5.0 INDIAN AND MOXLIE CREEK SYSTEMS

Indian and Moxlie Creeks carry similar volumes of water, but due to differing geologic and cultural influences are unique natural resources.

5.1 Overview of Indian Creek

The main stem of Indian Creek begins at Bigelow Lake in Thurston County and flows south in an unmaintained and heavily vegetated drainage ditch for approximately one mile. Downstream, the creek is piped under several arterial roads, an industrial site, and Interstate 5. On the south side of Interstate 5 the creek flows in a partially channelized and piped corridor that parallels the abandoned Burlington Northern Railroad grade. The creek is then piped back under Interstate 5 and joins Moxlie Creek near the intersection of Plum Street and Union Avenue in Olympia's central business district. The two creeks are piped 3,200 feet under downtown Olympia. In addition to the creek system, the drainage area also includes several extensive wetlands, two small lakes, and a major tributary.

Creek water velocities in the upstream portions of Indian Creek are typically very low. Much of the creek segment has been ditched to drain the extensive wetlands located south of Bigelow Lake. After crossing the interstate, the gradient of the creek increases and flows in a moderately deep canyon. Downstream of Fredrick Street, the creek exhibits more natural channel patterns and is suitable for salmon spawning. After flowing north under the interstate, the creek enters a large woodlot before being conveyed from Eastside Street to Plum Street where it joins Moxlie Creek.

Urban development has prompted numerous adverse changes to the physical traits of Indian Creek. Encroachment and filling of the wetlands associated with the creek have been common in the past, large sections of the creek have been ditched, and in many places the creek flows through long sections of pipe.

5.2 Overview of Moxlie Creek

Moxlie Creek originates at an artesian spring in Olympia's Watershed Park. The creek flows through the heavily forested and undeveloped park for approximately one mile before being piped under Interstate 5. Downstream of the interstate, the creek enters an urban area of high-density commercial and industrial land use. The creek flows to the intersection of Plum Street and Union Avenue where it joins Indian Creek and is piped under downtown Olympia to Budd Inlet.

The natural characteristics of the upper reaches of Moxlie Creek have been largely preserved through the protection of Watershed Park. The moderate gradient creek channel is densely wooded with large coniferous trees and shrubby undergrowth. The park generates only moderate foot traffic; boardwalks have been constructed to protect wetland areas and creek crossings from degradation. Fish and wildlife habitat within the park are of relatively high quality. Moxlie Creek is composed of a main stem and many small springs and tributaries that enter the creek in various locations. The creek carries considerable flows year-round.

5.3 Hydrology of Indian and Moxlie Creeks

The clearing of land and the creation of impervious surfaces associated with urbanization of the basins increases stormwater runoff. In turn, runoff is typically conveyed downstream to the creek system. Stormwater enters the creek quickly and in great volumes rather than slowly infiltrating through the soil. This chain of events is an alteration of the natural hydrology of the basin. Evaluations of undisturbed forested lands indicate that, in many locations, surface runoff is inconsequential under natural conditions.

In an undeveloped basin, occasional flood flows act to revitalize the biological community of the creek. In contrast, the flood flows associated with urbanized basins have greater magnitudes and occur more frequently than do natural flood flows. These flows generate chronic and/or permanent impacts to the system. Table A-5 in Appendix 2 presents numerous impacts of stormwater on creek systems.

Many of the wetlands historically associated with Indian Creek have been filled. Additionally, major portions of the creek have been ditched or rerouted. These factors tend to reduce the flood flow storage capacity of the creek riparian area and thereby increase flows through the system. The many instream culverts and pipes associated with Indian Creek present additional alterations in the flow patterns of the creek. Due to these influences, Indian Creek is hydrologically complex.

The flows in Moxlie Creek during low and moderate flow conditions are higher than in Indian Creek. Flood flows in Moxlie Creek are augmented by two primary inputs: a large public stormwater system outfall at the headwaters of the creek and Interstate 5 discharges.

The southern portion of Moxlie basin is not linked to the creek system by the natural topography. Historically, runoff generated in this area flowed to geologic depressions known as kettles and was infiltrated to aquifers. An appreciable portion of the area continues to drain to kettles; other portions drain to Moxlie Creek via a pipe system.

A sophisticated computer model (EPA SWMM) has been created by the City of Olympia to simulate creek flows within the basins. The model simulates flood flows for storm recurrence intervals of between 1 and 100 years for predevelopment, current, and a variety of potential full development conditions. The model was calibrated using two winter seasons of continuously recorded flow data and occasional wet and dry season flow data collected since 1986. Results of the analysis for predevelopment and existing land use conditions are presented in Tables A-6 and A-7 of Appendix 2. Appendix 4 presents a technical explanation of the model.

The analysis of Indian and Moxlie Creeks has provided the following findings:

- Current 2- and 100-year storm events generate Indian Creek peak flows at the Indian/Moxlie confluence of approximately 69 and 97 cubic feet per second (cfs), respectively.

- Current 2- and 100-year storm events produce Moxlie Creek flows at the confluence of the creeks of approximately 24 and 40 cfs, respectively.

- During storm events, Indian Creek contributes approximately 80 percent of the total flow of the combined creeks downstream of the confluence.

- Flows at the mouth of the combined Indian and Moxlie Creeks range from 215 to 348 cfs for 2- and 100-year storm events, respectively.

- Current flood flows in Indian Creek during a 2-year storm are higher than those generated by a 100-year storm under estimated past forested, predevelopment conditions.

- Current storm flows increase markedly in Indian Creek downstream of Fredrick Street.

- Flood flows in the creeks are appreciably moderated by the impoundment of water behind culverts in the middle segments of the creeks. These pipes flow under surcharged conditions and therefore limit the downstream conveyance of water from major storms to flow levels associated with the approximately 2-year storm event. Under worst-case conditions, these culverts impound approximately 19 and 5 acre-feet of water in Indian and Moxlie Creeks, respectively.

- Future development in the headwaters of Indian Creek could augment runoff flows that exceed downstream culvert capacities.

- In Indian Creek, numerous culverts and pipe systems generate water velocities well in excess of Washington Department of Fisheries (WDF) guidelines addressing fish passage. The culverts and pipe systems in Moxlie Creek generate water velocities within WDF guidelines.

- Tidal variations in water surface elevations impact the hydrology of Indian and Moxlie Creeks from Budd Inlet south to approximately the location of the Moxlie Creek instream culvert under Interstate 5. These tidal variations in the water surface elevation are a major consideration in the management of flood flows.

- Yearly low flows at the confluence of the creeks are approximately 1.5 and 2.0 cfs for Indian and Moxlie Creeks, respectively.

5.4 Geomorphology of Indian and Moxlie Creeks

The unnatural and frequent flood flows associated with urban runoff impact the physical shape and structure of creeks. In many urban creeks these physical impacts, such as erosion and streambed scouring, may be more problematic than water quality contamination (Pederson 1981; Scott, 1982; Steward, 1983). The impacts can be a significant cause of habitat destruction within the creek system.

The evaluation of possible impacts requires an in-depth field investigation of creek conditions and subsequent comparisons to conditions typical of natural creek systems. This work was conducted in conjunction with the Squaxin Island Tribe as part of the basin planning effort. The major evaluation parameters are described below.

5.4.1 Pool:Riffle:Glide Ratio

Three major types of channel configurations are present in the creeks: pools, riffles (relatively fast moving water), and glides (relatively slow moving water). These differing channel configurations support unique microhabitats for the various life stages of fish and insects that have conflicting biological needs, yet rely upon the productivity of each other. The proportion of each type of configuration within a creek segment reflects the geologic and hydrologic influences acting on the creek. Naturally occurring creeks typically have relatively equal portions of pools and riffles; creeks impacted by urbanization have a higher portion of riffles (Platts et al., 1983).

An increase in creek riffles can result from an increase in sediment load. If unable to carry the higher quantity of sediment, the creek may experience an increase in channel bed elevation. In response to the rise in channel elevation, the creek will continue to erode the streambanks and increase its width. The process results in a shallow stream channel. Several studies have documented increases in channel width due to increased flows, volumes, and water velocity as well as increased floodplain elevation (Hammer, 1972; Robinson, 1976).

5.4.2 Pool Spacing

A related measurement evaluates the spacing between pools in the channel. The specific location of pools and riffles within a creek segment are in a state of flux even with ideal streamflow conditions; pools are filled and new ones scoured. Although dynamic in nature, a creek can be expected to maintain a relatively constant spacing between pools.

With urbanization, the channel can become wider and shallower due to high flood flows and subsequent streambank erosion. Pools have a tendency to fill with sediment and thereby increase their spacing.

5.4.3 Large Organic Woody Debris

The presence of large organic woody debris (LOD), such as tree stems and root clusters, in the creek channel is critical to the physical and biological diversity of a creek. LOD acts as a relatively fixed structure in the channel thereby dictating scour patterns. Additionally, LOD provides cover from predators and high flows.

Frequent and excessive high flows such as those in Indian and Moxlie Creeks can remove LOD from the channel and deposit it in the floodplain or create log jams.

5.4.4 Sinuosity

Sinuosity compares the actual length of the creek between two points with the horizontal distance between the points. Healthy creeks have many channel meanders and bends; creeks subjected to high runoff volumes become straightened by the erosive energy of the flows.

5.4.5 Geomorphic Analysis of Indian and Moxlie Creeks

The field investigation and subsequent quantitative analysis indicate that Indian Creek is degraded, but not without the physical components necessary to provide beneficial aquatic habitat.

As expected, habitat conditions in the upstream portions of Moxlie Creek are better than conditions in Indian Creek. Moxlie Creek has a higher proportion of pools compared to riffles, less spacing between pools, and slightly greater volumes of LOD than does Indian Creek.

Table 2 summarizes the creeks' physical characteristics.

Table 2: Habitat Characteristics
Indian/Moxlie Creek Basins
(Ref: City of Olympia/Squaxin Tribe Field Survey, 1990)

Basin	Subbasin	Length of Creek Segment, feet	Total Piped Creek Segments, feet	Creek Gradient, percent	Pool/Riffle/ Glide Ratio	LOD Pieces/ 100 feet	Pool Spacing	Creek Substrate Dominant/ Subdominants	Fish Passage Barriers
Indian	I-1	2,800	90	0.04	0 : 0 : 1	N/A	N/A	Silt/Sand	0
	I-2	4,340	1,163	0.41	0 : 0 : 1	N/A	N/A	Silt/Sand	0
	I-3	1,290	93	0.16	0 : 0 : 1	N/A	N/A	Silt/Sand	0
	I-4	--	--	--	--	N/A	N/A	--	--
	I-5	2,920	757	1.0	1.0 : 1.8 : 0.9	1.7	7.6	Cobble <1.0"/ Silt/Sand	2
	I-6	2,170	851	1.3	1.0 : 2.5 : 0.8	3.4	7.8	Cobble <1.0"/ Silt/Gravel 1-3"	0
	I-7	3,325	1,227	1.0	1.0 : 1.8 : 1.6	5.2	8.1	Sand/Cobble <1.0"	1
Moxlie	M-1	--	--	--	--	N/A	N/A	--	--
	M-2	5,320	288	0.73	1.0 : 0.7 : 1.0	4.5	3.9	Sand/Cobble <1.0"/Silt	0
	M-3	1,910	622	0.27	1.0 : 0.4 : 1.6	1.3	9.5	Sand/Cobble <1.0"/Silt	0
	M-4	3,170	3,170	0.35	--	N/A	N/A	--	0

5.5 Sediment and Bedload Transport

Because the volume and velocities of flows within a creek increase with urbanization, the transport of sediments and gravels also increases. The degree of transport occurring in a creek is shown by the depth of streambed scour, channel instability, streambank erosion, and the frequency of deposition bars within the channel. The majority of the sediment transport occurs during the initial phases of a storm event.

Field observations indicate that Indian Creek experiences a moderate level of transport. The low gradient and slow-moving water associated with the upper reaches of the creek has insufficient velocities to carry sizable particles. The steeper gradient associated with the section of creek on the south side of Interstate 5 has an increased gradient and velocity which could carry more material. However, because the flood flows in the creek exceed the capacity of the many culverts located in this section of stream, water is impounded at several locations. As a result, materials are often deposited in the creek and floodplains during flood flows rather than being transported farther downstream.

Moxlie Creek also experiences a moderate amount of material transport. The relatively steep gradient at the headwaters of the creek in conjunction with sandy streambanks and stormwater discharges generates materials that are deposited in the downstream portion of the creek. Deposition is high immediately upstream of the culvert that carries the creek under Interstate 5.

5.6 Creek Corridor Characteristics

The upper reaches of Indian Creek have a densely vegetated riparian zone. The riparian corridor has been overtaken by dense patches of the wetland species and other water tolerant plants. Lower reaches of the creek are bordered by common riparian plants such as willow, red alder, and several types of shrubs. Large coniferous trees are common along the creek corridor in the lower reaches.

The naturally vegetated and isolated nature of several segments of the stream corridor, especially in the vicinity of the abandoned railroad grade, provide a wildlife and urban greenway corridor. Although some of these areas are narrow and separated by roads, the corridor does offer several large continuous sections of good wildlife habitat. The riparian corridor between Eastside Street and Boulevard Road encompasses approximately 100 acres.

Moxlie Creek flows through a deeply incised canyon in the 171-acre Watershed Park. North of Interstate 5 the unpiped creek channel has streamside vegetation ranging from insufficient herbaceous growth to thin strips of red alder and willow. This vegetation offers poor protective cover and woody debris to the creek. The lower portion of the creeks are entirely enclosed and piped under downtown Olympia.

5.7 Indian Creek Fish and Wildlife

The creek corridors and associated wetlands support a variety of urban wildlife. Several portions of the corridor provide adequate cover, protection, and year-round water for small mammals, deer, fish, and birds. The vegetative cover available within Watershed Park offers a variety of habitat for both fish and wildlife; downstream creek segments offer poor habitat.

5.7.1 Fish Habitat

The diverse needs of the different life stages of salmon necessitate physically and biologically complex creek and estuary habitats.

The availability of salmon spawning habitat is typically optimal when the quantity of pools and riffles in a creek is approximately equal and appropriate sized gravels are present. Conversely, low gradient creek segments (such as the upstream segments of Indian Creek) contain slow moving waters suitable for the rearing of juvenile salmon. Salmon habitat needs are described in Table A-9 and A-10 of Appendix 2.

In an urban setting, the diversity of salmon habitat is strongly influenced by chronic and lethal stressing factors such as water quality contaminants, water flow and velocity, the duration of sustained high flows, and physical changes to the creek pattern. The entire length of Indian Creek and downstream portions of Moxlie Creek have undergone changes that impact habitat for both anadromous and resident fish.

Due to the silty substrate of most of Moxlie Creek, spawning areas are limited. Past cooperative projects between the City of Olympia and Washington Department of Fisheries (WDF) have placed additional gravels in the creek and created additional or improved existing spawning areas.

The extensive wetland and estuary historically associated with the creek mouths have been filled. Estuarine environments are important to several life stages of salmon by providing for their adaption from freshwater to saltwater and vice versa.

5.7.2 Fish Utilization

WDF records and recent City of Olympia investigations indicate that both creeks are used by several species of salmon and trout. Chum, sea-run cutthroat, coho, chinook, and steelhead all migrate to Indian Creek. The fall chinook are likely strays from the WDF Deschutes River hatchery.

The 230-foot open channel west of the confluence of Indian and Moxlie Creeks has been the main spawning habitat for coho and chinook in Indian Creek. Due to an extensive upstream pipe system, the ability of salmon to migrate beyond this location was not possible. A major capital improvement project to correct a flooding problem at the Plum Street and Union Avenue intersection has resulted in the piping of the open channel stream segment. In 1992, the creek was rerouted around the problem area in an open channel. The reroute has been constructed with salmon habitat in mind and will ensure fish passage to upstream creek segments.

Additional pipe systems barring fish passage in Indian Creek are located under the abandoned railroad grade both east and west of Fredrick Street. WDF augments the utilization of salmon habitat by planting approximately 30,000 coho juveniles per year in Indian Creek near the Boulevard Street bridge. It is hoped that the coho juveniles colonize creek sections downstream of the barrier culverts.

According to WDF records, coho, chinook and steelhead spawn in Moxlie Creek. Spawning occurs primarily in the upstream creek segments within the park. WDF utilizes Moxlie Creek's rearing habitat by planting limited numbers of coho juveniles.

5.7.3 Resident Fish

The Northwest Environmental Database (NED) indicates that resident fish are found in the entire length of Indian Creek. The resident species include coastal cutthroat, cottids, and three-spined stickleback. Information on Moxlie Creek is not available.

5.8 Water Quality

Indian and Moxlie Creeks are Washington State Class A streams (Department of Ecology, 1985). This classification indicates that the creek system should exhibit excellent water quality traits (WAC 173-201).

5.8.1 Nonpoint Pollution Sources

The evaluation of water quality in the basins conducted as part of the planning effort focused on characterizing existing conditions and identifying nonpoint pollution sources within the basin. Types of nonpoint pollutants include sediments, pathogens, nutrients, and toxicants. Sources of these pollutants can be spread throughout the basin and, when summed, result in considerable water quality impacts. They can be conveyed to water bodies by natural processes and by urban runoff, contaminated air, and groundwater. Several sources of nonpoint pollution are discussed below.

Stormwater Runoff

Management of stormwater has historically focused on quantity rather than quality management. Unfortunately, stormwater carries numerous contaminants to receiving waters. Impervious surfaces accumulate sediments, heavy metals, toxic organic compounds, pathogens, and nutrients during dry weather. Subsequently, runoff carries the contaminants to water bodies.

Stormwater from urban sources has been analyzed nationwide for U.S. Environmental Protection Agency (EPA) priority pollutants as part of the National Urban Runoff Program (NURP, EPA, 1983). Priority pollutants as identified by the EPA are highly toxic contaminants. These pollutants include synthetic organic compounds and toxic metals. Although the NURP study revealed the presence of priority pollutants in stormwater, the potential threats to humans from the observed concentrations of these pollutants was considered minimal. Conversely, aquatic life can be impaired by the pollutants.

The NURP study also found high variability in runoff quality as a function of storm intensity and timing, land use, stormwater system maintenance, and illicit waste disposal activities. In general, residential areas provide higher levels of nutrients and lower levels of priority pollutants than do commercial and industrial land uses (Brown and Caldwell, 1989; Miller, 1984). Typically, the early stages of a storm event bring a pulse of contaminants to the creek. Attempts to monitor these pulses are often unsuccessful. The disposal of hazardous materials via storm systems by industry, businesses, and households has also been identified as a major source of water quality contamination (Murray, 1988).

Onsite Sewage Treatment

Septic systems require regular maintenance to insure adequate treatment of waste water. Surveys conducted in north Thurston County indicate that only a minority of septic system owners maintain their systems according to the recommended schedule (Thurston County Health Department, 1989). In addition to the potential lack of system maintenance, certain soils in the basins are inherently problematic for onsite waste disposal. Sanitary sewer service is not available in portions of the basin.

Improper Waste Management

The improper disposal of solid and liquid wastes presents a source for a wide range of contaminants. Poor waste management practices result in the placement of wastes in, or adjacent to, water bodies and stormwater systems.

Erosion

Urban development inadvertently promotes erosion by the act of clearing vegetation from the land. In addition to the impacts of erosion on the affected land segment, downstream impacts include destruction of fish habitat, decreased health of the biological community, and the depositing of sediments in drainage ditches and pipe systems. Sediment particles also carry and disperse pathogens, heavy metals, and organic chemicals.

Research indicates that on an annual basis urban creek systems readily discharge four times more sediment than do creeks in undeveloped basins. In a study of creeks in western Washington, Richey (1982) found that sediment transport is significantly associated with the quantity of flow in creeks. Additionally, the researcher noted that half of the total transport occurred during 10 percent of the year in an urban creek compared to 20 percent of the year in an undeveloped creek.

Vegetation and Pest Control

Herbicides and pesticides commonly associated with urban pest management can be transported to water bodies. Additionally, fertilizers, if conveyed to freshwater, provide nutrients readily available for nuisance algae production and subsequent dissolved oxygen depletion.

Agriculture

Agricultural land use within Indian/Moxlie Creek basin is limited to small operations supporting several animals and/or modest amounts of crops. The likelihood of a particular agricultural entity contributing to the contamination of a water body is a function of farm size, proximity of the farm to surface water, number and type of animals, waste handling methods, and fertilizer/pesticide use practices.

Table A-11 in Appendix 2 presents summarized information addressing water contaminant sources, impacts, and chemical traits.

5.8.2 Assessment Methodology

As part of the basin planning effort, water quality samples from Indian and Moxlie Creeks were analyzed four times during low, moderate, and high flow conditions. Several additional samplings of limited scope focused on evaluating problem areas. Sampling and field measurements were conducted by the Thurston County Environmental Health Department; analysis was performed by a certified laboratory. Data were collected for the following parameters:

- Fecal coliform
- Nutrients
- Stream flow
- Temperature
- Dissolved oxygen
- Conductivity
- pH
- Turbidity

Map 8 in Appendix 1 identifies the water monitoring sites used during the study. Bigelow Lake was also investigated once for nutrients and algal productivity. In addition to water quality sampling, creek sediments from areas prone to contamination by priority pollutants were analyzed once. Results of the water quality and creek sediment analysis are presented in Appendix 5.

5.8.3 Analytical Results

The results of fecal coliform bacteria and priority pollutant monitoring are discussed separately, while the results for the other conventional water quality parameters (e.g., nutrients, temperature, dissolved oxygen, conductivity, pH, and turbidity) are presented together.

Fecal Coliform Bacteria

Washington State Class A surface water standards require that fecal coliform bacteria in freshwater not exceed a geometric mean value of 100 organisms/100 ml, with not more than 10 percent of the samples exceeding 200 organisms/100 ml (WAC 173-201). Fecal coliform originate in animal waste and serve as an indicator of serious bacterial contamination problems.

The high fecal coliform bacteria levels in Indian and Moxlie Creeks has been identified as the primary source of bacterial contamination to Budd Inlet (URS, 1986). The *Budd Inlet Urban Bay Action Program* identifies the Indian/Moxlie Creek Basin Plan as a key mechanism for reducing the fecal coliform contamination in Budd Inlet.

The fecal coliform results are summarized as follows:

- Fecal coliform concentrations at nine of the ten locations sampled exceeded Class A water quality standards during a major storm event. For all wet weather monitoring events, samples taken at the confluence of Indian and Moxlie Creeks had a geometric mean of 1,990 organisms/100 ml. The overall geometric mean value for the two creeks during high flow conditions was 488 organisms/100 ml.

- Samples collected after the 100-year storm event of November 1990 showed fecal coliform levels exceeded standards but to a lesser degree than during the previous modest storm event. This may be due to flushing of contaminants out of the soil and creeks during the storm.

- Thirty percent of the samples collected during dry weather exceeded water quality standards.

- Although dry weather samples exceeded water quality standards at several locations, these samples show that the very high fecal coliform levels were generally storm related. However, fecal coliform levels during dry conditions remained very high at the creeks' outfall to Budd Inlet. The geometric mean, excluding the outfall samples, for the creeks during dry sampling periods was 55 organisms/100 ml.

- Wet/dry weather fecal coliform ratios were high at the confluence, within Watershed Park, and in Indian Creek at Martin Way. These results indicate septic system failures and/or animal-related contamination.

- Samples collected at the Indian/Moxlie Creek outfall had fecal coliform mean concentrations of 1,690 organisms/100 ml regardless of flow conditions. This level indicates a contamination source under downtown Olympia.

- Fecal coliform levels were high within Watershed Park. Contamination may be associated with stormwater/animal waste releases to the headwaters of the creek.

- Three rounds of wet weather follow-up monitoring work have failed to isolate the contribution of fecal coliform in the downtown Olympia area.

- Follow-up work on the downtown section of the creeks conducted during dry weather conditions and non-business hours detected modest fecal coliform levels with a geometric mean of 58 organisms/100 ml.

Priority Pollutants

The concentration of priority pollutants in freshwater samples is commonly below analytical detection limits. Investigative methods therefore focus on analyzing the concentrations of these pollutants in sediments. These contaminants tend to be adsorbed and retained by fine sediment particles.

Class A water quality standards require that "toxic concentrations shall be below those which may adversely affect characteristic water uses, cause acute or chronic conditions to the aquatic biotic, or adversely affect public health" (WAC 173-210-047). A list of priority pollutants has been developed by the EPA. Unfortunately, suggested acceptable upper limits on organic compound concentrations in Washington fresh waters and sediments have not been established.

Following a review of applicable criteria used throughout the United States, the freshwater sediment data from Indian and Moxlie Creeks were evaluated with respect to criteria for organic contaminants in Puget Sound marine sediments (Tetra-Tech, 1989). Since these criteria are applicable to marine sediments and not freshwater sediments, the evaluation of contamination threat is qualitative in nature. The criteria provide low and high biological impact thresholds for contaminants of concern. Past studies in the Olympia area have used similar evaluation techniques (Thurston County Health Department, 1989).

Similarly, trace metal concentrations were evaluated using interim criteria established for dredged materials in the Great Lakes (Wisconsin Department of Natural Resources, 1985). Trace metals of concern included arsenic, cadmium, copper, lead, mercury, nickel, and zinc. Lead and arsenic are especially toxic and potentially carcinogenic.

The results of the evaluation are as follows:

- Low and high apparent effects thresholds were exceeded by 11 and 3 organic contaminants, respectively, at a sampling site downstream of Pacific Avenue. Recent work at the Puget Power site has uncovered a likely source of the contamination. Corrective measures are being taken.

- Organic contaminants were present at all sediment monitoring sites, but with the exception of the Puget Power site, were less than the comparative criteria.

- The concentration of mercury, lead, zinc, and arsenic concentrations in the Pacific Avenue area of Indian Creek and at the confluence of the two creeks exceeded the threshold criteria developed for the Great Lakes.

- Sediments from the outfall of the creeks at Budd Inlet contained only modest levels of contaminants.

- Bigelow Lake sediments showed elevated levels of arsenic, cadmium, lead, and zinc.

The results of the sediment analysis and a comparison to the evaluation criteria are presented in Appendix 5.

Conventional Water Quality Parameters

The Washington State standards for Class A freshwater bodies require that:

- Temperature not exceed 18°C.
- Dissolved oxygen concentration exceeds 8.0 mg/l.
- pH range between 6.5 and 8.5.
- Turbidity not exceed 5 NTU over background levels.

Findings of the monitoring study are as follows:

- Temperature, dissolved oxygen, conductivity, and pH of Indian and Moxlie Creeks were generally within acceptable levels. Several exceptions were observed.

- Dissolved oxygen levels in the wetland areas south of Bigelow Lake were lower than the water quality standard during a November sampling. Low oxygen levels may be common occurrences in these stagnant waters during the summer season.

- Mean pH of the creeks was 6.9 units, with several readings falling below the water quality standards.

- Wet weather turbidity was very high in both creeks systems downstream of Interstate 5 during construction. Monitoring following completion of construction indicated much lower, and acceptable, turbidity levels.

- Although not addressed in the Washington State Class A water quality standards, nitrogen and phosphate levels were also monitored during two wet weather events. Nuisance plant growth tends to occur in freshwater when phosphate levels exceed 0.10 mg/l. The highest concentration of phosphates was 0.28 mg/l; this occurred in Moxlie Creek just west of Henderson Boulevard.

5.8.4 Lake Water Quality

Indian Creek basin contains one lake and several smaller ponds. A cursory investigation of nutrient availability and algal production in Bigelow Lake indicated that relatively good conditions exist. Comparison of current data to historical data of 1981 indicates relatively constant water quality conditions. Sediments from Bigelow Lake contained elevated levels of arsenic, cadmium, lead, and zinc. The concentration of these contaminations may have the potential to impact aquatic life, but do not pose a human health hazard

Moxlie Creek basin contains three small ponds: Hazard Lake, Moss Lake, and a small pond in the Governor Stevens neighborhood. Water quality of these ponds has not been investigated during the basin planning effort.

5.8.5 Summary of Water Quality Conditions

The water quality of Indian and Moxlie Creeks is degraded and commonly exceeds Washington water quality standards. Additionally, the conveyance of bacterial contaminants to Budd Inlet by the creeks has been identified as a major source of contamination in the inlet (URS, 1986).

Water quality characteristics in the creek systems are summarized as follows:

- Bacteria in general and priority pollutant concentrations at certain locations are at levels warranting corrective measures.

- Faulty septic systems and/or illicit sanitary sewer connections are suspected of contributing to the high bacteria levels. Specific sources of the contamination have not been identified.

- Parameters important to the biological health of the creeks such as dissolved oxygen and pH exceed standards at several locations within Indian Creek.

- Nutrient concentrations in the creeks are high, but in all likelihood are not contributing to problematic algal blooms in Budd Inlet.

- The urbanized nature of the basins and high levels of vehicular traffic contribute dispersed and difficult to manage contaminants to the creeks.

- Conventional water quality parameters in Bigelow Lake are acceptable, but levels of several priority pollutants exceed threshold concentration and may therefore pose a limited threat to aquatic life.

Water quality monitoring efforts to better identify bacteria contributions to the creeks will continue. Proposed activities to improve the water quality in the creeks are discussed in Chapter 6.

6.0 BASIN PROBLEM ANALYSIS

Study of the Indian Creek basin has identified numerous flooding, habitat, and water quality problems, and the potential for increased problems in the future. These problems are discussed briefly below and illustrated on Map 9 in Appendix 1. Preceding chapters have described the existing characteristics of the basin; subsequent chapters evaluate the potential management approaches for addressing the problems.

6.1 Flooding

Evaluation of the problems within the basin by the Indian/Moxlie ad-hoc citizen advisory committee has emphasized the importance of expediently correcting current and preventing future flooding problems in the basins. Input received during a public meeting addressing problems within the basins supported the concern over flooding issues.

6.1.1 Existing Flooding Problems

Flooding results when urbanization proceeds without adequate stormwater management infrastructure to manage the associated runoff. In recent years, high urban growth rates combined with inadequate regulation, capital improvements, and maintenance have stressed several of the stormwater storage and conveyance systems in the basin. Necessary improvements to the systems range from minor tasks such as removing sediments from catch basins to extensive and costly system upgrades.

Equally problematic, the Indian/Moxlie Creek system is expected to receive and convey unnaturally high flood flows. Field investigations conducted as part of this study indicate that increased runoff and associated flood flows have accelerated the erosion of the streambanks and impaired aquatic habitat. Over the years, the creek systems have been channelized, piped, and filled thereby reducing their natural ability to detain flood flows in wetlands and riparian zones.

In a study of numerous creek systems, Klein (1979) observed that stream hydrology and water quality are noticeably affected when impervious surfaces within a basin exceed 12 percent. Total impervious surfaces within the Indian/Moxlie Creek basin are currently approximately 34 percent of the basin area. Other areas, such as residential lawns, have been disturbed and therefore provide reduced permeability.

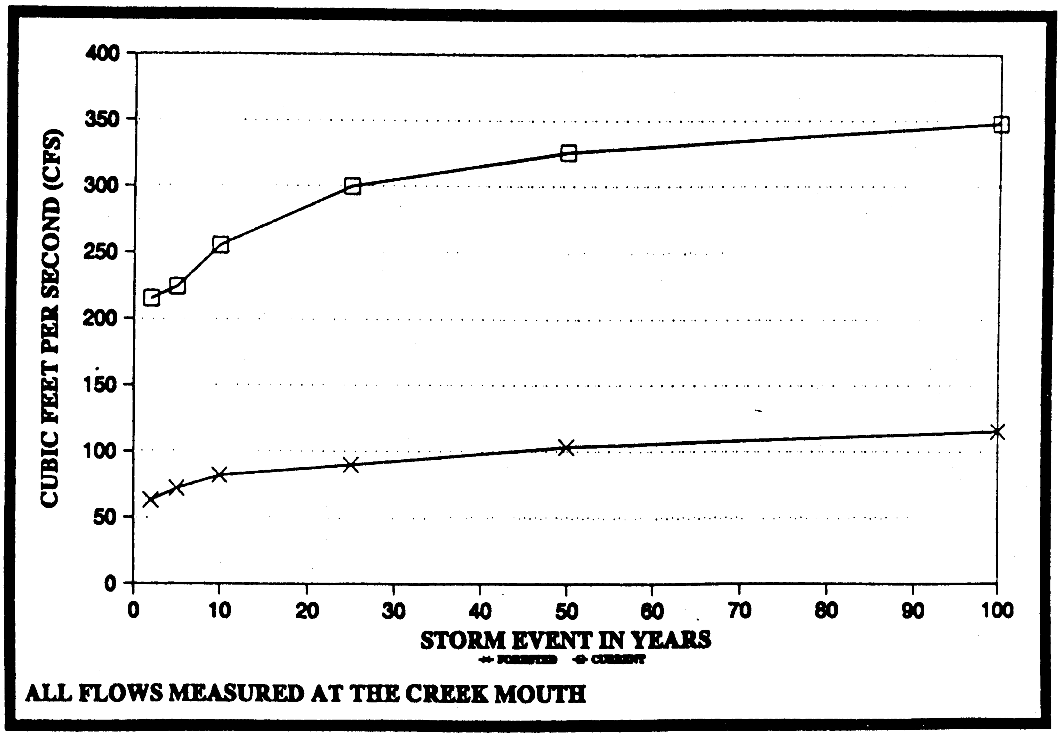
Both creek and upland flooding problems are discussed below.

Creek Flooding

Flood flows in the Indian/Moxlie Creek systems have been evaluated using the highly sophisticated EPA SWMM computer model. One aspect of the computer analysis sought to estimate the change in flood flows between historical forested conditions and existing conditions. In this analysis, existing channel configurations were used instead of suspected, but unknown, historical configurations. Over the years, the historical wetland that extended downstream from Bigelow Lake to the location of the Boulevard Street bridge has been largely channelized and filled. This change in creek configuration has, in all likelihood, appreciably reduced the flood flow storage capacity of the creek system. Because of these modeling limitations, the computer analysis generated higher historical flows than are expected to have occurred. Regardless of the accuracy of historical flood flow estimates, flows have increased appreciably with urbanization.

The following graph (Figure 1) illustrates estimated predevelopment flood flows compared to existing flows.

Figure 1: Predevelopment vs. Existing Flood Flows



Results of the computer analysis are presented in Tables A-6, A-7, and A-8 of Appendix 2.

High creek flows have created the following physical problems in Indian and Moxlie Creeks:

- Eroded streambanks in the moderate gradient segments of the creeks.
- Increased sediment transport and deposition.
- Widening of the creek.
- Reduced frequency of creek meanders.
- Reduced pool spacing.
- Large organic debris (LOD) levels 20 to 50 percent less than natural levels.

These physical impacts have been discussed in more detail in Chapter 5, Section 5.4.

Increased creek flows are the result of inadequate stormwater management. Stormwater management problems include the following:

- Stormwater storage in the basins totals approximately 1.9 acre-feet. Given the current quantity of impervious surfaces in the basin, stormwater management based on the requirements of the *Drainage Design and Erosion Control Manual for Thurston Region, Washington* would necessitate approximately 500 acre-feet of storage.

- Approximately 91 percent of the nonresidential developments in the basin do not provide stormwater storage and/or treatment.

- The remaining nine percent of the nonresidential developments provides varying, but typically inadequate, levels of management.

- Very few residential areas provide stormwater storage.

- Runoff from local streets and roads is not detained prior to release.

- Minimal stormwater detention is provided for flows from Interstate 5.

- Runoff released from developed sites is consistently higher than predevelopment runoff.

In addition to impacting the physical, and therefore, biological integrity of the creek system, creek flooding threatens or damages development. Creek segments not bounded by steep slopes or wetlands are subject to this type of flooding. Streamside flooding is a problem in the following areas:

- Plum Street and Union Avenue intersection and upstream businesses. Indian and Moxlie Creeks join immediately upstream of the intersection and flow in a short stretch of open channel before entering a pipe under downtown Olympia to Budd Inlet. Unnaturally high creek flows in conjunction with tidal impacts on the culvert under downtown Olympia has resulted in flooding and property damage.

- Indian Creek immediately downstream of Fredrick Street floods due to several undersized downstream culverts. The impoundment of flood waters behind these culverts has threatened several homes and necessitated emergency responses. Although a rigorous City and homeowner maintenance program has appreciably improved the situation, the threat of flooding remains.

The magnitude of existing, potential future, and predevelopment streambank flooding volumes in the two creek systems are illustrated by Figures 2 and 3. Table A-12 in Appendix 2 presents the associated computer modeling data.

Figure 2: Streambank Flooding Volumes in Indian Creek for Various Stormwater Management Scenarios, 100-Year Storm Event

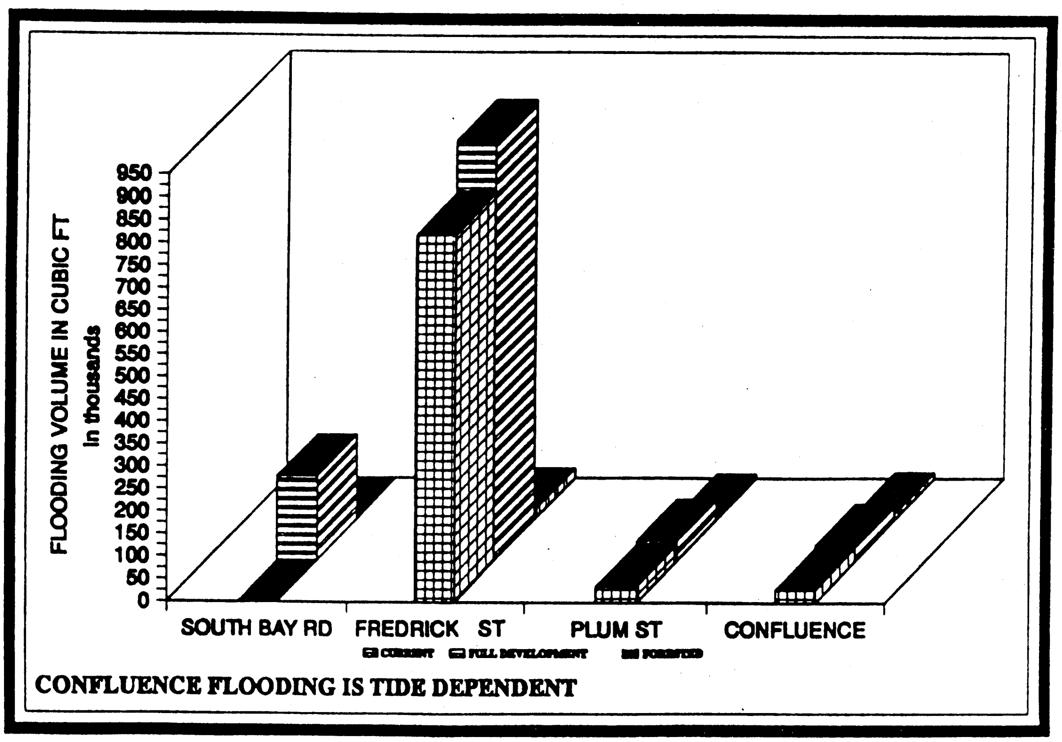
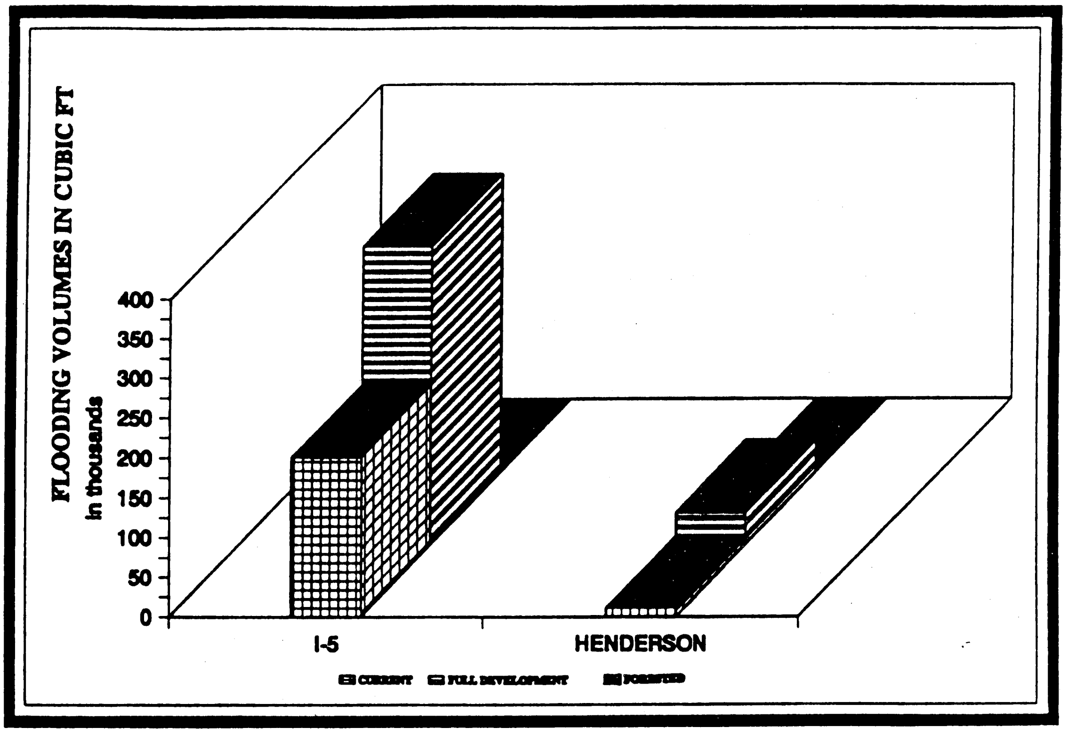


Figure 3: Streambank Flooding Volumes in Moxlie Creek for Various Stormwater Management Scenarios, 100-Year Storm Event



Upland flooding

Inadequate management of stormwater has also resulted in flooding of development and roads distant from the creek system. Upland flooding can occur in varying degrees, including minor inconveniences which are considered acceptable to community members. Other instances of flooding can involve the impairment of private property and closures of vital emergency travel routes.

Upland flooding is not an appreciable problem in Indian Creek basin. Conversely, the Moxlie Creek basin encompasses a relatively short creek system and an extensive upland terrace in the southern portion of the basin that drains to groundwater rather than Moxlie Creek. The isolated topography of this portion of Moxlie basin leads to stormwater management problems.

Upland flooding problems within the basin include:

- Several related flooding problems in the vicinity of Log Cabin and Cain Roads. Undersized public and private conveyance and storage facilities have resulted in overtopped detention ponds at two locations. Property damage has occurred at both locations. Several minor infrastructure improvements and prompt emergency response have provided short-term improvements in the situation.

- Combined sanitary sewer and stormwater systems in the downtown area has lead to LOTT Wastewater Treatment Plant capacity exceedances. Corrective measures are currently being investigated by LOTT.

Relatively minor problems are located throughout the basins and could be corrected by small-scale maintenance and system upgrade projects.

6.1.2 Potential Flooding Problems

Without adequate stormwater conveyance and storage systems, flooding within the basin can be expected to intensify as new developments are constructed and in-filling of undeveloped isolated parcels continues. An evaluation of the developable land within the basins indicates the potential for higher flood flows in the creeks.

Creek Flooding

Computer modeling has been used to estimate potential future flood flows in the creeks. The modeling approach assumed full implementation of the current drainage requirements, preservation of critical areas, and current land use zoning requirements.

Future development may prompt problems by the following activities:

- Development north of Bigelow Lake. High development densities and/or inadequate regulation of potential development within this area could lead to flood impacts throughout the Bigelow Lake and Indian Creek corridor.

- The gradual expansion of the Olympia business district and replacement of current low-density land uses with high-density land uses will generate greater quantities of runoff.

- Any filling of wetlands and floodplains would reduce the natural water storage capacity of the basin and result in increased flood flows.

- Additional development discharging runoff to the headwaters of Moxlie Creek could generate higher flood flows throughout the creek system.

Peak and average flood flows for current and potential land use conditions are illustrated in Figures 3 and 4, respectively. These graphs illustrate flood flows at the creek mouth and therefore do not adequately reflect higher flood flows in localized areas of the basin.

Figure 4: Current and Potential Peak Flood Flows
Indian Creek

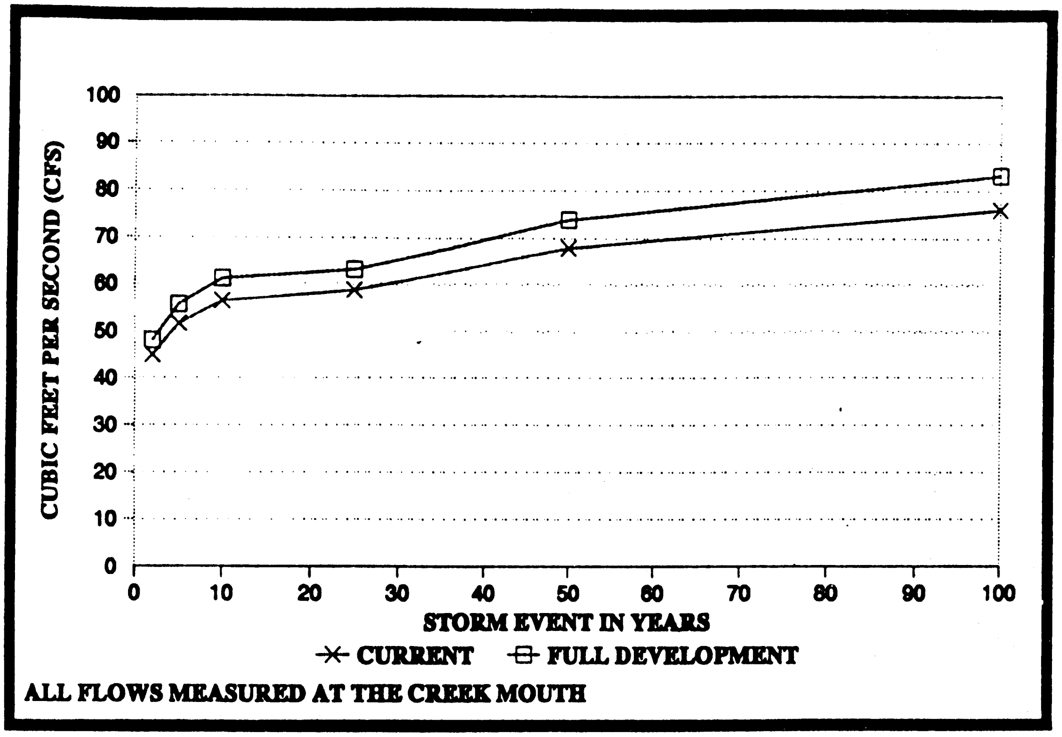
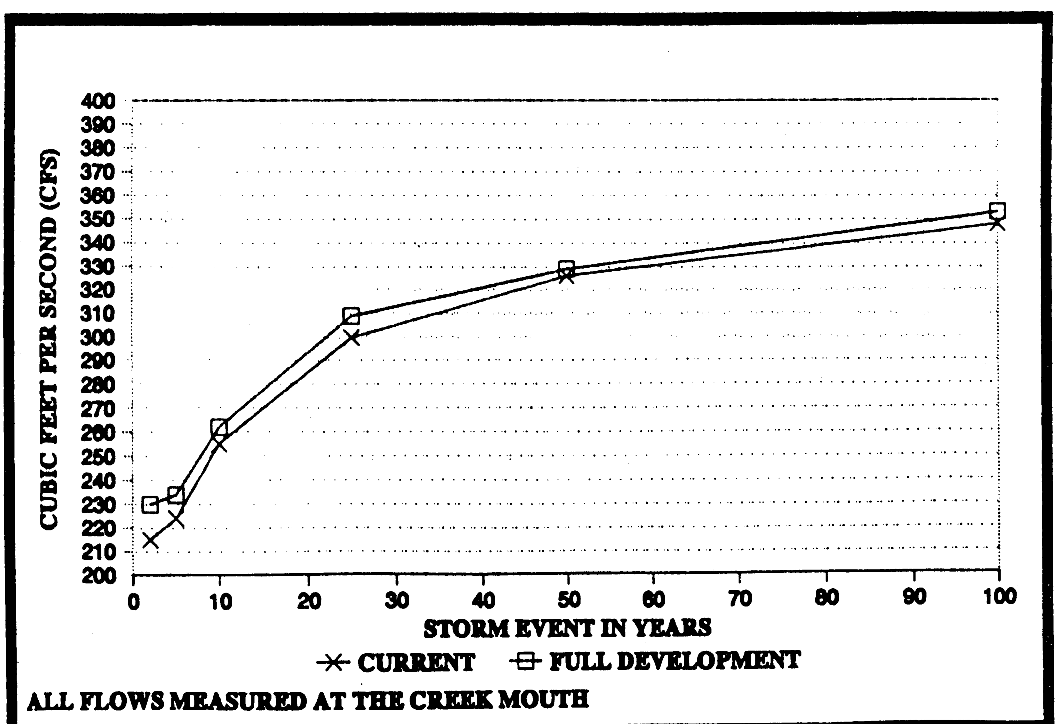


Figure 5: Current and Potential Average Flood Floods
Moxlie Creek



The results of the hydrologic modeling for full development is provided in Table A-8 of Appendix 2.

Potential development activities could generate the following instream problems:

- Increased impoundment of flood flows behind several instream culverts that are undersized for existing conditions. Flooding of private property and developments could be expected. Figures 2 and 3 in Section 6.1.1 illustrate potential increases in culvert impoundments. Table A-12 in Appendix 2 presents the associated computer modeling data.

- Increased erosion and habitat degradation in the creek systems.

- Increased flood potential in downtown areas. Major storm events in conjunction with high tides result in limited conveyance capacities under existing conditions.

Upland Flooding

Additional upland development could generate further problems in the following areas:

- Log Cabin/Cain Road neighborhoods. Although the potential for additional major developments in the area is limited, isolated parcels of land many become developed. Given the inability of the current infrastructure to accommodate high flows, additional flows would be problematic. However, analysis indicates that continued development within the two developments that currently generate the excessive runoff will contribute very modestly to the existing problem.

- Henderson Boulevard regional conveyance system. The arterial pipe conveying flows from the southern portion of Moxlie basin to Moxlie Creek is currently at capacity. Upgrading the capacity of the pipe is not advantageous, unless regional storage can be provided for the flows. The system discharges directly to the headwaters of the creek.

- Downtown and eastside Olympia conveyance systems. While major problems have not been identified in the downtown area, the various systems serving the area could become stressed with additional development. Given the existing highly impervious nature of the area, the quantity of runoff generated by in-fill and land use conversions is expected to be minimal.

Necessary improvements to minimize potential problems within the basin include:

- Increased stormwater storage.
- Upgraded conveyance systems.
- Replacement or removal of several culverts.
- Preservation of wetland and riparian storage capacity.

6.2 Habitat

Development within the Indian/Moxlie Creek basin has changed the natural traits of the creeks. These alterations impair the productivity of the aquatic and terrestrial biological community of the creeks. The following evaluation of basin habitat addresses instream, wetland, and riparian areas. Water quality problems are presented in Section 6.3.

6.2.1 Existing Habitat Problems

Although various development regulations implemented over the last 20 years have helped preserve the natural amenities of the creek system, deterioration has occurred.

<u>Instream Habitat</u>

The ability of creeks to support a productive biological community is directly related to the amount and complexity of habitat provided by the physical characteristics of the creek channel. Instream habitat is degraded by unnaturally high flood flows and streamside development.

Research conducted on urban streams provides the following conclusions:

- Impacts to the hydrology of a creek often have more profound effects on fish and overall stream health than does water quality degradation (Richey, 1982; Scott, 1982; Steward, 1983; Bissonnette, 1985).

- With urbanization, creeks move towards less diversity and experience subsequent decreases in the number and types of fish (Klein, 1979).

- Studies conducted with salmon embryo yielded greater mortality in urban stream environments than in rural environments (Scott, 1982; Steward, 1983). Respiratory anomalies were found to be relatively common among urban fish populations.

- Aquatic invertebrates also show a decrease in species diversity in urban creeks (Pederson, 1981; Richey, 1982). These insects can be stressed as a result of streambed scouring, high levels of suspended solids, the lack of riparian vegetation, and the rapid transport of detritus.

Further quantitative analysis of instream habitat is provided in Section 5.4. Environmental parameters for salmon are described in Tables A-9 and A-10 of Appendix 2.

Specific instream problems in Indian/Moxlie Creeks include the following:

- Creek segments have been channelized and ditched to increase drainage and/or reroute flows.
- Twenty-five stormwater outfalls contribute excessive quantities of runoff to the creeks. Several of these outfalls generate erosion problems.
- Approximately 4,500 feet and 950 feet of Indian and Moxlie Creeks, respectively, have been piped upstream of their confluence.
- Three culverts within the stream have been improperly constructed and present barriers to upstream fish passage.
- Several creek segments have been unnecessarily piped.
- Sediment has been deposited in salmon spawning beds.
- Moxlie Creek outside of Watershed Park has poor habitat diversity.
- The marine estuary associated with the creeks has been filled and the creeks piped 3,200 feet.

Wetlands

Wetlands provide many beneficial functions in healthy creek systems. The condition of the wetlands and associated buffer areas in the basins varies widely. Current wetland habitat problems within the basins include:

- Degradation of wetlands located within the basins through filling, sedimentation, pollution, invasion by exotic plant species, draining, and fragmentation. This has led to habitat destruction, loss of flow regulation functions, and flooding.

- Encroachment of remaining wetlands resulting from the urbanization of surrounding areas.

- Alteration of wetland hydrology as a result of stormwater discharges.

Virtually all wetlands in the basins have been affected by development of the basin. A few high-quality wetlands remain in the basin.

Riparian Habitat

Approximately 86 percent of the wildlife species native to the Puget Sound area reside in riparian zones (PSWQA, 1990). Many species of migratory wildlife require a contiguous riparian zone, rather than the patchwork of natural and impacted stream reaches typical of urban streams. The quality of instream habitat is highly dependent upon the integrity of the riparian zone.

The wooded habitat of the Indian Creek corridor and Watershed Park provides good terrestrial habitat and protects instream habitat. Several relatively minor road crossings deter from the quality of the wildlife corridor, but do not negate the benefits of the corridors.

Existing problems in riparian areas include:

- Loss of natural vegetation due to urban encroachment.
- Excessive flood flows altering the natural interface between aquatic and terrestrial habitats.
- Fragmentation of the corridor by developments and roads.

6.2.2 Potential Habitat Problems

The inclusion of the basins within the long-term urban growth management area (UGMA), will encourage high-density land uses to locate in the basins. Without adequate management, continued development would produce additional habitat losses in the creek system.

Instream Habitat

Increasing the impervious surfaces within the basin would, if not aggressively regulated, produce increasing flood flows and associated problems within the creek systems. Potential impacts from further increases in flood flows in Indian and Moxlie Creeks include:

- Increased creek velocities and volume would accelerate streambank erosion.

- Loss of sheltered areas for salmon rearing and refuge.

- Loss of beneficial aquatic insect populations and biological diversity. Investigations of invertebrates species within an impacted portion of Indian Creek indicate beneficial, but limited, populations of insects. (Soule and Neitzel, 1990).

- Potential elimination of salmon spawning areas. The availability of instream habitat suitable for salmon spawning is limited in the creeks.

- The loss of naturally migrating salmon populations from the creeks is a distinct possibility. Populations are very limited under current conditions.

- Increased water quality contamination. Specific water quality concerns are presented in Section 6.3.

Wetlands

The integrity of the remaining high-quality wetlands in the basin is dependent upon the management of future development. Potential impacts to the wetlands include the following:

- Physical degradation by development encroachment.
- Introduction of nonpoint source contaminants.
- Sedimentation.
- Alteration of the hydrologic regime.
- Fragmentation of extensive wetland systems.
- Introduction of highly competitive exotic plant species.
- Bigelow Lake wetland encroachment.

Potential problem areas include:

- Bigelow Lake wetland. The extensive peat bog remains a high-quality, biologically productive wetland. Future development in the rural area north of the Bigelow Lake and in-fill development south of the lake could degrade the quality of the wetland.

- A high-quality wetland/pond located east of Boulevard Street warrants preservation.

- Several wetlands are currently degraded and biologically unproductive, but offer important flood flow storage functions.

- The hydrology of several pothole wetlands could be impacted by stormwater discharges.

Riparian Habitat

In the future, the riparian habitat in the basins could be impaired by the following:

- Fragmentation of the corridor by streamside development, roads, and utilities.
- Mass wasting and subsequent replacement of coniferous tree species with lesser quality vegetation such as alders.
- Alteration of the hydrologic regime of the riparian area.
- Development of the Indian Creek corridor. The Indian Creek corridor associated with the abandoned railroad grade between Eastside Street and Boulevard Road offers important habitat and recreational opportunities to the Indian Creek basin and local residents.
- Encroachment upon and degradation of streamside areas.
- Wildlife habitat is found in several undeveloped potholes within the Moxlie Creek basin. These habitat areas may be threatened by adjacent development.

6.3 Water Quality

Degraded water quality in the creeks is a problem. Contamination impacts the creek system as well as the water quality of Budd Inlet. WDOE's *Budd Inlet Urban Bay Action Plan* identifies contamination in the creeks as a threat to the inlet and calls for corrective measures.

6.3.1 Existing Water Quality Problems

Common contaminants in the creek system include:

- Fecal coliform bacteria. Concentrations exceed Washington State Class A water quality standards at several locations in the creek during high flow conditions. Bacteriological contamination such as fecal coliform is often associated with faulty septic and/or sanitary sewer systems and animal wastes.
- Priority pollutants. Analysis of creek and lake sediments revealed potentially high levels of trace organic compounds and metals at several locations.

- Nutrients. Nitrogen and phosphate concentrations may be prompting excessive biological productivity in the creeks.

Sources of contamination in the basins include:

- Nonpoint pollutants. Urban areas commonly generate runoff that contains sediments, trace heavy metals, and organic compounds. Contamination results from the flushing of these pollutants from impervious surfaces to the creek system. Stormwater in the Indian Creek basin generally receives little, if any treatment, before discharging to the creek.

- Erosional sediment has numerous adverse impacts on the habitat of the creek.

- Vehicular traffic and industrial practices introduce priority organic and trace metal contaminants to the creek at numerous locations within the basin.

- Water quality within the 3,200-foot pipe under downtown Olympia decreases as the creeks are conveyed to Budd Inlet. Due to the intensive land use within the downtown area, the stormwater system serving this area carries appreciable quantities of untreated runoff to the creeks.

- Septic systems provide wastewater treatment for relatively large portions of the basin. Given the elevated levels of bacterial contamination in several portions of Indian/Moxlie Creeks, it is expected that some of the systems are failing.

- Interstate 5 runoff is typically not stored or treated prior to discharge to the creeks.

6.3.2 Potential Water Quality Problems

Continued development and vehicular traffic can contribute to the water quality problems in the basins. If not properly managed, existing problems could increase in the creek system as well as in the lakes and wetlands of the basin. Given existing high levels of contamination, future degradation of water quality is not acceptable.

Research indicates that:

- Urbanization increases the input of contaminants by at least an order of magnitude (Schueler, 1987).

- Pollutants in a creek have been shown to increase in response to increased urban concentration (Jones and Smart, 1980).

- The annual export of sediment in the Puget Sound region is approximately three times greater in an urbanized creek than in a rural stream (Richey, 1982).

- Phosphate and inorganic nitrogen levels were found to be three and eight times higher, respectively, in urban creek basins compared to forested creek basins (Omerick, 1977). The concentration of inorganic phosphorus and nitrogen in stormwater can exceed concentrations found in wastewater treatment plant effluent (Pitt and Bozeman, 1980). High phosphorous levels encourage algal growth.

- Development in the rural areas of the basin may rely upon septic systems in inappropriate soils and thereby present long-term threats to water quality.

Potential problems in Indian/Moxlie Creeks include the following:

- The majority of the development potential is located in the upstream portions of the creek system. Contaminants introduced in these portions would impact the entire downstream system.

- Increased vehicular traffic in the urban core as the region continues to develop could generate additional quantities of priority pollutants.

- Increased usage of septic systems could generate additional bacterial contamination.

- Lake and creek water quality could be impaired by additional inputs of fertilizers, herbicides, and pesticides.

- Groundwater quality could be contaminated by the infiltration of untreated stormwater in highly developed areas of the basin, and accidental or illicit discharge of hazardous materials to stormwater infiltration systems.

- Increased erosional rates due to higher flood flows in the creeks could reduce water quality as well as instream habitat.

- The removal of streamside vegetation could increase creek water temperatures thereby reducing instream habitat.