveloped. Existing development is concentrated around Lake St. Clair and in the area between Lacey and McAllister bluff (see Map 8 in Appendix A). Eaton Creek is fed primarily by springs, and flows through level agricultural fields before entering a fairly steep ravine and draining into Lake St. Clair. The creek flows through a large concrete box culvert under Yelm Highway, the only major road crossing. The potential for flooding along the creek and at the road crossing is low. McAllister Creek flows north along the base of a bluff, passing through agricultural fields and onto a large floodplain at the Nisqually Delta, which has a large capacity to absorb flood flows. Three roads cross the creek on the floodplain: Steilacoom Road, Martin Way, and Interstate 5. None of these crossings present an existing or potential flood hazard. Neither stream is likely to develop severe flooding problems associated with other Thurston County streams, because neither have major stormwater outfalls or seasonal snowmelt feeding them.

3.1.2 <u>Erosion</u>

Increased runoff from development activities such as clearing, paving, ditching, and building can cause stream channels to erode, resulting in degraded fish and wildlife habitat and loss of property. In extreme cases, Thurston County homeowners have lost their houses due to erosion, such as along the Deschutes River.

Streamside vegetation and channel complexity create resistance which helps dissipate the energy of water moving down the channel, thereby reducing erosion. The role of vegetation in reducing stream velocity and increasing channel resistance to erosion is most important at high flows, when erosion is most likely. Hydrologists and engineers often characterize a channel's resistance with a "roughness coefficient" such as Manning's n. The table below demonstrates Manning's n values for a variety of channels. The resistance offered by natural streams can be ten times greater than smooth artificial channels, and five times higher than a straight, cleaned out stream channel.

The effects of upstream clearing and debris removal accumulate as water moves down a channel, and the stream gathers energy. Vegetation that increases the channel's resistance and depletes the water flow's energy can significantly reduce erosion. These factors have contributed significantly to erosion in the loose, unconsolidated soils of the Eaton and Little McAllister creek channels.

Table 3-1: Stream channel roughness factors.[1]

Channel type	Roughness factor[2]
Rigid channel (concrete, planed timber, clay, brick, firm gravel)	0.011-0.017
Earth canals	
In best condition	0.017
In poor condition, considerable moss growth	0.035
Natural channels, full flood stage	
Straight, no pools, clean	0.029
Winding, pools and shallows, large stones	0.042
Natural stream, sinuous, snag-choked, sandy	0.150

[1] Source: Sedell and Beschta, 1991

[2] Manning's n coefficient of various channel types less than 30m wide at flood stage. Values are average; variations of 20% or more should be expected, especially in natural channels.

3.1.3 Water Quality Degradation

Types of Contaminants The contaminants of concern in the McAllister/Eaton Creek basin include nutrients, pesticides, sediments, heavy metals, fecal coliform, and petroleum products.

- Nutrients refer to the substances required for plant growth, especially phosphorous, potassium, and nitrates. Nutrients are contained in chemical fertilizers and human and animal feces.

  Nitrates provide a valuable indication of other related water quality threats. They dissolve into water and move with the water flow, and they are not readily absorbed, filtered, or degraded, so they usually end up in receiving waters. Most commonly used fertilizers contain nitrates as well as other contaminants. Land uses which employ fertilizers, such as agriculture and residential development, often employ other potential contaminants such as pesticides. Consequently, increased nitrate levels may indicate that other pollutants that were not monitored have entered the ground water system.

  In addition, elevated nitrates in drinking water can pose a direct threat to public health by causing an infant blood disorder called methemoglobinemia, and have also been linked to certain forms of cancer. Natural nitrate levels in the McAllister area are extremely low, indicating that recent elevated nitrate counts are probably the result of local land use practices.

- Pesticides include a variety of chemicals used on lawns, gardens, and agricultural fields to control insects, weeds, and fungi. Some wells in McAllister basin, including wells near Lake St. Clair, have been contaminated with the agricultural pesticides EDB, DCP, and DBCP. Stormwater may have played a role in transporting these contaminants into ground water.

  EDB, or 1,2-ethylene dibromide is a fumigant usually used to kill fruit fly larvae, insects, and certain worms in the soil, but it is also used to kill Mediterranean fruit fly on harvested citrus fruit, cherries and plums. EDB causes severe irritation of skin, eyes, nose, throat, and lungs in humans, and is suspected of causing cancer, birth defects, and miscarriages.

  DCP, or 1,2-dichloropropane is a soil fumigant which causes severe skin and eye irritation in humans, and can cause dermatitis. It is considered one of the most toxic of a group of hazardous materials called chlorinated hydrocarbons. In animals, DCP causes degeneration of the liver, kidneys, and occasionally the heart, and it is fatal to mice.

  DBCP, or 1,2-dibromo-3-chloropropane is a liquid pesticide which is one of only three substances regulated by the Occupational Health and Safety Administration (OSHA) on the basis of hazard to human reproductive health. DBCP causes reduced sperm counts, abnormal chromosomes, sterility, decreased testicular size, and increased level of follicle stimulating hormones in men. It is also suspected of causing cancer.

- Sediments include fine soil and decomposed minerals which result from erosion. Sediments harm fish and aquatic insects, destroy fish spawning gravels, and reduce water clarity. Stormwater runoff often contains high sediment loads.

- Heavy metals include copper, lead, zinc, and other trace metals which come largely from vehicle traffic. Heavy metals attach themselves to sediments and accumulate at points where streams and runoff slow down. Heavy metals present health threats to humans, fish and wildlife.

- Fecal coliform is a type of bacteria contained in human and warm-blooded animal feces which can cause severe illnesses, and, in extreme cases, death. Fecal coliform also indicates that other contaminants contained in feces may be present, such as nutrients.

- Petroleum products include gasoline, kerosene, oil, and a variety of solvents. Contamination by petroleum products usually results from traffic-related accidents, spillage during transfer from one container to another, or leaking storage tanks. Petroleum products in drinking water present a health hazard to humans.

<u>Surface Water Contamination from Stormwater</u> Stormwater collects all sorts of materials as it washes over the landscape and pours into streams and lakes. Pollution carried by stormwater runoff is called "nonpoint source pollution", or simply "nonpoint pollution", because it originates from so many dispersed sources rather than from a single point such as a sewage pipe. Pollutants accumulate over the landscape during the dry season, because there are few storms to carry them away. Consequently, the initial storms in the autumn carry the highest levels of contamination as the first flush of runoff scours catch basins, lawns, fields and streets.

Stormwater runoff in agricultural areas often contains manure contaminated with fecal coliform. Runoff from residential areas often contains pet wastes which is also contaminated with fecal coliform. Stormwater conveys the bacteria from these sources into streams and inlets. Flood waters can carry large amounts of fecal coliform into receiving waters.

The manure in stormwater runoff contains nutrients, and lawn fertilizers also contribute nutrients to runoff. When nutrients run into lakes, they can cause algae blooms and feed aquatic weeds which can overtake the lakes. Some of the shallow areas of Lake St. Clair have experienced algae blooms and weed growth. When the vegetation in lakes and streams decomposes, it robs the water of oxygen which is critical to fish survival. Depending on the severity of the problem, decreased oxygen levels can cause everything from declining fish health and reproduction to fish kills.

Stormwater runoff often collects sediments from streets and impervious areas as well as from bare construction sites and eroding banks. Even uncontaminated sediments can damage fish runs by clogging up gills, suffocating fish eggs, and preventing fish fry from emerging out of stream gravels. Sediments can also fill up pools and slow-moving areas of streams, which reduces fish habitat. Contaminated sediments can pose health threats and usually must be taken to a hazardous waste facility.

<u>Ground Water Contamination from Stormwater</u> Stormwater directly and indirectly affects ground water quality. Stormwater collects nonpoint pollutants such as oil, fertilizer, pesticides and animal waste as it runs over lawns, roads and other surfaces. Land development increases stormwater runoff from impervious surfaces, and increases the "chronic loading", or long-term background level of pollutants in the runoff. Stormwater also collects point source pollutants such as large spills of hazardous materials.

When stormwater runoff eventually infiltrates into the ground, it can contaminate the ground water. An estimated 85% of the runoff in the McAllister area infiltrates to ground water through dry wells and infiltration ponds which are designed to collect stormwater and put it into the ground. This can transport contaminants into ground water, and provide a direct route for hazardous materials spills to reach ground water. Ground water contamination in McAllister Springs would have profound consequences because it supplies drinking water to most of Olympia.

- **Stormwater-related Septic System Failures** Stormwater affects on-site septic systems which rely on aerobic, non-saturated soils to remove bacterial and viral contamination. A well-maintained, properly functioning septic system requires 2-4 feet of unsaturated, relatively fine soil for complete removal or absorption of contaminants. Coarse soils drain rapidly without filtering pollutants out of the septic effluent, and provide a direct route to ground water. Conversely, soils saturated by stormwater due to high water tables or poor drainage can flood out septic systems and cause septic effluent to flow directly into surface and ground water.

  Investigation of well logs and drainage complaints in the McAllister/Eaton Creek basin shows the potential for both of these problems with septic systems. Areas with thick, coarse soils, such as around Lake St. Clair, drain rapidly to the underlying aquifers and provide little treatment. Other areas have thin soils perched on impervious till layers with high water tables, such as around Hidden Forest. Thin soils saturate rapidly in winter months and no longer provide effective septic effluent treatment. The stormwater runoff infiltrated into the ground through dry wells and ponds can exacerbate soil saturation and increase septic system failures, or make septic systems ineffective at treating wastewater.

  Even properly functioning septic systems release nitrates. When septic systems fail, fecal coliform and nitrates can reach the ground water. Development increases runoff and wastewater, so the risk that pollutants will enter the ground water in sufficient quantities to contaminate drinking water supplies increases with development.

3.1.4 Fish and Wildlife Habitat Loss

Fish and wildlife habitat consists of the food and shelter which living organisms rely on for their survival, including the environment that supplies that food and shelter. Habitat loss results from vegetation clearing, erosion, flooding, and water quality degradation.

Vegetation Loss Vegetation clearing is most often associated with land development for a variety of uses including residential, commercial and industrial structures, agriculture, forestry, roads, and parking lots. Vegetation clearing degrades fish and wildlife habitat directly by reducing available cover and food sources. Clearing degrades habitat indirectly by raising stream and lake temperatures to levels unsuitable for fish, reducing the water storage and cleansing capacity of vegetation, increasing erosion and sedimentation which harm salmon spawning gravels, disrupting wildlife travel corridors, and disturbing mating and reproduction behavior of wildlife. The conversion of forest lands to agriculture and other developments increases the frequency of floods in the creeks, so the riparian vegetation never gets a chance to recover and grow through natural succession.

Streamside, or "riparian" vegetation plays an important role in providing habitat for fish. Overhanging trees, shrubs and grasses provide cover and resting places for fish. Trees and shrubs create shade which cools the water temperature and prevents fish from dying due to overheating. Leaves and needles fall into the creek and provide food for insects which form the base of the food chain in the stream system. Trees and roots fall into the creek and create pools, trap food, and offer resting places for fish. Live roots stabilize the stream banks and prevent erosion, and trees and shrubs take up water and reduce soil saturation. Fish biologists have realized the importance of streamside vegetation, and the destructive effects of removing it, for more than 100 years.

Riparian vegetation also serves to maintain and enhance stream water quality. Shrubs and groundcovers filter sediments out of runoff entering the stream. Trees and shrubs absorb large quantities of nutrients such as nitrogen and phosphorous which are significant constituents of agricultural runoff in areas such as Evergreen Valley. Riparian soils are especially effective at removing nitrogen from water because they receive large amounts of organic material like leaves and twigs, they are seasonally waterlogged, and they receive large amounts of nitrogen in subsurface flow. Studies in Maryland have found that a 50 foot wide buffer strip between agricultural lands and streams can remove more than 75% of the nitrogen and more than 40% of the phosphorous from sub-surface water before it reaches the streams.

Riparian areas provide travel corridors, food and cover for a variety of wildlife. Biologists consider riparian zones to be some of the most critical habitat for sustaining wildlife corridors. In the McAllister/Eaton Creek basin, Oregon white oaks are often found growing in well-drained riparian areas and along wetland margins. These oaks are critical to the survival of the endangered Western grey squirrel.

Fish Blockages Artificial blockages to fish migration include undersized and poorly designed culverts which create flow velocities too high for fish to swim against, raised culvert outfalls which create cascades too high for fish to jump, and tidegates which periodically prevent passage. Fish blockages reduce a stream's capacity to sustain fish production.

Flooding Flooding degrades fish habitat directly by reducing the number of available in-stream pools and eddies and washing away streamside vegetation, woody debris, and spawning gravels. Flooding at road crossings may create barriers to fish passage. Flooding degrades fish habitat indirectly by causing erosion and siltation, and washing contaminants into the stream. Fish and overall stream health often suffer more severe damage from changes to stream hydrology than from water quality degradation.

Water Quality Degradation Water quality degradation affects fish habitat in many ways. Nutrients such as phosphates and nitrates cause eutrophication and algae blooms which can be toxic to fish. Low dissolved oxygen levels can also be lethal to fish. Soap products dissolve the natural oils that protect fish. Extremely acid or alkaline substances can alter water pH so that fish and insects die. Sediments have a profound affect on fish and insect habitat, and are often a greater concern than other contaminants.

3.2 MCALLISTER CREEK BASIN PROBLEMS

This section describes problem sites in the McAllister Creek drainage, including the Little McAllister Creek, and Medicine Creek sub-basins. Map 9 in Appendix A shows the problem locations. The problems include:

- Evergreen Terrace flooding
- Hidden Forest flooding
- Mountain Aire flooding
- Little McAllister Creek erosion
- Fecal coliform contamination at the mouth of McAllister Creek
- McAllister Creek habitat loss
- Little McAllister Creek mouth blockage

All of the flooding problems described below are caused by inadequate or failing infiltration facilities. McAllister basin contains 141 dry wells and 20 infiltration ponds, and there are only six detention ponds which drain to surface water, all located in the Meadows/Alpine Meadows subdivision. Chapter 4, Section 4.1.2 (Types of Facilities) gives a more detailed explanation of infiltration facilities and detention ponds.

FL-1: Evergreen Terrace Flooding

Evergreen Terrace is an existing subdivision with a history of drainage problems. The street drainage system consists of a series of dry wells connected to infiltration trenches. Severe road flooding has been recorded along Lawson Street, 9th Way, Tanbark Street, and Torrey Street, stranding some homeowners for up to three days. The antiquated Tanbark Street/8th Avenue stormwater system consists of catch basins piped into a perforated pipe laid in an infiltration trench at the east end of 8th Way. Drawings indicate that the perforated pipe ends in an open field east of 8th Avenue, but field crews were not able to locate the pipe. The Torrey St/8th Way stormwater system has catch basins piped to a perforated pipe and infiltration trench in an easement that runs east-west between Torrey and Tanbark streets.

All the infiltration facilities have failed, and the area experiences chronic road flooding, especially on 9th Avenue between Torrey and Lawson Streets, and near the east end of 8th Avenue. The dry well density is about 1 per 5-6 acres, which is not sufficient for the existing soil conditions. This problem was evaluated and ranked as a high priority on a list of remedial maintenance projects in 1992, largely because of the frequent flooding (Appendix I contains a project rating form). However, the project was not completed due to the cost.

FL-2: Hidden Forest Flooding

Hidden Forest is a subdivision with a history of severe basement and road flooding problems, built partly on a historic wetland lying in a depression at the base of a hill north of Steilacoom Road. The Hidden Forest drainage system consists of two components. The cul de sac at the north end of Hidden Forest Drive drains to two catch basins connected to a dry well and infiltration trench on the south side of the road. The remaining lots and the main north-south stretch of Hidden Forest Drive drain through infiltration trenches to an infiltration pond behind the houses on the east side of the street. An infiltration trench at the north end of the street connects the two components. This drainage system is also connected to the Hawks Glen drainage system via an 8" pipe set under 6th Way SE at 0% slope.

The soils in Hidden Forest are relatively permeable, very gravelly Everett outwash, but these soils form a thin mantle over a seasonal high water table. The water table drops off to the southwest, near the intersection of Hawks Glen Drive and Steilacoom Road. The final project approval for Hidden Forest specified fill to raise the base elevation of the north half of Hidden Forest Drive and the lots on both sides of the street above the predicted high water level, but the fill was never installed.

In fall of 1992, maintenance crews from Thurston County Public Works Department excavated about four feet from the bottom of the pond. The excavated material was mostly gravel with small quantities of fine material, and the new pond bottom is also mostly gravel. Following fall and early winter rains, the pond was filled with standing water to a depth of two feet. This indicates that siltation is not the cause for the pond's failure. Flooding occurs because the pond is located over a perched water table, which rises in the winter due to increased rainfall, reducing the pond's capacity and preventing infiltration. The seasonal high water table probably also floods the infiltration trenches and dry wells.

FL-3: Mountain Aire Flooding

Mountain Aire is a small subdivision constructed adjacent to an isolated pothole just northeast of Long Lake, on the extreme eastern edge of the drainage basin. The drainage system consists of a combination of dry wells and infiltration ponds. The subdivision experiences chronic road flooding problems, and the county facilities inventory shows at least eight failed or failing dry wells. The dry well density in this development is 1 per 4-5 acres, which is probably insufficient.

The soils in this area are Nisqually loamy fine sand according to the SCS inventory. Similar fine sandy soils in the Portland, Oregon area have shown poor infiltration characteristics and numerous facilities failures due to trapped sediments clogging the facilities.

ER-1: Little McAllister Creek Erosion

Existing Erosion Field reconnaissance trips in 1991, 1992 and 1993 revealed severe erosion in Little McAllister Creek. The south branch of the creek is fed by springs in a wetland area south of Pacific Highway across from Rockcress Drive. The south branch flows north through a 2 foot diameter culvert under Pacific Highway, and daylights again northwest of a Puget Power substation and east of the Meadows subdivision. More springs feed the south branch of the creek in a cleared area before it drains into a steep, narrow ravine which is suffering from extreme erosion problems.

Ditching in the wetland south of Pacific Avenue has cumulatively lengthened the upper channel feeding Little McAllister Creek by about 1 mile. More recently, the hills draining to the ditch from the south were cleared in preparation for development. Increased runoff from the cleared hills flows directly into the ditched area and creates high stream velocities that are causing downstream erosion. The historic straightening of the stream channel exacerbates the erosion in the ravine below. Eventual development of the drainage basin south of Pacific Highway could cause flooding on Pacific Avenue.

A second, west branch feeds Little McAllister Creek directly from the Meadows subdivision drainage system. A series of ponds detain and treat runoff in the southeast section of Meadows. The last pond, located southeast of the intersection of Goldenrod Drive and Mallard Court, drains into a small ravine that quickly steepens and widens as it joins with the south branch of the creek. The plat identifies this pond as reserved for future stormwater detention. However, this pond already overflows during intense winter storms. Wetlands in the small wooded area west of Foxfire Drive also contribute some flow to the west branch.

Development on the hill above the pond drains through a piped system to a swale connected to the pond by a culvert. The swale has been breached in two spots, and runoff flows directly down into forested wetlands feeding the creek. During storms, the pond backflows through the culvert into the swale and down to the creek. The pond mitigates peak flows and erosion to some extent, until it overflows during heavy storms. The west branch of the creek has severe erosion problems, and the main creek channel below the junction of south and west branches has eroding banks more than 30 feet high.

Future Erosion Development on the hills above the ditches feeding the south branch of Little McAllister Creek would increase runoff draining into the creek if the stormwater is not adequately controlled. This would accelerate the rate of erosion in the south branch and downstream. The south branch ravine runs through a forested area, but clearing along the southeast edge of the Meadows subdivision has encroached to within a few hundred feet of the ravine's western edge. If existing erosion is not halted, the tree cover along the ravine will continue to collapse as the stream undercuts its banks. The trees stabilize the ravine, so loss of tree cover will result in accelerated erosion. The banks are too steep to stabilize with biotechnical erosion control techniques, and artificial hardening of the banks with rip rap, gabions, or retaining walls would be expensive and would probably create new erosion problems further downstream.

The Meadows' drainage system appears to be eroding the west branch ravine at a somewhat slower rate. The existing forest cover offers good protection for the banks and provides good wildlife habitat. However, if the slopes west of Foxfire Drive are developed, if new development north of Mallard Court overloads the existing drainage system, if the forest canopy around the west branch is cleared, or if the existing ponds are not maintained, severe erosion would be likely to occur in the west branch ravine and downstream, which would increase tree fall and loss of vegetation.

WQ-1: Fecal Coliform Contamination at Mouth of McAllister Creek

The Washington Department of Health reclassified 520 acres of commercial shellfish beds in Nisqually Reach near the mouth of McAllister Creek from certified to conditionally certified, on June 1, 1992. Shellfish cannot be harvested from this area for five days following a rainstorm of 1" or more in 24 hours, because the rainfall washes fecal coliform into the shellfish area.

The Department of Health regulates commercial shellfish growing and harvesting, and places conditions on harvest certification depending on the degree of potential fecal coliform contamination. The conditions placed on the Nisqually Reach shellfish area are as restrictive as in any other area in south Puget Sound. The severity of these restrictions indicates the high level of fecal coliform washing into the Reach from even small amounts of rainfall in this area. Department of Health monitoring indicates that McAllister Creek is likely to be the major conveyance for contamination entering Nisqually Reach.

Preliminary assessment by the Puget Sound Cooperative River Basin Team in August 1992 identified 20 farms in the lower McAllister area which could be contributing fecal coliform to McAllister Creek. The farms include two dairies, four vegetable farms (two of which have livestock), two medium sized livestock operations (10-50 animals), and twelve small livestock operations (less than 10 animals).

The Department of Fisheries speculated that a high concentration of migratory waterfowl contributed to high fecal coliform readings in the fall of 1984. Waterfowl have contributed to fecal coliform contamination in other parts of the county; for example, Canada geese have added to contamination of Capitol Lake. In a follow-up report, the Fisheries Department attributed high readings in April 1986 to agricultural runoff.

Staff from the Washington Department of Ecology and the Nisqually Indian Tribe canoed McAllister Creek in July 1992, and identified and mapped 10 tide gates along the creek. The tide gates drain ditches from agricultural fields, which are potential sources of contamination. Staff also identified homes along the edge of the creek which might have failing septic systems, but they did not investigate the condition of those septic systems. The county, the Nisqually Indian Tribe, and state agencies have developed an Initial Response Strategy to the shellfish harvesting restrictions, and begun work to pinpoint the sources of contamination.

HAB-1: McAllister Creek Habitat Loss

Field reconnaissance in the winter of 1992-93 revealed that the creek is virtually devoid of tree canopy cover and overhanging vegetation for approximately three miles between Steilacoom Road and the Olympia-owned watershed around McAllister Springs. The creek has been diked on both banks for almost the entire three miles, and the dikes displayed freshly placed fill material. The vegetation on the dikes is limited to reed canary grass and an occasional willow shrub. Frequent maintenance has further suppressed growth of native vegetation which could stabilize the banks and reduce erosion and the need for even more maintenance.

HAB-2: Little McAllister Creek Mouth Blockage

The mouth of Little McAllister Creek has been routed south along the toe of McAllister bluff and into an agricultural drainage ditch network, by a dike. The lower section of the creek contains excellent salmon spawning gravels, and the Department of Fisheries found smolts there in the mid-1980s. The drainage ditches empty into McAllister Creek through several tide gates located at various points along the west bank. The creek is inaccessible to fish when the tide gates are closed, and the flow is so low and ill-defined that fish cannot easily find the mouth of the creek, even when the tide gates are open.

3.3 EATON CREEK BASIN PROBLEMS

This section describes problem sites in the Eaton Creek/Lake St. Clair basin, including the Eaton Creek, Lake St. Clair, St. Clair Potholes, and Fort Lewis Potholes sub-basins. Maps 9 and 10 in Appendix A show the problem locations. The problems include:

- Lake St. Clair flooding
- General pothole flooding
- Eaton Creek erosion
- Fecal coliform contamination of Eaton Creek and Lake St. Clair
- Eaton Creek fish barrier at Yelm Highway
- Eaton Creek fish barrier at Evergreen Valley Road
- Loss of riparian vegetation on Eaton Creek

FL-4: Lake St. Clair Future Flooding

The sub-basin that drains to Lake St. Clair encompasses about 7,900 acres. About 4,600 acres of the sub-basin drain into Eaton Creek, and the remaining 3,300 acres drain directly to the lake. Due to its size and the number of houses on its shores, Lake St. Clair could experience massive flooding problems from the effects of development. The potential rise in lake level depends on the level of development around the lake, the rate of runoff into the lake, the rate of ground water flow out of the lake, and the severity of rainstorms.

Based on the soil runoff characteristics, Brown and Caldwell estimated the potential lake level rise for a rainstorm of 12" over seven days, which is the projected 100-year, 7-day storm. They assumed that soils in the Fort Lewis area and the sub-basin draining directly to Lake St. Clair would contribute little runoff, because they are mostly undeveloped Class A soils which infiltrate rapidly, except for the houses immediately around the lake. The area draining to Eaton Creek was assumed to be poorly drained Class D soils which generate most of the runoff draining into the lake following a storm. The hydrologic characteristics of the developed areas were based on a computer model calibrated for an area south of Tacoma.

The modeling estimated the amount of runoff likely to flow into the lake under various development scenarios. The model did not consider the outflow from the lake to the aquifer because it is insignificant compared to the runoff entering the lake from major storms. The estimated runoff was used to project lake level rises under the different scenarios.

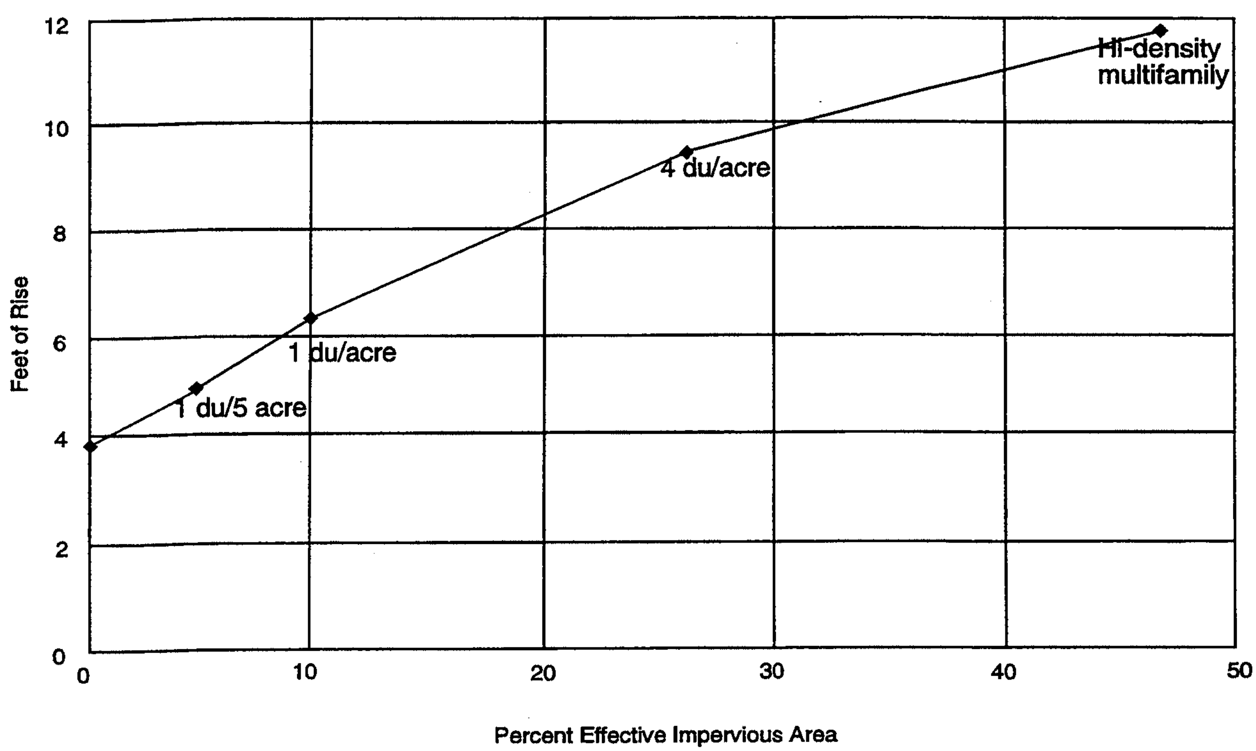
The results of this study are shown in Figure 3-1. The vertical axis shows feet of rise in lake surface. The horizontal axis indicates the level of development of the surrounding basin (excluding Fort Lewis, which was assumed to be protected from development). The graph indicates the lake level could rise more than nine feet during a 100-year rain event if the entire developable sub-basin were built out at 4 units per acre. That level of rise would flood many structures around the lake. If the sub-basin is built-out at one unit per five acres, as currently zoned, a 100-year rainfall would potentially raise the lake level almost five feet.

These figures can only be taken as a rough estimate of the magnitude of potential flooding. The model was not calibrated with actual observed data, the soils were lumped into broad categories, infiltration was not factored in, and sub-basin boundaries were only roughly delineated. Nevertheless, comparisons between various development densities should give a good indication of the relative impact of development on lake levels.

FL-5: General Pothole Flooding

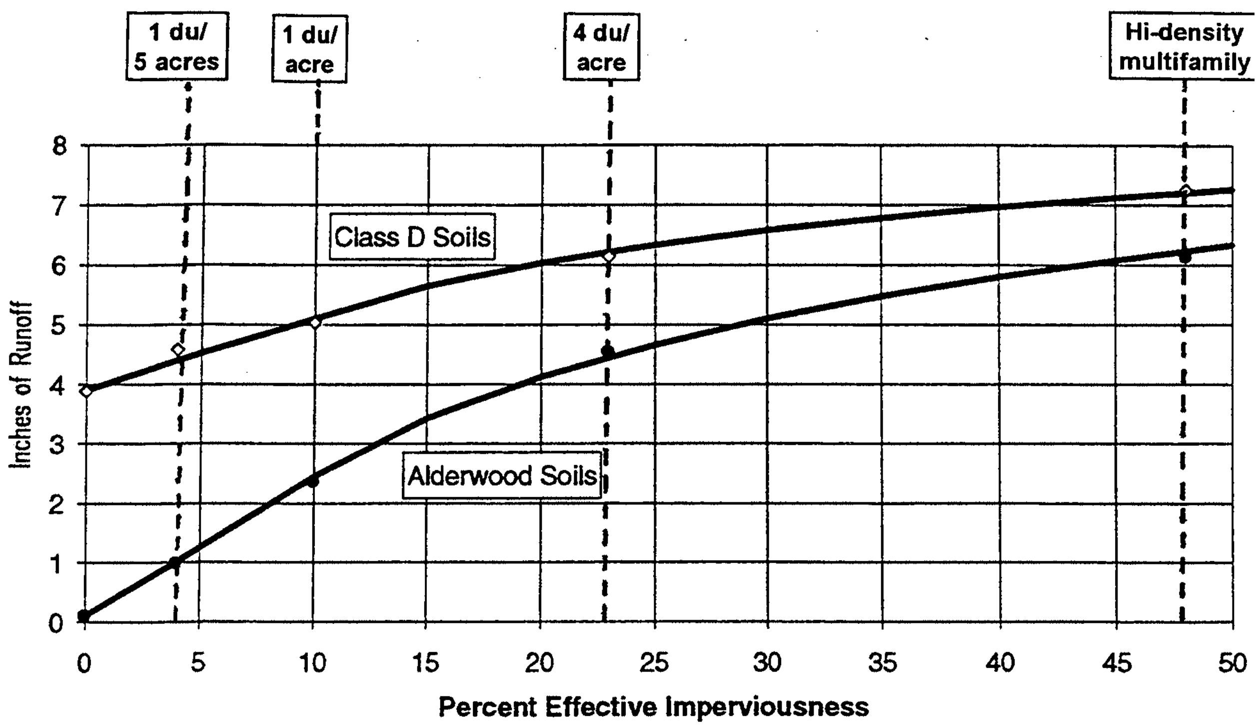
Brown and Caldwell applied the technique described in the Lake St. Clair analysis to develop a generalized methodology for estimating the impact of development on potholes. The results are shown in Figure 3-2. The Alderwood soils represents a mix of Class C and D soils typical of much of Thurston County. The vertical axis represents inches of stormwater runoff, and the horizontal axis represents impervious area from 0% (undeveloped) to 50% (high density). In an undeveloped state, the runoff from Class D soils is much higher because relatively little water can infiltrate those soils. Runoff increases more from development on the pervious Alderwood soils than from development on the relatively impermeable Class D soils, which already generate a high level of runoff. The runoff estimates from Figure 3-2 can be used to project the maximum potential rise in the water

Figure 3-1: Estimated maximum potential rise in Lake St. Clair level at various development densities, from the 100-year, 7-day storm



*du=dwelling unit

Figure 3-2: Estimated runoff from the 100-year, 7-day storm according to development density and soil type



surface of a pothole with the following equation:

Inches of rise = Inches of runoff/PSA
where PSA = pothole area/tributary area

If the pothole showed significant infiltration, the infiltration would have to be subtracted from the runoff estimate. However, most of the potholes in the area have poorly drained muck soils in the bottom, where infiltration is negligible. If the sidewalls had loose gravelly soils, sidewall infiltration would have to be factored in.

Using this methodology, the water level in a sample pothole of 15 acres in a 100 acre sub-basin consisting of Alderwood soils would rise 30" following the 100-year flood if the sub-basin were developed at 4-5 units/acre. Review of the potholes in the basin suggests that their surface area is generally about 10-15% of the tributary area. Water level rises of 3-4 feet during 100-year, 7-day rainstorms should be expected if these potholes are built-out at suburban densities (4 units per acre). These figures represent rough, uncalibrated estimates which compare the relative effects of different development densities.

ER-2: Eaton Creek Erosion

Field reconnaissance trips in 1993 revealed severely eroding streambanks on Eaton Creek just south and north of Yelm Highway. The creek flows between a buffalo ranch and a Christmas tree farm, dropping out of broad Evergreen Valley into the narrow ravine leading to Lake St. Clair. The soil is thick, unconsolidated sand from the top of the bank to the creek bed, a depth of more than 15 feet. This soil is classified as Indianola loamy sand in the 1990 Soils Survey of Thurston County. Occasional small glacial deposits of cemented clay and cobbles occur in the upper 5 feet. The erosion is causing property damage on both sides of the stream, and will eventually threaten a residential building on the east side.

The erosion appears to be caused by the cumulative impacts of riparian vegetation removal, removal of in-stream woody debris, and channelization. The debris and vegetation removal and channelization have increased flow velocity in the stream, and vegetation removal has destabilized the banks and increased soil saturation, resulting in mass wasting of the banks.

WQ-2: Fecal Coliform Contamination of Eaton Creek and Lake St. Clair

The Thurston County Health Department monitored fecal coliform levels at five locations in Eaton Creek and Raymond Ditch from 1985 through 1987. Health Department employees and volunteers began collecting samples for fecal coliform analysis again in 1992. Table 3-2 presents the results of this monitoring. Every station except the headwaters shows high levels of fecal coliform, with both average levels and maximums well above state water quality standards for the creek.

Table 3-2: Fecal coliform levels in Eaton Creek and Raymond Ditch

Sample Site:	Eaton Cr @ Headwaters (Tucker Rd)	Eaton Cr @ Evergreen Valley Road	Raymond Ditch @ Evergreen Valley Road	Eaton Cr @ Yelm Highway	Eaton Cr @ mouth (Lk St Clair)
4/30/85	4	NA	98	NA	284
6/5/85	2	NA	84	1288	250
7/8/85	12	NA	265	NA	55
8/8/85	15	NA	79[1]	875	570
9/18/85	5	NA	95[1]	NA	115
10/9/85	10	NA	[1]	NA	175
11/5/85	0	100	30	NA	110
12/4/85	35	105	425	285	230
1/22/86	10	10	250	58	126
2/18/86	1	0	70	80	105
3/31/86	0	NA	>1000	NA	140
4/22/86	8	NA	82	NA	42
7/22/86	55	NA	25[1]	NA	555
8/19/86	25	NA	NA	NA	590
9/29/86	30	NA	205	NA	400
10/27/86	105	NA	>1000	>1000	NA
12/19/86	15	NA	1000	150	245
1/27/87	15	65	>1000	750	650
5/5/87	10	NA	160	NA	150
9/15/92	NA	350	NA	NA	180
1/26/93	55	85	470	NA	NA
2/23/93	5	90	40	NA	NA
3/24/93	15	120	240	NA	NA

[1] Ditch was not flowing

The state classifies Eaton Creek as an AA water body with a maximum allowable geometric mean fecal coliform count of 50 fc/100 ml. The geometric mean fecal coliform count for Eaton Creek at Yelm Highway, where it drains from Evergreen Valley, was 199 fc/100 ml, or about 4 times the standard. The state standard also allows a maximum of 10% of the samples to exceed 100 fc/100 ml. Seventy five percent of the samples collected at the Yelm highway crossing exceeded this standard. Upstream sampling indicates that Raymond Ditch south of Evergreen Valley Road is the major contributor of fecal coliform to Eaton Creek, with occasional large influxes directly entering Eaton Creek between Evergreen Valley Road and Tucker Road.

Raymond Ditch showed especially high fecal coliform counts, and water in the ditch appeared brown from manure during a visit in February, 1993. Agricultural runoff from unfenced pastures is the likely source of contamination in Raymond Ditch. Field reconnaissance revealed many sites with unrestricted farm animal access to streams and drainages in Evergreen Valley.

The pastures around Raymond Ditch south of Evergreen Valley Road flood regularly, even from small storms. The best approach for preventing the flooded pasture from contaminating the creek will depend on the cause of flooding, which could be a natural phenomenon related to high water table and low gradient, or could be the result of inadequate ditch capacity or culvert capacity. Lack of vegetation along the ditch and in the surrounding fields compounds the problem. If the flooding occurs naturally, the most effective solution will probably involve changing the pasture management practices.

Field examination of Eaton Creek south of Evergreen Valley Road failed to reveal any major sources of fecal coliform contamination. However, some of the creek's flow is diverted through a culvert into a pond a few hundred feet upstream of the road, which empties back into the creek through a second culvert. A house sits next to the pond, and the septic system could be contributing to fecal coliform in the creek.

In addition to the health concerns directly related to the high bacteria levels entering Lake St. Clair, these findings indicate the possibility that other agricultural contaminants are running into the lake, and subsequently making their way to McAllister Springs.

HAB-3: Eaton Creek Fish Barrier at Yelm Highway

Eaton Creek flows north under Yelm Highway through a square concrete culvert, 7 feet wide by 115 feet long. The downstream end of the culvert drains out 3 feet above the creek surface. This large jump prevents fish from passing to upstream spawning habitat. Even if the jump was lower, the flow velocity is so high that fish cannot make it through the culvert. This passage is especially critical to the creek's kokanee population, because kokanee require streams for spawning, but rear exclusively in lakes. Conversations with lakeside property owners indicate that trout and kokanee populations in the lake have steadily declined over the past decades. The lower creek supports a run of cutthroat trout, and the Department of Wildlife believes that the lake and stream could support higher cutthroat and kokanee populations if the fish could reach upstream areas.

HAB-4: Eaton Creek Fish Barrier at Evergreen Valley Road

Eaton Creek flows north under Evergreen Valley Road through twin concrete culverts about 4 feet diameter by 55 feet long. The culverts end on the downstream side about 1.5 feet above the water surface of the creek, which prevents fish from entering the culverts, and the flow velocity is fairly high due to the culverts' gradient. Sections of the culverts have settled, resulting in an irregular bottom that creates steps and resting places in all but peak flow conditions, for fish that manage to enter the culvert. However, the stream bed near the culverts' outfalls has no logs or debris to create pools and resting places for fish. The combination of high velocities at the outfalls, a large drop, and lack of pools present a barrier to fish passage.

HAB-5: Loss of Riparian Vegetation on Eaton Creek

On Eaton Creek, much of the stream has been substantially cleared of riparian vegetation in Evergreen Valley. Homeowners, farmers, and tree farmers have cleared trees and shrubs right up to the water's edge. These practices have degraded most of the streambanks in the southern reach of Eaton Creek. Stream banks are eroding significantly both above and below the Yelm Highway culvert. Very little riparian vegetation exists along Raymond Ditch, due to unrestricted access by farm animals. Riparian vegetation could play an important role by preventing agricultural runoff from directly entering the ditch, and by removing nutrients such as nitrogen and phosphorous from the runoff.

3.4 MCALLISTER GEOLOGICALLY SENSITIVE AREA (GSA) PROBLEMS

This section describes specific concerns over ground water contamination within the McAllister GSA, which were analyzed by consultants Brown and Caldwell, and Golder and Associates. The problems occur over a large area which has been divided into 21 source areas shown in Appendix A, Map 10. The sources of ground water contamination include:

- Contamination from traffic-related spills
- Contamination from septic systems
- Contamination from agriculture
- Contamination from lawn fertilization
- Contamination from stormwater
- Contamination from on-site spills
- Contamination from railroad accidents

The county has spent considerable time and resources to study the complex interactions between surface and ground water in the McAllister Springs area, identify trends in ground water contamination in the area, and determine the area's vulnerability to further contamination. Early studies identified two contaminants of special concern: nitrates, and pesticides.

Studies conducted since 1988 found that nitrate levels at McAllister Springs have increased steadily for the past several years, and nitrate levels in wells within the McAllister GSA are significantly higher than in other wells in north Thurston County.

Pesticides including EDB, 1,2-DCP, and DBCP have been found in wells along the south sides of Pattison Lake and Lake St. Clair at concentrations higher than existing or proposed standards. These are commonly used as soil fumigants used in agricultural operations. Pesticide applications on agricultural fields in the surrounding area are the likeliest sources of contamination.

3.4.1 Ground Water and Risk Modeling of the McAllister GSA

The county commissioned two consultant studies in 1989, which were completed in 1990. The objectives of these studies were specifically to model ground water flows in the GSA, to determine the relationship between land use and ground water quality in the GSA, and to assess the risks of future ground water contamination. The United States Geological Survey (USGS) is also developing a ground water model for the McAllister area, but neither county-commissioned study utilized the USGS model because it was not available at the time and still has not been released.

The Golder Associates Inc study, Report to the Thurston County Health Department on Hydrogeologic Evaluation of McAllister Springs Geologically Sensitive Area, evaluated raw data collected by the USGS and the county, mapped ground water flows, estimated ground water velocities, and calculated nitrogen contamination of ground water. The Golder study focussed on nitrogen contamination of McAllister Springs from a variety of potential pollution sources, including stormwater runoff, septic systems, lawn fertilizers, agriculture, and precipitation.

The study of Brown and Caldwell in association with Adolfson Associates and Sweet Edwards/EMCON, McAllister/Eaton Creek Basin Stormwater Management Plan and Ground Water Risk Assessment, evaluated USGS and county data and modelled future growth scenarios to identify and rate potential sources of ground water contamination. The Brown and Caldwell study evaluated the risk of hazardous materials spills contaminating ground water in all existing and potential future wells in the GSA, and also assessed pollution from septic systems and stormwater runoff. This study considered spills resulting from traffic accidents, railroad accidents, and on-site transfer of hazardous materials at commercial sites. Appendix H describes the computer risk model developed by Adolfson Associates.

McAllister Springs has its source in an aquifer fed mainly by rainwater falling on a fairly small area surrounding the springs. This area includes Lake St. Clair, which is fed by Eaton Creek, but has no surface outlet. The Golder study estimated that more than 90% of ground water recharge in the GSA comes from Lake St. Clair and Eaton Creek, and that recharge water from the lake basin contributes 20-40% of the flow at McAllister Springs. Recent work by a consultant to the city of Olympia included drilling 18 test wells between Lake St. Clair and McAllister Springs. Findings from these wells confirm the connection between the Lake and the Springs, and indicate that water from Lake St. Clair may travel to McAllister Springs in as little as 180 days. The water quality in Lake St. Clair and Eaton Creek, which is strongly influenced by stormwater runoff, has a direct impact on McAllister Springs.

The results of the Golder and Brown and Caldwell studies were summarized in the McAllister Springs Geologically Sensitive Area Resource Protection Report by the Thurston County Health Department in June 1990. Most of this report's recommendations were incorporated into the County Board of Health Resolution H-3-90 and the Board of County Commissioners Resolution No. 9534, which revised and extended the original GSA in August, 1990. Appendix J contains these resolutions.

Based on the 1988 GSA boundaries, the risk assessment found that:

- The overall risks of ground water contamination in the basin from site and traffic related spills are likely to increase by an average of 220% by the year 2010.
- The largest source of risk is from catastrophic spills related to traffic accidents involving large quantities of petroleum products.
- Spills related to storage and transfer of potential contaminants at commercial and industrial sites also pose significant risks.
- Risks related to septic systems and stormwater runoff are highest in areas with dense development, high ground water recharge rates, and low ground water flow volumes.

The stormwater-influenced problems identified by these studies are detailed below.

WQ-3: McAllister GSA Ground Water Contamination from Traffic-Related Spills

Stormwater has the potential to convey hazardous materials spills into ground and surface water. The consultant estimated the probability that a traffic accident-caused spill would contaminate ground water, based on actual traffic surveys and accident rates for each section of roadway. The study calculated the volume of spill for each category of hazardous materials according to the size and type of container, because not every accident results in 100% of the material being spilled. The study divided the vicinity of the GSA into 21 source areas, shown on Map 10 in Appendix A.

The risk analysis produced startling results. By far the greatest risk to ground water in the GSA comes from the potential for a catastrophic spill of 2,500 gallons or more of petroleum products resulting from a traffic accident. Under existing conditions, transportation accidents are four times likelier to result in water quality exceedances than on-site spills. Currently, transportation accidents represent about 80% of the total risk. The future scenario predicts 322% more spill-related exceedances, and transportation accidents represent 66% of the total predicted future risk.

Specifically, the study found that:

- The risk of transportation-related spills is currently greatest in Source Areas 206, 207, and 203, which includes Pacific Avenue and part of Yelm Highway. Pacific Avenue runs within 1/4 mile of McAllister Springs, so spills in that area present a particularly onerous threat.

- Increased traffic in the future will significantly increase the risk of transportation-related spills in Source Areas 208, 303, 306, and 400, which includes Steilacoom Road and Mullen Road.

Gasoline and related petroleum products constitute 70% of all hazardous materials transported through the basin, represent 88% of the total spills and cause 96% of the water quality exceedances.

Typically, 60% of the petroleum products are transported in 5,000 gallon containers (tank trucks), or 42% of all hazardous materials. An accident involving this type of truck characteristically results in spillage of half the total volume, or 2,500 gallons. The large volume of a potential spill combined with the high level of truck traffic create the high risk of a catastrophic accident.

In comparison, 20% of the petroleum products move through the area in 55 gallon containers, or 14% of all hazardous materials. Typically, traffic accidents involving trucks carrying 55 gallon containers result in spillage of 80% of the total volume. The smaller volume of a potential spill combined with the lower volume of traffic carrying 55 gallon containers create a lower, though still significant, risk of ground water contamination.

WQ-4: McAllister GSA Ground Water Contamination from Septic Systems

Stormwater has the potential to convey septic effluent into ground water and surface water, as explained above. Brown and Caldwell's study assumed that septic-related exceedances of water quality standards are chronic, nonpoint occurrences that affect entire source areas uniformly by raising the background nitrogen levels of the underlying aquifer. Soils, rainfall patterns and ground water flow rates were assumed to control the rate at which septic effluent reached the water table and moved toward wells.

Table 3-3: Comparison of Nitrate Standard Exceedances from Septic Systems at Varying Standards

Source area	Maximum 10 mg/l		Maximum 5 mg/l	
	1988	2010	1988	2010
100	NO	NO	NO	NO
101	NO	NO	NO	YES
102	NO	YES	NO	YES
103	NO	NO	NO	NO
200	NO	NO	NO	NO
201	NO	NO	NO	NO
202	NO	NO	NO	NO
203	NO	NO	NO	NO
204	NO	NO	NO	NO
205	NO	NO	NO	NO
206	NO	NO	NO	NO
207	NO	YES	YES	YES
208	NO	NO	YES	YES
209	NO	NO	NO	NO
302	NO	NO	NO	NO
303	NO	NO	NO	NO
304	NO	YES	YES	YES
305	YES	YES	YES	YES
306	NO	YES	YES	YES
400	NO	YES	YES	YES
Total at risk	1	6	6	8

"**YES**" means the area is likely to exceed the standard.
See Map 10 in Appendix A for Source area locations.

The study revealed that existing wells in densely developed areas of the McAllister GSA are at risk of nitrogen contamination from on-site septic systems. Shallow wells (less than 50 feet deep) have the greatest risk of contamination. The Golder study came to similar conclusions, that shallow wells are particularly at risk and nitrogen levels in densely developed areas could reach 12 to 20 mg/L. Based on the current nitrate-nitrogen standard of 10 mg/L, Brown and Caldwell found that:

- Existing septic systems are likely to cause drinking water to exceed standards under current conditions in Source Area 305, a 715 acre area of dense development east of Long Lake (see Table 3-3 and Map 10).

The Brown and Caldwell study also analyzed the consequences of lowering the standard for nitrate-nitrogen to 5 mg/l, presented in Table 3-3. The Northern Thurston County Ground Water Management Plan sets 10 mg/l as the interim standard, until the need for a more restrictive standard is documented. However, the Ground Water Plan acknowledges that a lower standard may be needed to comply with the antidegradation policy in Washington law.

- If the nitrate standard was lowered from 10 to 5 mg/l, more than 4,000 acres in Source Areas 207, 208, 304, 305, 306, and 400 would be currently at risk of exceeding standards (see Table 3-3).

The Brown and Caldwell study predicts that, in the future, five more source areas would be threatened by septic contamination, even under the existing 10 mg/l nitrate standard. Specifically, the consultant predicts that:

- Under the future scenario, septic systems would be likely to cause drinking water to exceed standards in Source Areas 102, 207, 304, 305, 306, and 400, an area of almost 4,000 acres (see Table 3-3).

The Thurston County Comprehensive Plan specifies eventual sanitary sewer service for most of this area. Sanitary sewer service would eliminate the risk of further ground water contamination from septic effluent.

WQ-5: McAllister GSA Ground Water Contamination from Agriculture

Both consultants found that agricultural contaminants have probably contributed to existing ground water pollution in the GSA and surrounding area. Brown and Caldwell estimated that 4 kg per acre per year of nitrogen fertilizer enter the ground water through runoff. That study included agricultural runoff as part of the background level of nitrogen in ground water, and did not assess the impacts of future agricultural practices on water quality. The Golder study evaluated nitrogen contamination from agriculture, lawn fertilization, and precipitation in addition to septic systems and stormwater. Golder assumed that agricultural lands had an average application of 16 kg per acre per year, and 50% was absorbed by plants and soils. The actual land area in agricultural production was estimated from aerial photographs.

Golder developed computer models to calculate the speed at which contaminants would reach wells, including McAllister Springs. The Golder models did not differentiate between contamination coming from the various loading sources, other than to identify the proportional contributions of each type of source. The Golder study found specifically that:

- Within the McAllister Springs capture zone (the approximate current boundary of the GSA), agricultural nitrogen constitutes 60% of the total nitrogen loading.

WQ-6: McAllister GSA Ground Water Contamination from Lawn Fertilization

Stormwater infiltrating into the ground through lawns carries soluble nitrates into ground water. The Golder study estimated lawn fertilizer application rates at 1 kg of nitrogen per 1,000 square feet of lawn, and assumed that 50% would be absorbed by plants and soils. The actual land area in residential lawns was estimated from aerial photographs. The Golder study found that lawn fertilizers contributed 7.1% of the total nitrogen entering ground water in the McAllister Springs capture zone, which is the approximate current boundary of the GSA. (Map 3 shows the GSA boundaries; the problem locations map does not indicate the location of WQ-6 because it is basin-wide).

WQ-7: McAllister GSA Ground Water Contamination from Stormwater

Brown and Caldwell's study estimated contaminant loading levels in stormwater for various contaminants commonly found in runoff in the Puget Sound area. The loading levels differentiated between residential, commercial and industrial land uses, and runoff from roadways was assumed to be identical to runoff from commercial sites. Runoff quantities for each source area were calculated from effective impervious area estimates for each land use, and the portion of runoff infiltrating to ground water in each source area was calculated from inventories of stormwater facilities in the source areas. Stormwater was considered to be a nonpoint source similar to septic tanks, so that it affected all ground water within each source area, and the wells in each source area, uniformly.

The study revealed seven source areas currently at risk of water quality standard exceedences caused by stormwater. The high risk areas have a high level of runoff which infiltrates to ground water, and the underlying volume of ground water flow is relatively small. Shallow wells have the highest susceptibility. Specifically, Brown and Caldwell found that:

- More than 5,000 acres in Source Areas 101, 102, 207, 208, 304, 305, and 400 are currently at risk of contamination from slightly water-soluble materials, such as petroleum products, in stormwater (see Map 10 in Appendix A).

Furthermore, making the water quality standard slightly more stringent significantly increased the number of water quality exceedences, indicating that ground water contamination is currently quite close to the exceedance standard.

WQ-8: McAllister GSA Ground Water Contamination from On-Site Spills

Stormwater can contaminate ground water with hazardous materials spilled on commercial and industrial sites while transferring materials between containers, or from improper storage. Brown and Caldwell estimated the risk of ground water contamination resulting from on-site spills based on records of reported spills in Thurston County from 1986 through 1989. Spills were characterized according to hazardous material category and quantity. The study assumed that about 50% of all spills went unreported. As in transportation-related spills, the volume of spills depended on the size and type of container.

The study indicated that on-site spills currently constitute a significant threat to ground water. On-site spills comprise 43% of all predicted spills. However, these spills result in only about 20% of all exceedances, primarily because of the smaller volumes spilled. A ban on new commercial and industrial activities in the GSA which utilize or store hazardous materials was enacted in 1990, and should prevent the risk of on-site spills from increasing.

Specifically, the current risk of ground water contamination resulting from on-site spills is greatest in Source Areas 204, 206, 207, and 304, primarily because of a higher number of on-site containers in those areas (see Map 10 in Appendix A).

WQ-9: McAllister GSA Ground Water Contamination from Railroad Accidents

Stormwater has a high probability of conveying hazardous materials into ground water near McAllister Springs, if a railroad accident occurs. A mainline railroad owned by Burlington Northern runs directly across the GSA, coming within 1/8 mile of McAllister Springs, immediately uphill from the Springs. A railroad derailment accident occurred in the GSA in 1991, emphasizing the potential risk. Luckily, no hazardous materials were spilled during that accident. In the vicinity of the springs, soils are coarse and porous, the water table is close to the surface, and ground water velocities are relatively high. A hazardous material spill in this area could have catastrophic consequences. Farther up-gradient, west of the springs, the railroad bed crosses over spring-fed wetlands. The railroad bed is coarse, rocky fill that is rapidly permeated by liquids.

Nationally, railway accidents constituted about 15% of all reported hazardous materials spills in 1985. Railway spills present a grave concern because of the large quantities of hazardous materials being transported, typically 10,000-20,000 gallons per tanker car, and the sensitive hydrogeology beneath the railroad.

The Brown and Caldwell computer model did not evaluate the risks presented by the Burlington Northern line. Burlington Northern did not supply data on hazardous materials transportation or accident rates for the main line through the GSA. Brown and Caldwell estimated that 10-20% of all material transported on the railroad is hazardous, because the railway is the main line between two major industrial centers, Seattle and Portland.

The implications of a railroad spill of hazardous materials near McAllister Springs are enormous for all residents of Thurston County. A Hazardous Materials Transport Work Group convened by the state Department of Health estimated that replacing McAllister Springs with alternate drinking water wells would cost a minimum of $2.5 million, not including the environmental costs of cleaning up the spills. Connection of the new wells to water supply lines would take at least 6 to 8 weeks. In the meantime, drinking water for 47,000 people would have to be trucked into the area.

Such a disruption would have major consequences to the county and the state. Many businesses would have to shut down, and residents would have to move to other areas until new water sources became available. State offices would also close due to lack of water. The local economy would probably experience a major loss of revenues. The long-term economic consequences of environmental damage are difficult to estimate, but fisheries and shellfish harvesting in Nisqually Reach and McAllister Creek could be affected.