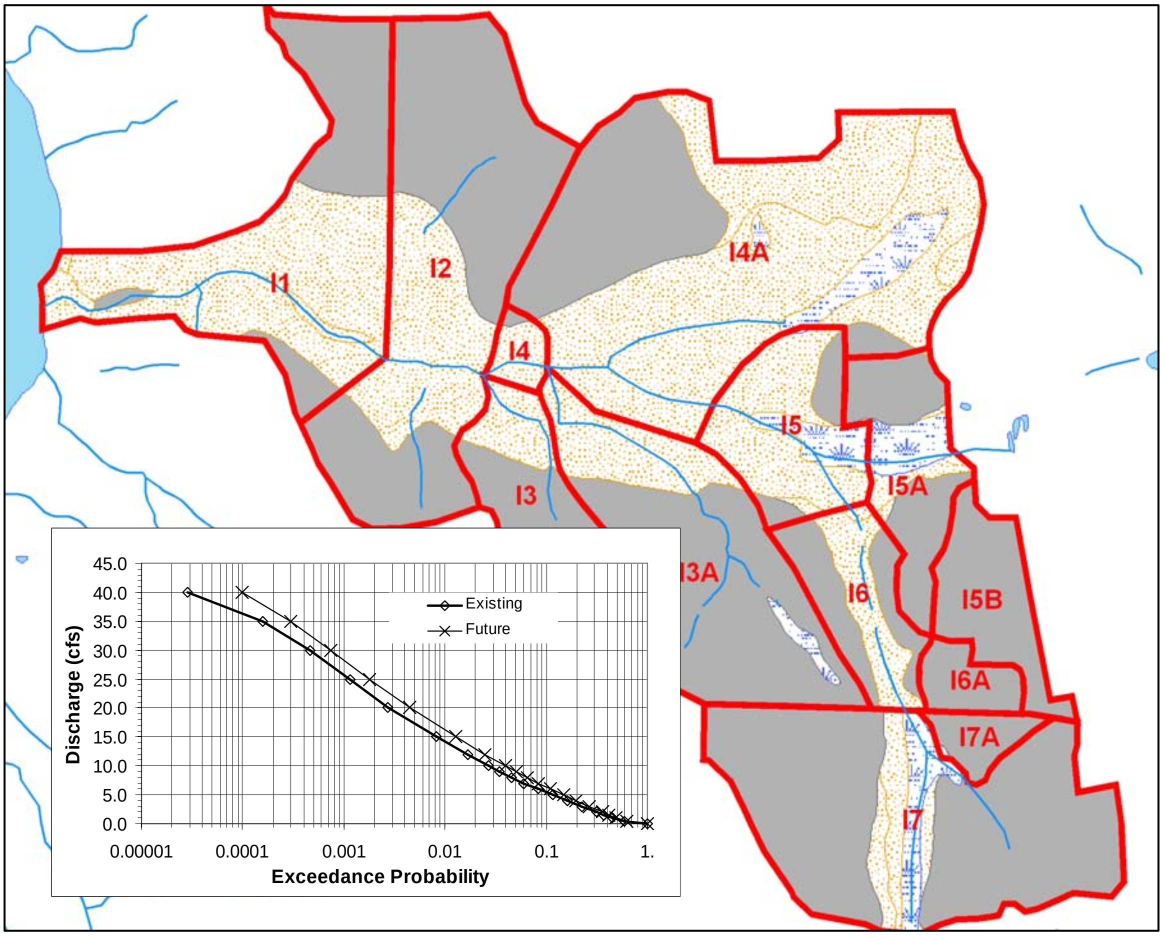
# Hydrologic and Hydraulic Analysis of Inglewood Creek Using the HSPF Model




**Prepared for**

## The City of Sammamish

**by**


MGS Engineering Consultants, Inc.

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**Olympia, WA 98506**
**(360) 570-3450**


**March 2004**

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The engineering analyses and technical material presented in this report were prepared under the supervision and direction of the undersigned professional engineer.


Bruce Barker, P.E.

## EXECUTIVE SUMMARY

This report presents findings of a hydrologic analysis of the Inglewood Creek watershed using the Hydrological Simulation Program-Fortran (HSPF) model. The purpose of the analysis was to determine streamflow magnitude-frequency and flow duration statistics at locations of interest in the watershed as part of the Inglewood Subbasin Plan.

The Inglewood Creek watershed encompasses approximately 1640 acres (2.6 square miles) of suburban land in the City of Sammamish. The stream originates at a wetland area on the Sammamish plateau, flows through a relatively flat channel for several miles, then drops approximately 300 feet in less than a mile to Lake Sammamish.

The geology of the central portion of the watershed is composed of highly infiltrative glacial outwash deposits. The presence of glacial outwash in the central part of the watershed infiltrates the majority of surface flow produced in the upper parts of the watershed and results in little or no flow in the stream immediately upstream of the ravine. The stream intersects the groundwater table in the ravine and receives the majority of flow via groundwater discharge in this area. The groundwater discharge also produces year around base flow in the lower reaches of the stream. The outwash deposit infiltrates and stores runoff from the upper watershed and is equivalent to approximately 7,000 acre-feet of stormwater detention storage. Flows in the lower stream reaches are relatively low (attenuated) during floods because of the storage that occurs in the outwash deposit.

HSPF model input was developed by King County as part of East Lake Sammamish Basin Plan in the mid 1980's. The model input was updated and refined for the current study and recalibrated to streamflow data collected over a 20 month period from October 2001 through May 2003.

Existing and future build-out conditions were simulated with the HSPF model and flood peak and flow duration statistics were computed. Relatively small increases in runoff rates were predicted under future land use, with flows predicted to increase an average of 15 percent relative to existing land use. The future land use scenarios were simulated with the assumption that the outwash deposit would continue to infiltrate surface runoff from the upper watershed.

The report includes the following recommendations to maintain a stable flow regime to ensure the health of the stream system in the future:

- Maintenance of Outwash Infiltration Areas - The glacial outwash deposit in the central part of the watershed is currently infiltrating the majority of surface runoff from the upper watershed. Maintaining the infiltration function of this area is critical to ensuring a stable flow regime and the health of the stream.

- On-Site Detention Standard – New development in the watershed is required to provide stormwater detention according to the 1998 King County Surface Water Design Manual (KCSWDM) Level 3 standard. This is the most stringent runoff control standard in the KCSWDM. As a minimum, this standard should be maintained for future development to reduce the rate of stormwater runoff reaching the outwash deposit and facilitate infiltration.

- Identification of Flood Prone Properties – This recommendation addresses the potential for increased flooding of structures near the stream in the central part of the watershed (Subbasins I2, I3, and I4) if increased runoff in the future overwhelms the infiltration capacity of the outwash deposit. Structures that would be flooded should discharge rates increase should be identified and measures taken to reduce the likelihood of flooding should flows increase.

- Streamflow Monitoring in Upper Watershed – Currently, there is only one streamflow gage on Inglewood Creek, located near the mouth. Two additional stream gages should be installed upstream to provide an indication of the quantity and rate of flow from the upper reaches of the watershed that infiltrates to the outwash deposit.

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# Hydrologic and Hydraulic Analysis of Inglewood Creek Using the HSPF Model

## INTRODUCTION

This report presents findings of a hydrologic analysis of the Inglewood Creek watershed using the Hydrological Simulation Program Fortran[1] (HSPF) hydrologic model. The purpose of the analysis was to determine streamflow magnitude-frequency and flow duration statistics at locations of interest in the watershed as part of the Inglewood Subbasin Plan.

## HSPF MODEL ANALYSIS APPROACH

### SUBBASIN DELINEATION

The Inglewood Creek watershed encompasses approximately 1640 acres (2.6 square miles) of suburban land in the City of Sammamish. The stream originates at a wetland area on the Sammamish plateau and drops approximately 400 feet in three miles to Lake Sammamish (Figure 1).

HSPF model input for the watershed was developed by the USGS[2] and utilized by King County as part of the 1991 East Lake Sammamish Basin Plan[3]. The model input was modified in the current analysis to reflect changes to the stream channel in Subbasin I3, which had been rerouted and enters the mainstem further upstream. Subbasins I5A, I6 and I7 were subdivided to account for on-site detention associated with a recently constructed residential development.

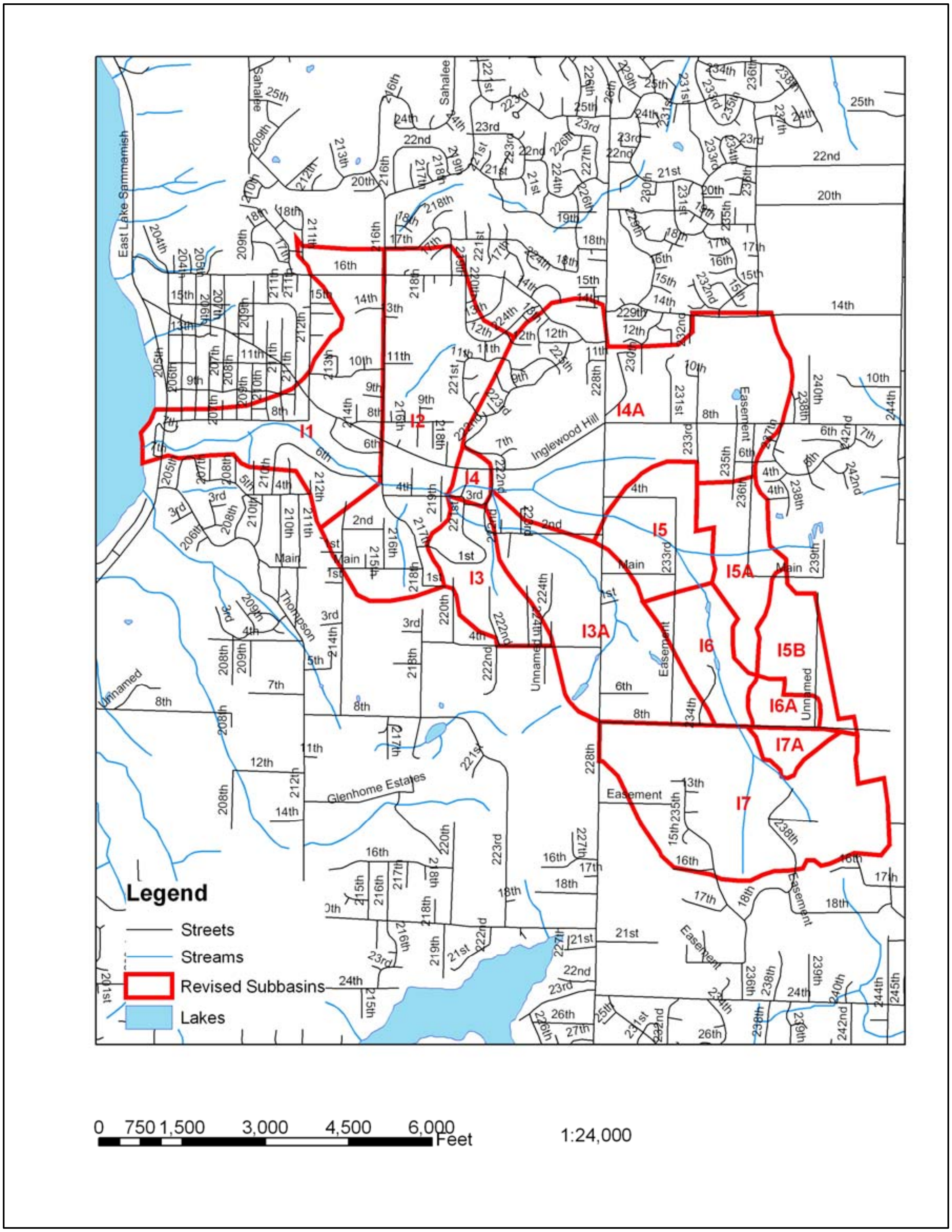



**Figure 1 – Inglewood Creek Watershed and Subbasin Map**

## Geology and Land Cover

The area within each subbasin was classified into areas of common land cover and geologic/soil type, called *PERLNDS*. The HSPF model computes the hydrologic response of each PERLND within a subbasin on a per-unit-area basis and proportions the amount of surface runoff, interflow and groundwater entering the stream within each subbasin consistent with the PERLND area total for the subbasin. The watershed geology was obtained from King County Department of Natural Resources[4] and land cover was obtained from the City of Sammamish. Existing (year 2003) and future build-out land use based on current zoning were analyzed (Figures 2 and 3). Four land cover classes were considered in analyzing the watershed hydrology: forest, grass, wetland, and impervious. The percentage of each cover allocated to the mapped land uses are shown in Table 1. The effective impervious surface areas were determined based on relationships with mapped impervious surface developed by Sutherland[12] and Dinicola[5].

Land use under existing and future build-out conditions are summarized in Tables 2 and 3 respectively.

**Table 1 – Land use and Percentage of HSPF Cover Categories**

| Land Use Code | Land Use | Effective Impervious | Grass | Forest | Wetland |
|---|---|---|---|---|---|
| C | Commercial/Industrial | 85% | 15% | 0% | 0% |
| MF | Multi-Family | 48% | 52% | 0% | 0% |
| H | High Density Residential | 23% | 75% | 0% | 0% |
| L | Low Density Residential | 10% | 90% | 0% | 0% |
| RF | Rural Residential Forest | 4% | 0% | 96% | 0% |
| RG | Rural Residential Grass | 4% | 0% | 0% | 0% |
| G | Grass | 0% | 100% | 0% | 0% |
| F | Forest | 0% | 0% | 100% | 0% |
| W | Wetlands/Open Water | 0% | 0% | 0% | 100% |

**Table 2 – Existing (year 2003) Land Use (acres)**

| Subbasin | Impervious | Till Forest | Till Grass | Outwash Forest | Outwash Grass | Wetland | Total |
|---|---|---|---|---|---|---|---|
| I1 | 20.0 | 18.9 | 42.4 | 56.6 | 65.5 | 0.0 | 203.3 |
| I2 | 27.0 | 60.3 | 95.3 | 13.7 | 53.6 | 0.0 | 250.0 |
| I3 | 6.3 | 5.6 | 35.9 | 3.2 | 12.1 | 5.1 | 68.2 |
| I3A | 12.0 | 48.5 | 62.9 | 4.8 | 17.2 | 32.5 | 178.0 |
| I4 | 0.8 | 1.2 | 0.0 | 2.2 | 8.9 | 0.0 | 13.1 |
| I4A | 96.3 | 22.2 | 66.7 | 48.2 | 119.3 | 21.9 | 374.6 |
| I5 | 24.7 | 3.2 | 3.6 | 8.7 | 22.7 | 19.3 | 82.3 |
| I5A | 1.0 | 28.5 | 22.2 | 2.2 | 2.2 | 14.6 | 70.7 |
| I5B | 10.7 | 5.1 | 38.6 | 0.0 | 0.0 | 0.0 | 54.4 |
| I6 | 2.3 | 17.6 | 16.3 | 5.4 | 20.9 | 0.0 | 62.5 |
| I6A | 4.9 | 0.0 | 16.4 | 0.0 | 0.0 | 0.0 | 21.3 |
| I7 | 34.0 | 61.0 | 109.1 | 21.5 | 0.8 | 17.5 | 243.8 |
| I7A | 4.1 | 0.4 | 13.4 | 0.0 | 0.1 | 0.0 | 18.0 |
| Total | 244.0 | 272.6 | 522.8 | 166.6 | 323.2 | 110.9 | 1640.2 |

**Table 3 – Future Build-Out Land Use, According to City of Sammamish Zoning (acres)**

| Subbasin | Impervious | Till Forest | Till Grass | Outwash Forest | Outwash Grass | Wetland | Total |
|---|---|---|---|---|---|---|---|
| I1 | 37.8 | 2.6 | 46.3 | 22.0 | 94.9 | 0.0 | 203.7 |
| I2 | 52.7 | 0.0 | 145.0 | 0.0 | 52.3 | 0.0 | 250.0 |
| I3 | 13.4 | 0.0 | 37.2 | 0.0 | 12.6 | 5.1 | 68.3 |
| I3A | 34.0 | 0.0 | 93.7 | 0.0 | 18.6 | 31.7 | 178.0 |
| I4 | 1.8 | 0.0 | 0.9 | 0.0 | 10.4 | 0.0 | 13.1 |
| I4A | 131.8 | 0.0 | 69.1 | 0.0 | 152.2 | 21.5 | 374.6 |
| I5 | 34.3 | 0.0 | 5.7 | 0.0 | 22.9 | 19.3 | 82.3 |
| I5A | 11.1 | 0.0 | 41.2 | 0.0 | 3.8 | 14.6 | 70.7 |
| I5B | 12.5 | 0.0 | 41.9 | 0.0 | 0.0 | 0.0 | 54.4 |
| I6 | 10.7 | 0.0 | 29.5 | 0.0 | 22.3 | 0.0 | 62.5 |
| I6A | 4.9 | 0.0 | 16.4 | 0.0 | 0.0 | 0.0 | 21.3 |
| I7 | 48.5 | 0.0 | 160.2 | 0.0 | 17.8 | 17.4 | 243.9 |
| I7A | 4.1 | 0.0 | 13.9 | 0.0 | 0.1 | 0.0 | 18.0 |
| Total | 397.8 | 2.6 | 701.0 | 22.0 | 407.7 | 109.6 | 1640.7 |

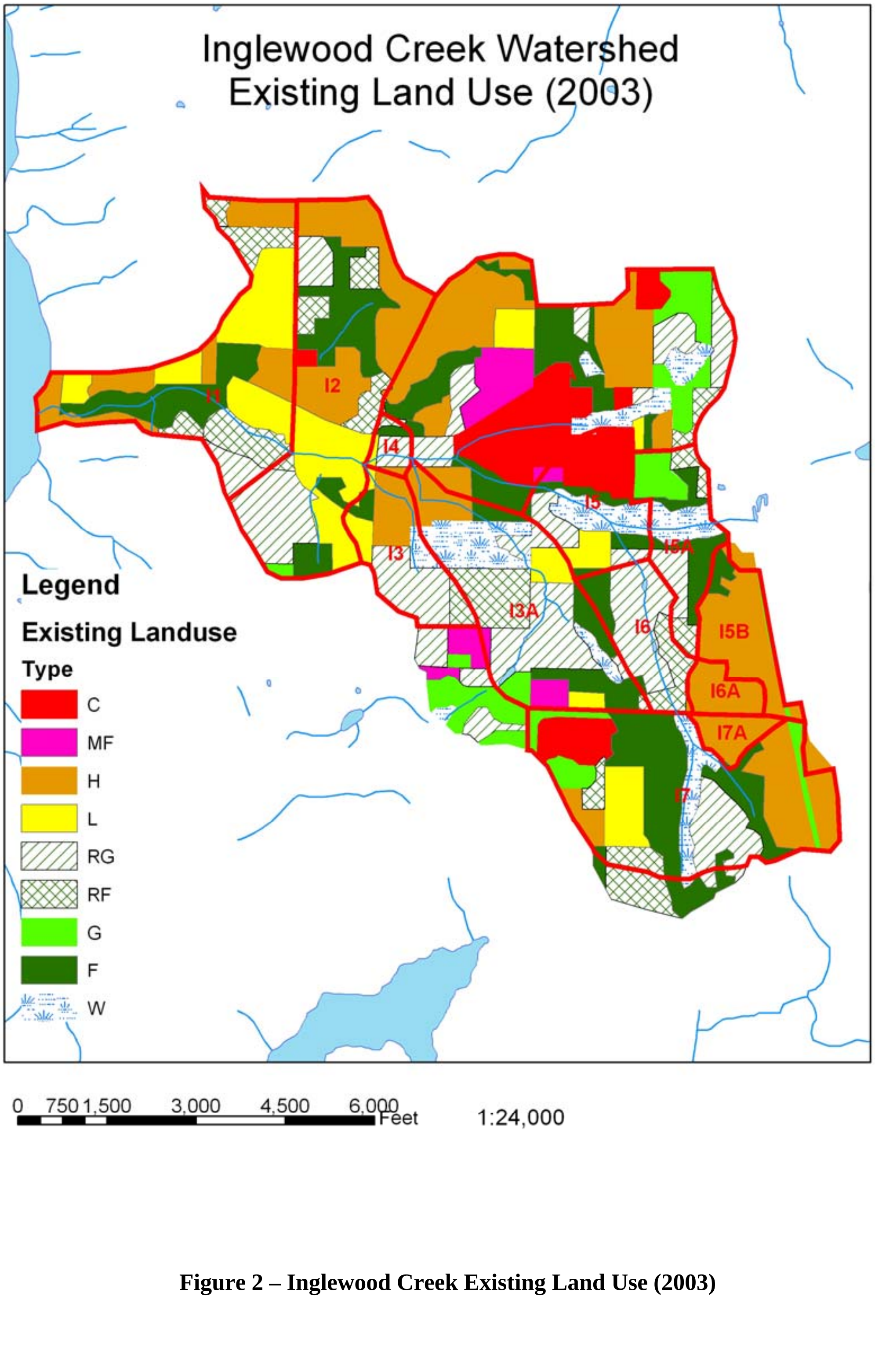



**Figure 2 – Inglewood Creek Existing Land Use (2003)**

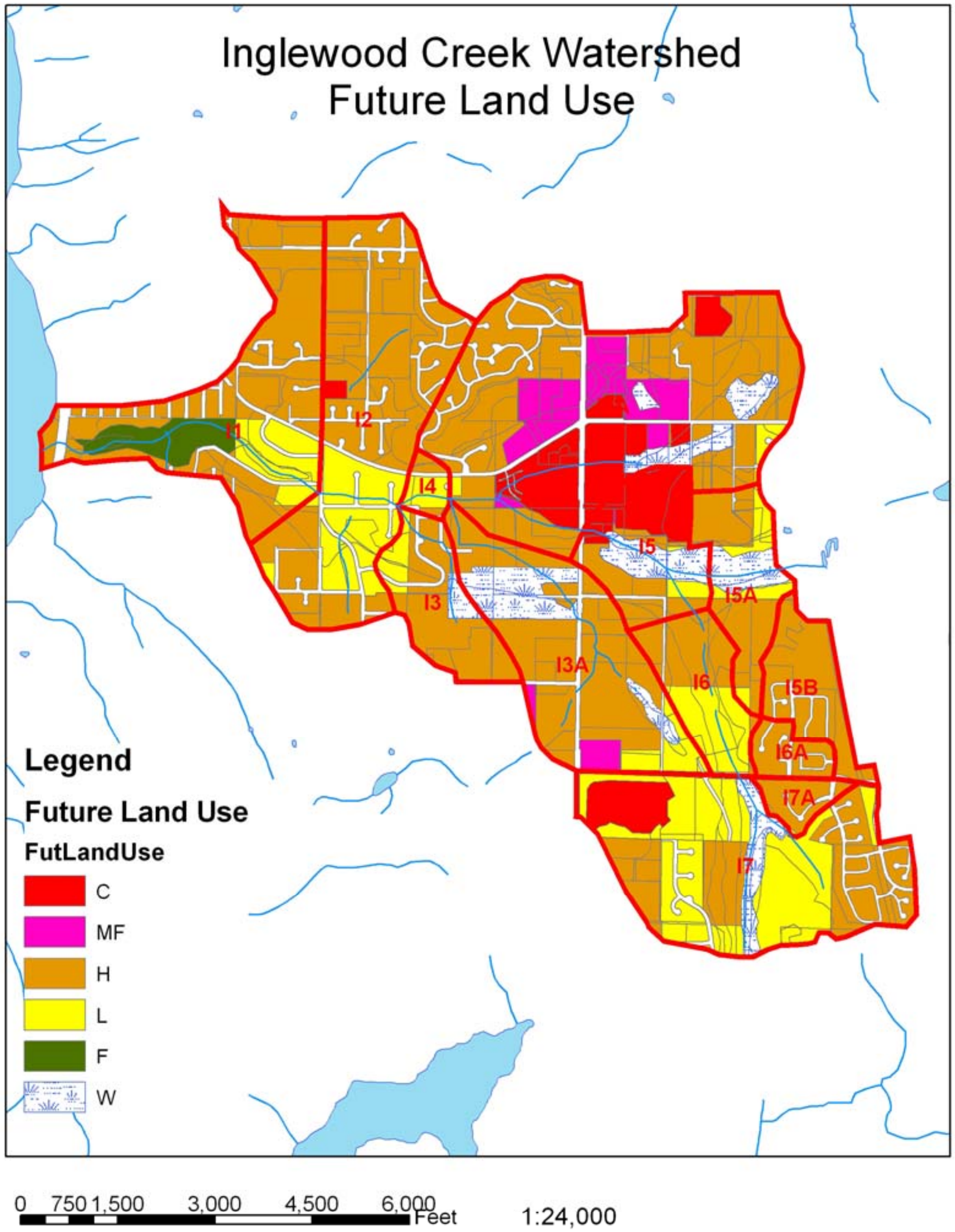



**Figure 3 – Inglewood Creek Future Land Use, City of Sammamish Zoning**

The Inglewood Creek watershed consists of a broad till-capped plateau drained by gently sloping channels (Figure 4). The main stream channel flows across recessional outwash deposits incised into the till. Runoff generated on the adjacent till areas must migrate through the outwash before reaching the stream channel. In locations where the perched water table remains near the surface, several wetlands have formed. In the central portion of the watershed (Subbasins I2, I3, and I4), the groundwater is relatively deep, and the stream channel remains dry the majority of the time. Downstream of this point, the stream flows through an incised ravine and drops approximately 300 feet in less than a mile to Lake Sammamish. The lower stream reaches in Subbasin I1 receive discharge from the regional groundwater, which provides a reliable source of base flow to the stream throughout the year.

For hydrologic modeling purposes, each geologic association in the watershed was assigned to one of three categories; till, outwash, or wetland according to the HSPF modeling methodology developed by the USGS[2,5]. These were combined with surface cover categories consisting of urban grass, forest, wetland/saturated soils, and impervious to form the PERLND groups shown in Table 4.

**Table 4 – HSPF Land Cover/Geology (PERLND) Combinations**

| HSPF PERLND | Land Characteristics |
| --- | --- |
| Till Forest | Glacial till soils mature cover, all slopes |
| Till Urban Grass | Glacial till soils urban grass, all slopes Includes impervious surfaces not directly connected to the drainage network. |
| Outwash Forest | Glacial outwash soils mature cover, all slopes |
| Outwash Urban Grass | Glacial outwash soils urban grass, all slopes. Includes impervious surfaces not directly connected to the drainage network. |
| Wetland/Saturated Soils | Wetlands or areas with saturated soils |
| Impervious (HSPF IMPLND) | Impervious surfaces that are directly connected to the drainage network. |

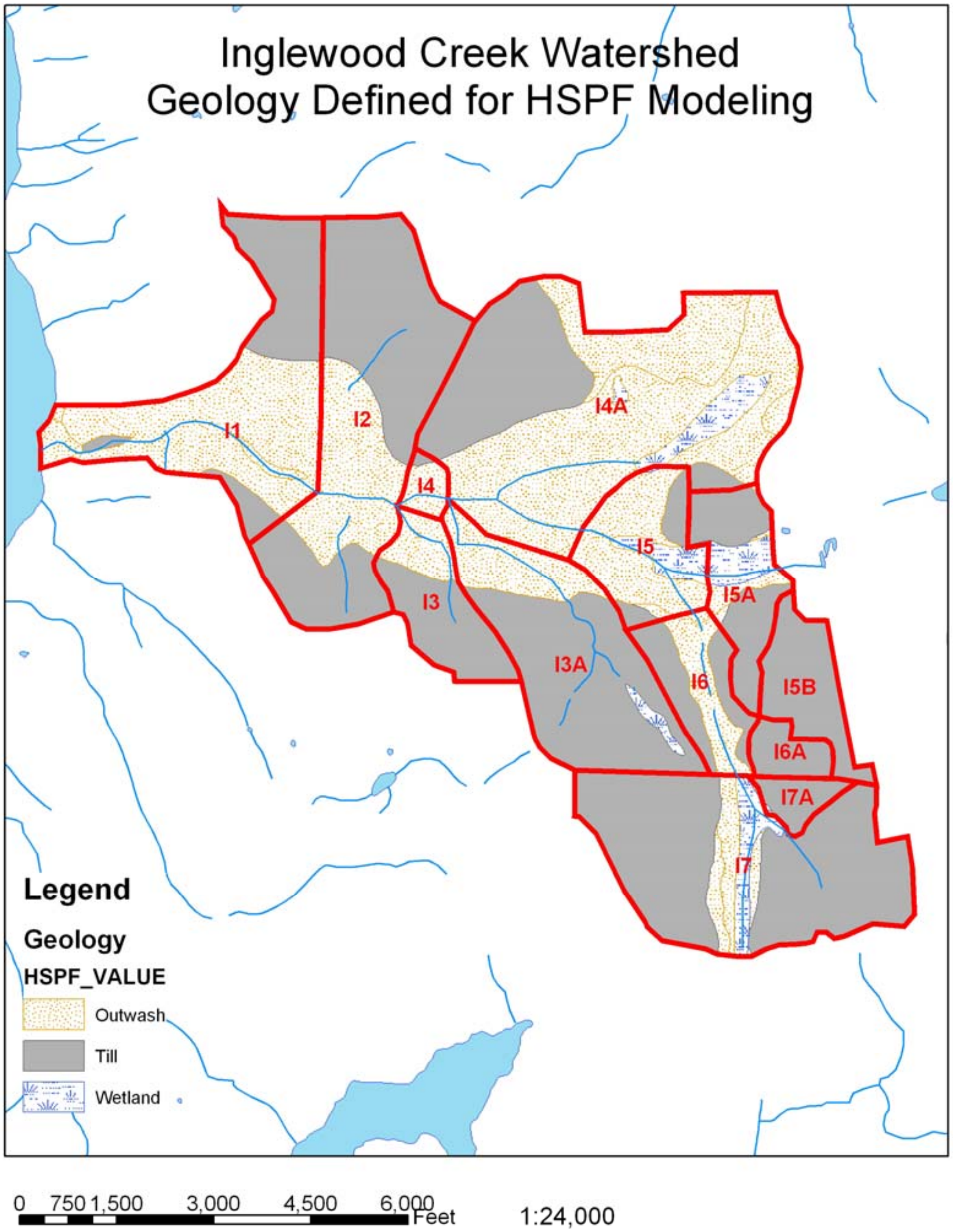



Figure 4 – Inglewood Creek Watershed Geology as Defined for HSPF Model

## HSPF MODEL CALIBRATION

### INTRODUCTION

Calibration of the HSPF model was performed to ensure that the hydrologic processes simulated by the model were representative of the conditions in the Inglewood Creek watershed. Calibration is the process whereby the model input parameters are adjusted until simulated and recorded discharge data match to the greatest extent possible.

The HSPF model input used in this study was adopted from the input developed as part of the 1994 King County East Lake Sammamish Basin and Nonpoint Action Plan[3]. Land use was updated to reflect changes in the watershed that have occurred since the model input was developed. The model parameters were refined through calibration using streamflow data collected near the mouth and concurrent precipitation collected near the headwaters (City of Sammamish Gage 18Y) for the period October 2001-May 2003. Daily evaporation data were developed from data collected at the Puyallup 2 West Experimental Station (station number 45-6803)

### HSPF MODEL CONFIGURATION

As indicted previously, the geology of the watershed consists of till in the uplands with glacial outwash in the ravine that carries the stream channel. Surface runoff and interflow produced in the upland till areas is infiltrated as it flows across the outwash deposit and results in a markedly attenuated runoff response from the watershed.

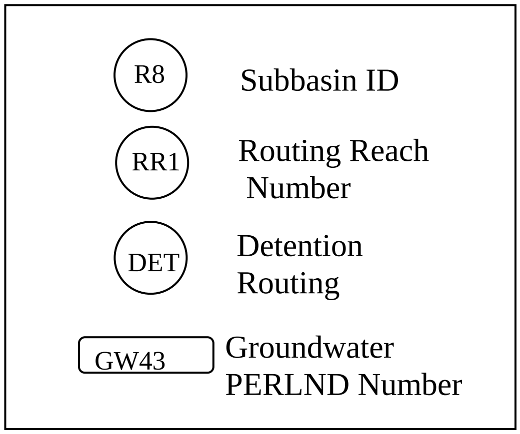
The HSPF model configuration developed as part of the East Lake Sammamish Basin Plan was adopted for use this analysis. A separate outwash Pervious Land Segment (PERLND) was defined for each subbasin that represents moisture inputs from both precipitation falling on the surface of the outwash and from lateral inflow from the till uplands. The area of these groundwater PERLNDS is equal to the area of outwash within the subbasin. The surface runoff and interflow from the adjacent upland till areas were then connected to each groundwater PERLND which were then connected to the stream channel.

Several large residential developments were constructed in the upper washed in the time since the King County East Lake Sammamish Basin Plan was completed. The stormwater detention facilities associated with these new developments were included in the HSPF model developed for the present analysis. Subbasin I5B, I6A, and I7A were added and define the tributary area to each stormwater pond associated with the new residential development. The ponds were designed according to the King County[6] Level 2 standard and HSPF routing tables (FTABLES) were developed for each subbasin such that they represented the detention pond discharge characteristics in the subbasin. A schematic of the Inglewood Creek HSPF model configuration is shown in Figure 5.

The USGS calibrated the HSPF model to the Inglewood Creek watershed as part of a study to develop and validate regionalized parameters for the HSPF model for use in western Washington[2,5]. The USGS simulated the flow attenuation caused by the outwash using the HSPF channel routing (RCHRES) routine. They added flood storage volume to the stream reaches in each subbasin until the simulated and gaged streamflows matched. This approach produced a reasonable calibration but was not used in the present analysis because it was thought to be less physically representative of the watershed than the approach used. The flood storage volume in the USGS model totaled approximately 7,000 acre-feet, which indicates that 7,000 acre-feet of stormwater detention storage would be required to replicate the flood storage and attenuation provided naturally by the outwash deposit.

Because of the high level of flood attenuation provided by the outwash deposit, on-site detention was not included for new development in the future land scenarios. The flow attenuation resulting from on-site detention would be indistinguishable after routing through the outwash deposit and was therefore not included out of convenience. This does not mean that on-site detention should not be required in future developments in the watershed; on the contrary, on-site detention should be required for future developments to ensure that flow discharge rates reaching the outwash do not increase to the point where they overwhelm the infiltration rate of the outwash deposit. This would result in a dramatic increase in the discharge rate in Inglewood Creek as surface runoff in excess of the outwash infiltration rate discharged downstream.

**Legend**



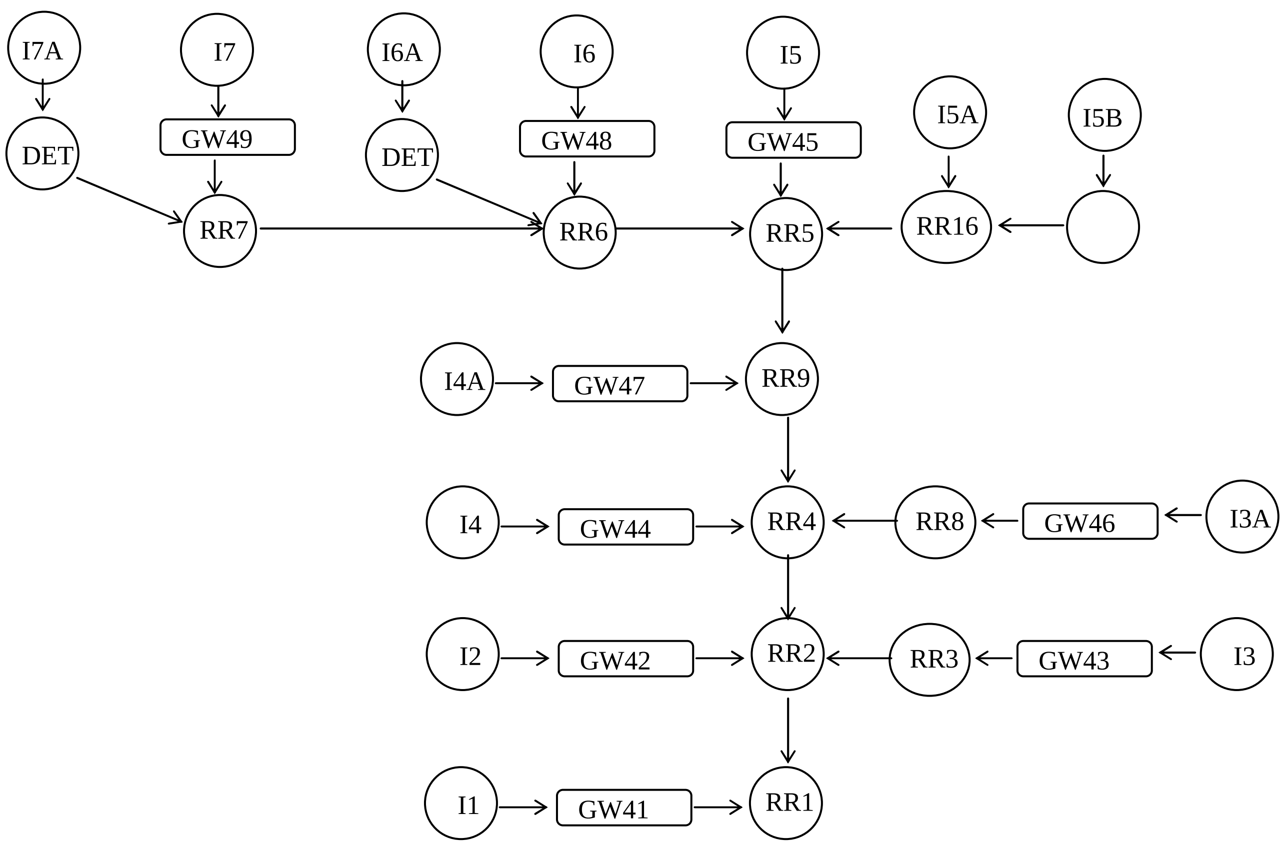




Figure 5 – Inglewood Creek HSPF Model Schematic

**HSPF MODEL CALIBRATION RESULTS**

Hourly streamflow data recorded by the City of Sammamish (Gage 15G) from October 2001-May 2003 near the outlet of Inglewood Creek was used to calibrate the model. Existing land use (year 2003) was used for model calibration. Initial HSPF runoff parameters for the pervious land segments (PERLNDS) were adopted from the model input developed by King County as part of the East Lake Sammamish Basin Plan. Model parameters were then adjusted until simulated and recorded discharge rates matched to the greatest extent possible.

Initial model calibration simulations resulted in a significant over-estimation of flood peak discharge as some upstream subbasins. The cause of the over-simulation was traced to the revised land use (year 2003) which includes more impervious surface than the original input developed by King County in the late 1980's. Surface runoff from the uplands was connected to the PERLND representing the outwash in each subbasin. The increased runoff from the impervious surface resulted in moisture input that overwhelmed the infiltration rate of the outwash and resulted in an unrealistic "spike" of surface flow from the outwash PERLND. This was corrected by increasing HSPF INFILT parameter and connecting the surface runoff from the upland till and impervious areas to the outwash interflow in subbasins I3A, I4, I6, and I7. A comparison of the runoff response using the original and revised model configurations for Subbasin I3A is shown in Figure 6.

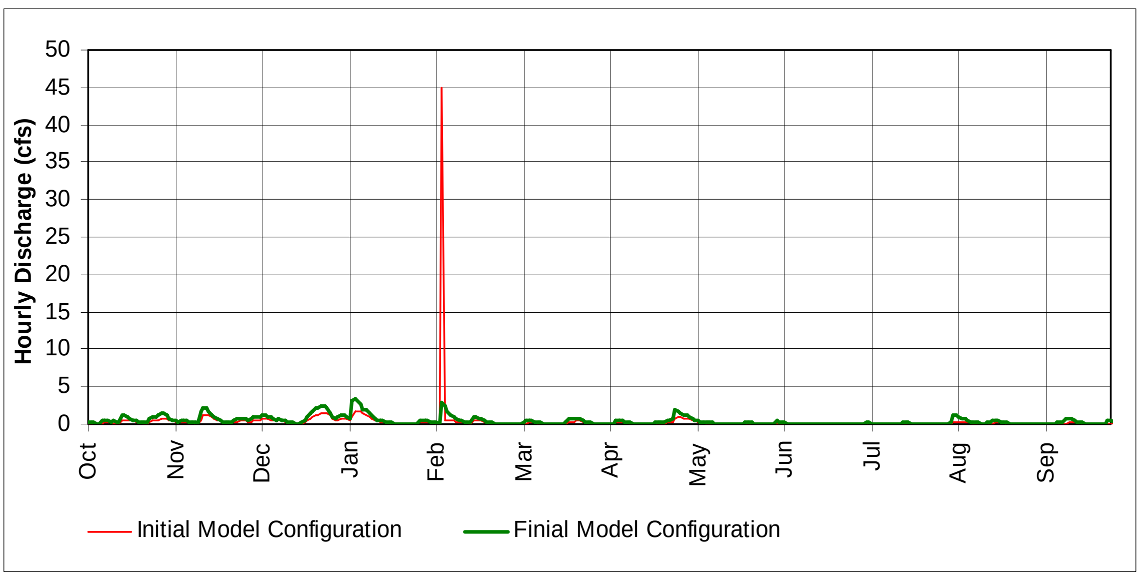



Figure 6 – Comparison of Runoff from Subbasin I3A, Initial and Final Model Calibration

A comparison of simulated and recorded discharge during water years 2002 and 2003 is shown in Figure 7. In general, the magnitude and timing of discharge compared well between simulated and recorded. The general shape of simulated winter storm flows and the magnitude of summer base flows matched well with the recorded streamflow for this period. Several large runoff spikes in the streamflow record (December 2001, October 2002, and March 2003) were attributed to gage malfunction or poor quality data and discounted in the model calibration. The streamflow record was not of sufficient quality to compute runoff volume or other statistics. The calibration was therefore judged qualitatively by the goodness of fit between simulated and recorded streamflow shown in Figure 7.

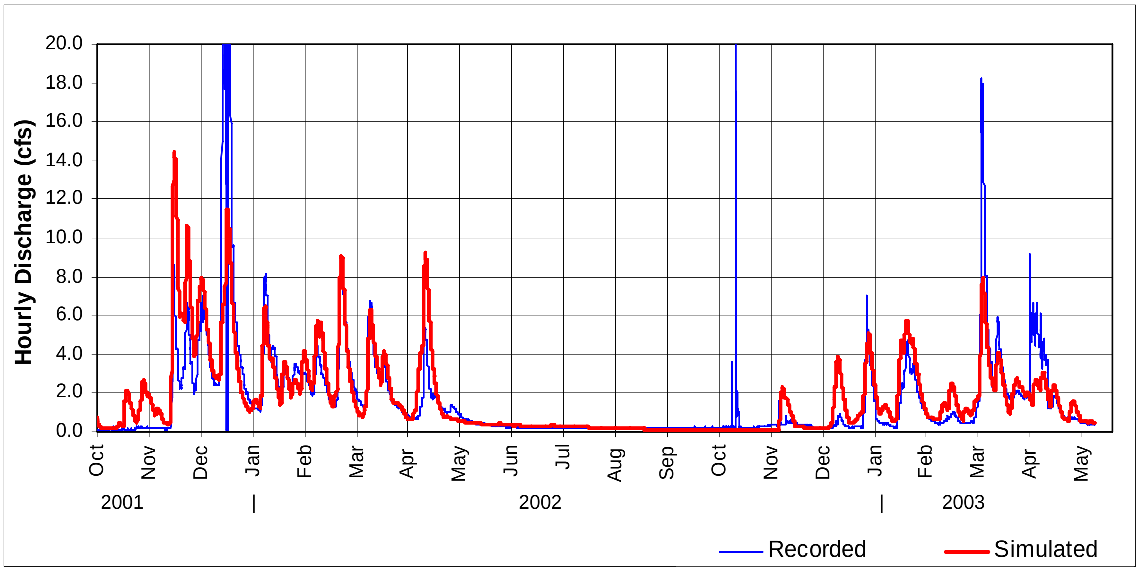



Figure 7 – HSPF Model Calibration, Inglewood Creek

## HSPF WATERSHED MODEL – ANALYSIS/PREDICTION APPROACH

### SIMULATION PERIOD

Following the calibration phase, the model may be used for analysis and prediction of streamflows for various land use conditions. For this application, long-term, high-quality, precipitation timeseries are needed that are representative of the hourly, daily, weekly and monthly precipitation characteristics that have occurred in the past, and can be expected to occur in the future.

The Washington State Department of Transportation Extended Precipitation Timeseries for Continuous Hydrologic Modeling[7,8] was used as input for the analysis of the Inglewood Creek watershed. This timeseries has a 1-hour timestep, is 158-years in length, and represents the rainfall characteristics of the Inglewood Creek watershed.

### PEAK FLOW MAGNITUDE-FREQUENCY STATISTICS

Peak discharge magnitude-frequency estimates were computed at locations of interest in the watershed using the HSPF model. The annual maxima discharge rates were saved at each location from the 158-years simulated. Peak flow and elevation magnitude-frequency relationships were computed using the Gringorten[9,10] plotting position formula (Equation 1).

$$Tr = \frac{N + 0.12}{i - 0.44} \qquad (1)$$

Where: *Tr* is the recurrence interval of the peak flow,
*i* is the rank of the annual maxima peak flow ordered from highest to lowest,
*N* is the total number of years simulated (158 in this case).

### FLOW DURATION STATISTICS

Modifications to the land surface during urbanization increases both the runoff peak rate and volume. The increase in runoff volume is the result of the loss of water storage in the soil column because of the compaction of the soil and the introduction of impervious surfaces. The increase in runoff volume combined with the increase in runoff rate results in higher stream discharges occurring for a longer duration. The increase in duration of a given flow rate results in more erosive work being performed on the stream channel over time, particularly when the discharge rate exceeds the threshold for stream bedload movement in the receiving channel.

Flow duration statistics provide a convenient tool for characterizing streamflow computed with a continuous hydrologic model. Duration statistics are computed by tracking the fraction of time that a specified flow rate is equaled or exceeded. HSPF does this by dividing the range of flows simulated into discrete increments and then tracks the fraction of time that each flow is equaled or exceeded. The fraction of time that a particular flow is equaled or exceeded is called *exceedance probability*. It should be noted that exceedance probability for duration statistics is different from the *annual exceedance probability* associated with flood frequency statistics and there is no practical way of converting/relating annual exceedance probability statistics to flow duration statistics.

## FLOOD FREQUENCY AND FLOW DURATION RESULTS

### INTRODUCTION

Precipitation timeseries 158-years in length at a 1-hour timestep and daily evaporation derived from the Puyallup 2 West Experimental Station (station number 45-6803) were used as input to the model, which resulted in a 158-year, 1-hour timeseries of flow at the outlet of each subbasin simulated. Flood magnitude-frequency and duration analyses were subsequently performed on the flow timeseries at locations of interest in the watershed.

### FLOOD PEAK DISCHARGE RESULTS

Peak flow magnitude-frequency estimates at each subbasin outlet were computed using the HSPF model under Existing and Future land use conditions (Figure 8). Resulting flood frequency estimates are presented in Tables 5a and 5b for existing and future land use, respectively. Figure 9 compares flood magnitude-frequency estimates for existing and future land use at the outlet of Inglewood Creek (Subbasin I1).

In general, the increases in peak discharge rate under future conditions are relatively small with a watershed average 15-percent increase in discharge. The reason for the small increase in discharge rate is the presence of the glacial outwash deposit, which infiltrates the majority of surface runoff produced in the till capped uplands. As discussed in the model calibration section, the outwash deposit is equivalent to approximately 7,000 acre-feet of stormwater detention storage in the Inglewood Creek watershed.

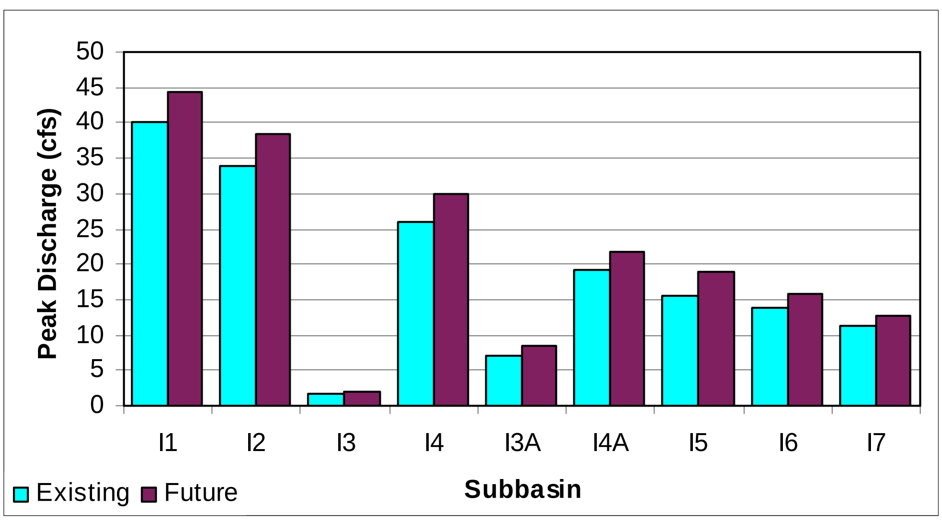



**Figure 8 – Comparison of 100-Year Flood Peak Discharge Existing and Future Land Use**

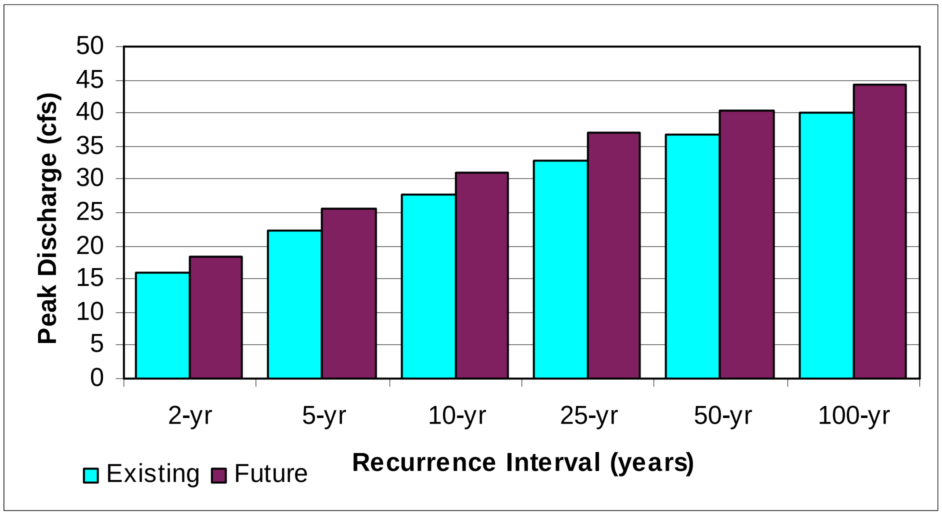



**Figure 9 – Comparison of Flood Peak Discharge at Mouth of Inglewood Creek Existing and Future Land Use**

**Table 5a – Inglewood Creek Flood Magnitude-Frequency Estimates (cfs) Existing Land Use (2003)**

| Subbasin | Flood Magnitude-Frequency Estimates (cfs) | | | | | |
|---|---|---|---|---|---|---|
| | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| SUBBASIN I1 | 16 | 22 | 28 | 33 | 37 | 40 |
| SUBBASIN I2 | 13 | 18 | 24 | 28 | 31 | 34 |
| SUBBASIN I3 | 1 | 1 | 1 | 2 | 2 | 2 |
| SUBBASIN I4 | 11 | 15 | 19 | 23 | 24 | 26 |
| SUBBASIN I3A | 3 | 4 | 5 | 6 | 6 | 7 |
| SUBBASIN I4A | 9 | 11 | 14 | 17 | 18 | 19 |
| SUBBASIN I5 | 7 | 9 | 12 | 14 | 14 | 16 |
| SUBBASIN I6 | 6 | 8 | 10 | 12 | 13 | 14 |
| SUBBASIN I7 | 5 | 6 | 8 | 10 | 10 | 11 |

**Table 5b – Inglewood Creek Flood Magnitude-Frequency Estimates (cfs) Future Land Use**

| Subbasin | Flood Magnitude-Frequency Estimates (cfs) | | | | | |
|---|---|---|---|---|---|---|
| | 2-yr | 5-yr | 10-yr | 25-yr | 50-yr | 100-yr |
| SUBBASIN I1 | 18 | 26 | 31 | 37 | 40 | 44 |
| SUBBASIN I2 | 16 | 21 | 26 | 32 | 35 | 38 |
| SUBBASIN I3 | 1 | 1 | 1 | 2 | 2 | 2 |
| SUBBASIN I4 | 13 | 17 | 21 | 26 | 27 | 30 |
| SUBBASIN I3A | 3 | 5 | 6 | 7 | 8 | 8 |
| SUBBASIN I4A | 10 | 13 | 15 | 19 | 20 | 22 |
| SUBBASIN I5 | 8 | 11 | 13 | 16 | 17 | 19 |
| SUBBASIN I6 | 7 | 9 | 11 | 14 | 15 | 16 |
| SUBBASIN I7 | 5 | 7 | 9 | 11 | 12 | 13 |

FLOW DURATION RESULTS

Flow duration statistics provide an indication of the relative amount of erosive work performed on the stream channel. The increase in duration at a given flow rate results in more erosive work being performed on the stream channel over time. As urbanization occurs in the watershed, the frequency of discharge that exceeds the historic bedload movement threshold increases. This results in greater erosive work on the stream channel leading to an expansion in the channel cross section and leads to larger sized stream gravel as the smaller gravel fraction is carried downstream.

Figures 10a and 10b show a relatively small change in the Inglewood Creek flow duration statistics for future relative to existing land use. This suggests that under build-out conditions, the potential for increased stream channel erosion is relatively small. Again, this is due to the presence of highly infiltrative outwash in the central part of the watershed, which greatly reduces the surface runoff response from the watershed. Flow duration statistics for each subbasin are summarized in Tables 6a and 6b for existing and future land use respectively.

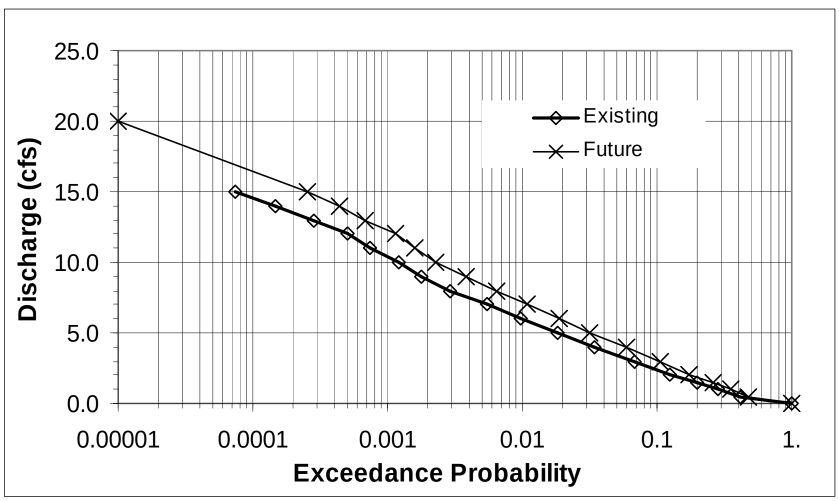



Figure 10a – Comparison of Simulated Flow Duration, Existing and Future Land Use
Inglewood Creek at Subbasin I5

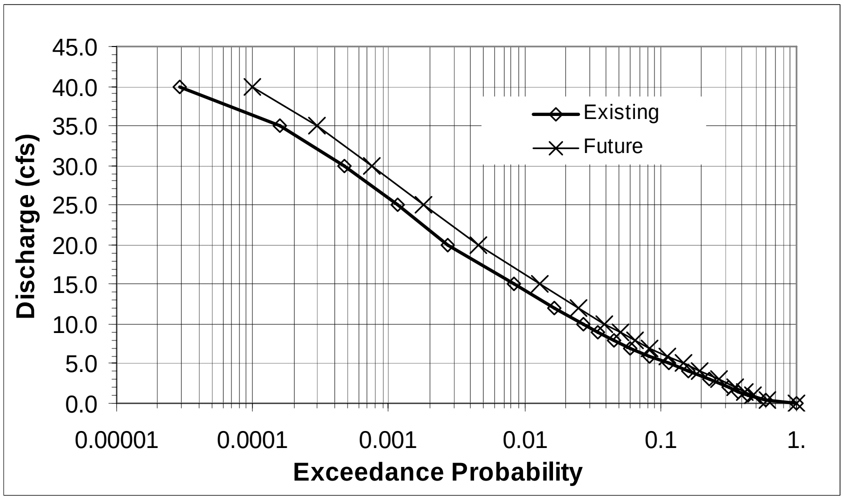



Figure 10b – Comparison of Simulated Flow Duration, Existing and Future Land Use
Inglewood Creek at Mouth (Subbasin I1)

**Table 6a – Flow Duration Analysis Results, Existing Land Use**

| | **Existing Land Use Discharge Corresponding to Exceedance Probability (cfs)** | | | |
|---|---|---|---|---|
| **Subbasin** | **90%** | **50%** | **20%** | **10%** |
| **I1** | 0.10 | 0.80 | 3.36 | 5.46 |
| **I2** | 0.06 | 0.38 | 2.17 | 3.84 |
| **I3** | 0.01 | 0.10 | 0.23 | 0.33 |
| **I4** | 0.07 | 0.47 | 2.40 | 3.97 |
| **I5** | 0.06 | 0.39 | 1.48 | 2.36 |
| **I6** | 0.05 | 0.34 | 1.23 | 2.07 |
| **I7** | 0.05 | 0.32 | 1.03 | 1.71 |
| **I3A** | 0.03 | 0.23 | 0.56 | 0.96 |
| **I4A** | 0.06 | 0.43 | 1.85 | 3.02 |

**Table 6b – Flow Duration Analysis Results, Future Land Use**

| | **Existing Land Use Discharge Corresponding to Exceedance Probability (cfs)** | | | |
|---|---|---|---|---|
| **Subbasin** | **90%** | **50%** | **20%** | **10%** |
| **I1** | 0.11 | 0.93 | 3.93 | 6.36 |
| **I2** | 0.07 | 0.43 | 2.69 | 4.68 |
| **I3** | 0.02 | 0.11 | 0.26 | 0.37 |
| **I4** | 0.09 | 0.69 | 2.93 | 4.94 |
| **I5** | 0.07 | 0.47 | 1.82 | 3.11 |
| **I6** | 0.06 | 0.39 | 1.56 | 2.53 |
| **I7** | 0.05 | 0.36 | 1.26 | 2.04 |
| **I3A** | 0.04 | 0.28 | 0.79 | 1.27 |
| **I4A** | 0.07 | 0.49 | 2.22 | 3.65 |

## SUMMARY AND RECOMMENDATIONS

A hydrologic analysis of Inglewood Creek was performed using the HSPF model as part of the Inglewood Creek Subbasin Plan. HSPF model input developed by King County as part of East Lake Sammamish Basin Plan was obtained for the current study, updated, and refined. The model was recalibrated to streamflow data collected over a 20 month period from October 2001 through May 2003.

The presence of glacial outwash in the central part of the watershed infiltrates the majority of surface flow produced in the upper parts of the watershed and results in little or no flow in the stream immediately upstream of the ravine (Subbasin I2). Downstream, the stream intersects the groundwater table (Subbasin I1) and receives the majority of flow via groundwater discharge. The groundwater discharge also produces year around base flow in the lower reaches of the stream. The outwash deposit infiltrates and stores runoff from the upper watershed and is equivalent to approximately 7,000 acre-feet of stormwater detention storage. Flows in the lower stream reach are relatively low (attenuated) during floods because of the storage that occurs in the outwash deposit.

Existing and future build-out conditions were simulated with the HSPF model and flood peak and flow duration statistics computed. Relatively small increases in runoff rates were predicted under future land use, with increases averaging 15-percent relative to existing land use. The future land use scenarios were simulated under the assumption that the outwash deposit would continue to infiltrate surface runoff from the upper watershed.

### RECOMMENDATIONS

1. <u>Maintenance of Outwash Infiltration Areas</u> –The glacial outwash deposit in the central part of the watershed is currently infiltrating the majority of surface runoff from the upper watershed. Maintaining the infiltration function of this area is critical to ensuring a stable flow regime and the health of the stream in the future.

   Infiltration of stormwater with pretreatment should be encouraged for new developments located in areas with outwash deposits. A general map of the geology of the Inglewood Creek watershed showing the extent of the outwash deposit is shown in Figure 4. Local site conditions will dictate whether infiltration is feasible on an individual development site and must be evaluated by the site development engineer. Stormwater conveyance should also be maintained in open channels to the greatest extent possible to promote infiltration into the outwash deposit.

2. On-Site Detention Standard – Currently, the City of Sammamish requires new development to design stormwater detention according to the 1998 King County Surface Water Design Manual (KCSWDM) Level 3 standard. This is the most stringent standard available for runoff control in the KCSWDM. As a minimum, this standard should be maintained for future development to reduce the rate of stormwater runoff reaching the outwash deposit and facilitate infiltration. A more stringent detention standard, such as that proposed in the 2001 Washington State Department of Ecology Stormwater Management Manual for Western Washington[11], is recommended since it would further reduce the discharge rate from development in the upper reaches of the watershed.

3. Identification of Flood Prone Properties – This recommendation addresses the potential for increased flooding of structures near the stream in the central part of the watershed (Subbasins I2, I3, and I4) if increased runoff in the future overwhelms the infiltration capacity of the outwash deposit. The previous recommendations seek to maintain the infiltrative function of the outwash deposit and analyses with the HSPF model indicate that if this function is maintained, then increases in future runoff rates will be negligible. However, if the outwash deposit is not as effective at infiltrating and reducing the rate of surface runoff from the upper watershed under future conditions or if the runoff rate increases to the point where it cannot be infiltrated, then the flow rate could increase dramatically in the central reaches of the watershed. To that end, this recommendation seeks to identify those structures that are located relatively close to the stream and to ensure that they are not flooded should the flow rate increase in the future. Conveyance upgrades or other means should be taken to reduce the likelihood of flooding at the structures identified as flood-prone.

4. Streamflow Monitoring in Upper Watershed – Currently, there is only one streamflow gage on Inglewood Creek, located near the mouth. Two additional stream gages should be installed upstream to provide an indication of the quantity and rate of flow from the upper reaches of the watershed that infiltrates to the outwash deposit. This would provide an indication of the infiltration performance of the outwash deposit and whether runoff from new development was increasing to levels that would cause flooding in the central reaches. One gage should be installed near the outlet of Subbasin I2 and another near the outlet of Subbasin I5.

## REFERENCES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## APPENDIX – HSPF MODEL INPUT