CHAPTER 3.
HYDROLOGY

3.1 HYDROLOGIC MODELING METHOD

3.1.1 Software Used

The HSPF model (version 10) used for this report is a versatile model that allows for a complete range of hydrologic analysis. King County generally encourages the use of HSPF for tributary areas larger than 200 acres. The Judd Creek and Shinglemill Creek drainage basins are 3,292 acres and 1,846 acres respectively. The subbasins for Judd Creek range from 998 to 1,214 acres and the subbasins for Shinglemill Creek range from 310 to 801 acres. Other strengths of using HSPF for this project include its ability to do the following:

- Model, link, and route many separate subbasins
- Calibrate a model to local site conditions
- Account for the groundwater component of stream flow
- Address groundwater connections and perform low-flow analysis
- Handle complex hydrologic accounting.

The HSPF model was supplemented by the use of the hydrologic data management program ANNIE (version 1). ANNIE is used to store, retrieve, list, plot, check, and update spatial, parametric, and time-series data for hydrologic models. HSPF Version 11 and ANNIE Version 4 are the most current versions of these programs, but the earlier versions were used because of problems extracting peak hourly flow data from ANNIE Version 4.

3.1.2 Analyses Conducted

Two land use scenarios were modeled: predevelopment, for which it was assumed that the basin is entirely forested; and existing land use, as described in Chapter 2. Future land use allowed by current zoning was not explicitly modeled, but anticipated future flow rates were inferred based on changes in land cover, including effective impervious area. For predeveloped and existing land use, the following stream flow parameters were analyzed:

- Mean daily flow
- Flow duration
- Low flow characteristics (e.g., 7-day mean low flow)
- Flow frequency.

3.1.3 Rainfall Variation

King County supplied Sea-Tac rainfall data for use in this analysis. Rainfall regions and regional scale factors defined in the *King County Surface Water Design Manual* (King County, 1998; Figure 3.2.2.A) were used to estimate the rainfall difference between Sea-Tac and the study site. These factors were developed for scaling runoff rates, but in the absence of direct scaling factors for precipitation they are suitable for approximating rainfall variations. Using this approach a scale factor of 1.08 on the Sea-Tac rainfall data was identified for all subbasins in the Judd Creek and Shinglemill Creek basins.

3.1.4 Land Coverage and Impervious Area

The land cover analysis described in Chapter 2 established the categories of coverage for each subbasin. The land cover, soil type, topography and basin boundaries were used as inputs for the HSPF model. The regionalized HSPF parameters for these segments were used in this analysis. In addition, the “pasture” coverage was included using the parameters provided by King County. Through the GIS analysis, area coverages were established and used as input into the model.

The land coverages “Bare Earth” and “Recent Clearcuts” were assigned to the “grass” coverage category for HSPF modeling purposes. The HSPF “pasture” category was assigned to the “Herbaceous Vegetation” and “Shrub/Scrub Vegetation” land coverages.

King County provided a table of estimated EIA values for existing land cover categories except for the “Mixed Urban/Low Density” and “Urban/High Density” categories. For these categories, Tt/KCM developed, and the County accepted, EIA estimates based on development in the areas and EIA estimates from previous work. The future land use analysis estimated EIA using typical values for the zoning categories in the study area.

The pervious portion of developed residential areas in the basin was assumed to be predominantly grass, but 10 percent of this pervious area was assumed to be forested in order to represent buffers and other untouched forested areas often incorporated into residential developments.

3.1.5 Channel Characteristics

No survey information was available for this project. Consequently, channel features were estimated based on a field visit and interpretation from limited available U.S. Geological Survey (USGS) topographic mapping. A channel cross-section was estimated for each of the seven channel reaches. Rating curves were developed for each reach using these cross-sections, estimates for channel roughness, and normal flow assumptions. Information from the rating curves was put into the format suitable for use with HSPF.

The exception to this procedure was the estimation of storage for the wetland area near the Judd Creek headwaters in Subbasin 3. For this area, a HEC-RAS model was developed to approximate stage, discharge and storage characteristics. The culvert under Singer Road SW was the downstream HEC-RAS model limit.

3.2 MODELING RESULTS

3.2.1 Mean Daily Flow

Table 3-1 summarizes the mean daily flow calculated for each channel segment over the model period of October 1, 1948 through September 30, 1997 for predeveloped and existing land use conditions. The results, in cubic feet per second (cfs), show mean daily flow throughout the study area consistently higher for existing land use conditions than for predeveloped conditions. This may be interpreted as the consequence of increased runoff from impervious areas and the conversion of forested areas to other pervious areas, such as grass, that promote more runoff. The largest increase is about 6 percent at the mouth of Judd Creek (RCHRES 100). For Shinglemill Creek, the increase is about 7 percent at the mouth (RCHRES 100).

TABLE 3-1.
MEAN DAILY FLOW RATE, CFS

RCHRES Segment	Mean Daily Flow (cfs) Predeveloped Land Use	Existing Land Use
Judd Creek		
400	2.9	3.0
300	5.3	5.6
200	7.9	8.4
100	7.9	8.4
Shinglemill Creek		
400	1.9	2.1
300	2.9	3.1
100	4.4	4.7

3.2.2 Flow Duration

The flow duration analysis is an accounting of how many one-hour periods over the modeling period experienced flows within each of a number of specified ranges. The results for the most downstream channel reach of Judd Creek (RCHRES 100) are shown in Table 3-2 and Figure 3-1. The results for the most downstream channel reach of Shinglemill Creek (RCHRES 100) are shown in Figure 3-2. Complete results for all stream segments are included in Appendix B and C.

Both Judd Creek and Shinglemill Creek experienced a reduction in low flow durations as land use changed from predevelopment to existing. In other words, the low flows became larger under existing land use conditions. During high flow periods, the frequency of higher flow rates increased under existing land use. This is a typical response in a developing watershed where changes in land use, such as increased impervious area and more grassed areas resulting from tree removal, promote more runoff, particularly during extreme events.

TABLE 3-2.
JUDD CREEK RCHRES 100 HOURLY FLOW RATE DURATION ANALYSIS

Flow Range (cfs)		Predeveloped Land Use		Existing Land Use	
Greater than or Equal to	But Less Than	Number of Cases[a]	Percent of All Intervals	Number of Cases[a]	Percent of All Intervals
0.00	0.93	0	0.00	0	0.00
0.93	1.20	0	0.00	0	0.00
1.20	1.60	4,865	1.13	1,035	0.24
1.60	2.20	40,998	9.54	30,718	7.15
2.20	2.80	63,541	14.79	56,014	13.04
2.80	3.80	71,934	16.75	73,665	17.15
3.80	5.00	50,958	11.86	55,253	12.86
5.00	6.60	40,029	9.32	44,823	10.44
6.60	8.70	37,639	8.76	40,291	9.38
8.70	11.00	29,837	6.95	32,554	7.58
11.00	15.00	32,287	7.52	34,436	8.02
15.00	20.00	24,225	5.64	24,753	5.76
20.00	27.00	16,915	3.94	17,321	4.03
27.00	35.00	8,835	2.06	9,483	2.21
35.00	46.00	4,425	1.03	5,163	1.20
46.00	61.00	1,939	0.45	2,446	0.57
61.00	81.00	692	0.16	950	0.22
81.00	110.00	234	0.05	377	0.09
110.00	140.00	90	0.02	128	0.03
140.00	190.00	49	0.01	76	0.02
190.00	250.00	24	0.01	30	0.01
250.00	330.00	8	0.00	8	0.00
330.00	430.00	4	0.00	4	0.00
430.00	570.00	0	0.00	0	0.00
570.00	—	0	0.00	0	0.00

a. Number of cases is the number of one-hour intervals in which the flow was within the specified range over the model period of October 1, 1948 through September 30, 1997.

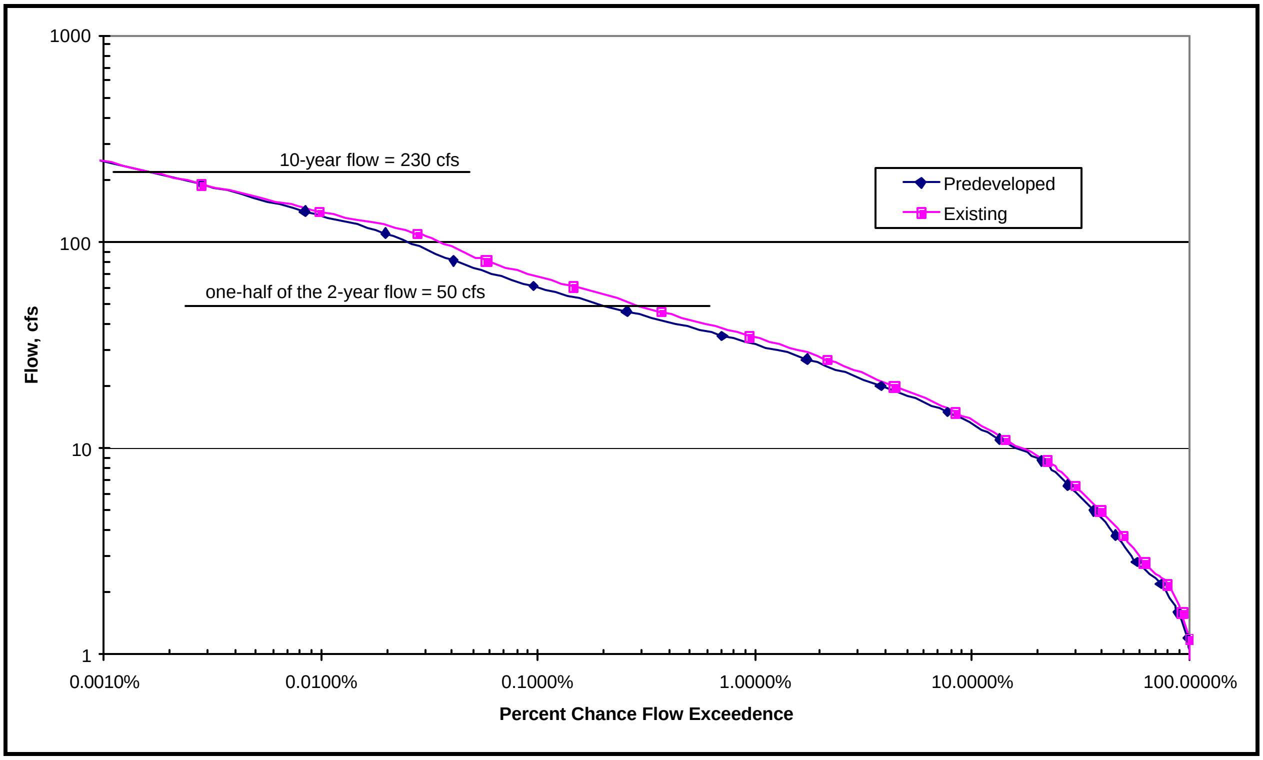

Figure 3-1. Judd Creek RCHRES 100 Flow Duration Comparison

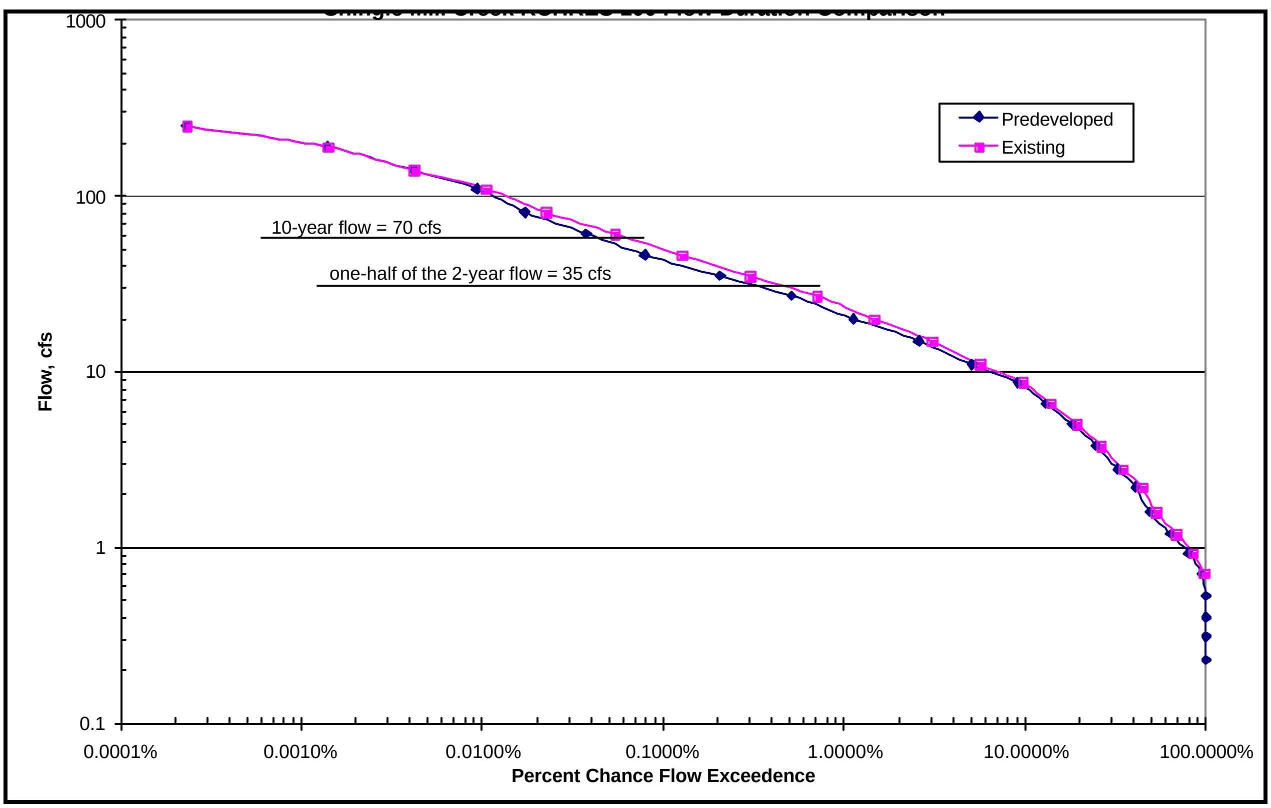

Figure 3-2. Shinglemill Creek RCHRES 100 Flow Duration Comparison

3.2.3 Low Flow Characteristics

Low flow characteristics of each channel segment were analyzed for 1-, 2-, 3-, 7-, 10-, 30-, 60-, 90-, and 183-day periods. Table 3-3 lists the mean 7-day low flows over the entire model period for predeveloped and existing basin conditions. Other low-flow results are provided in Appendix B and C.

TABLE 3-3.
MEAN 7-DAY LOW FLOW

RCHRES	Mean 7-Day Low Flow (cfs)	
Segment	Predeveloped	Existing
Judd Creek		
100	2.09	2.20
200	2.09	2.20
300	1.31	1.38
400	0.73	0.75
Shinglemill Creek		
100	0.97	1.02
300	.64	.67
400	.41	.43

For Judd Creek RCHRES 100, the average 7-day low flow under predeveloped conditions was 2.09 cfs. Under existing conditions, it increased to 2.20 cfs. On Shinglemill Creek RCHRES 100, the average 7-day low flow under predeveloped conditions was 0.97 cfs, increasing to 1.02 cfs under existing conditions. These results match those of the duration analysis, in which low flows increase with the land use transition from predeveloped to existing conditions.

3.2.4 Flow Frequency Analysis

A log-Pearson Type III distribution analysis using the Bulletin 17B procedure was used to estimate flow frequencies in each stream reach. Table 3-4 lists the results of the flow frequency analysis for predeveloped and existing conditions.

Due to a statistical anomaly using the log-Pearson Type III frequency analysis, the extreme floods under predeveloped conditions are greater than those under existing conditions. This is the result of a skew that is applied. The raw numbers show that the largest flood flows are about the same for the predeveloped and existing conditions. More frequent flood flows under the predeveloped conditions, such as the 2-year, are lower than under existing conditions. Consequently, when the theoretical curve is fitted to the data, it has the effect of pivoting around the midpoint, thus overstating the larger flood flows. This condition is aggravated by the small difference in basin-wide impervious area between predeveloped and existing (0.2 percent vs. 2.2 percent for Judd Creek, 0.3 percent vs. 2.0 percent for Shinglemill Creek). As development continues, particularly when more impervious area is added, this statistical anomaly will disappear.

TABLE 3-4.
FLOW FREQUENCY ANALYSIS

	Peak Annual Discharge (cfs)									
	2-yr		5-yr		10-yr		25-yr		100-yr	
RCHRES Segment	Predeveloped	Existing	Predeveloped	Existing	Predeveloped	Existing	Predeveloped	Existing	Predeveloped	Existing
Judd Creek										
100	99.6	116.6	172.8	187.7	230.2	239.2	312.2	308.2	453.2	417.5
200	104.5	121.2	181.8	195.7	242.3	250.4	328.7	324.7	476.8	444.9
300	82.4	94.7	143.5	152.3	190.6	194.3	256.9	251.1	368.0	342.2
400	33.8	41.1	57.1	64.6	75.1	81.6	100.5	104.4	143.8	140.8
Shinglemill Creek										
100	70.3	84.2	131.1	142.7	183.6	189.8	265.5	259.1	422.8	383.4
300	50.4	61.0	96.1	106.6	136.1	142.7	198.7	194.7	319.7	285.0
400	40.3	49.0	77.1	83.9	108.6	112.1	156.9	153.7	247.5	228.5

The flows at the mouth of Judd Creek were compared to flood frequency results published by the U.S. Geological Survey in 1998 (*Magnitude and Frequency of Floods in Washington, Water-Resources Investigations Report 97-4277*). The USGS analyzed peak flows recorded at the "Judd Creek near Burton, WA" gauge site (12091700) from 1969 through 1979. The results are summarized in Table 3-5.

TABLE 3-5.
USGS FLOOD FREQUENCY ANALYSIS, CFS

Flood Event	Flood Discharge (cfs)	95% Confidence Interval (cfs)
2-year	92	77-110
10-year	144	120-200
25-year	172	138-260
50-year	194	152-311
100-year	216	165-366

The HSPF analysis results are consistently higher than the USGS data. Using the same period of record as the USGS, the 100-year flood flow (using the log-Pearson Type III analysis) was 348 cfs. The statistics appear to be dominated by the largest flood flow in this period, the flood flow during water year 1972. The USGS estimated this flow to be 200 cfs and the HSPF model predicted 291 cfs. The model should be refined using surveyed cross-sections. However, the model may be used as-is to indicate trends, such as base flows, as development occurs in the watershed.

There were no recorded stream flows at Shinglemill Creek for any similar comparison.

3.3 QUALITATIVE ANALYSIS OF FUTURE BUILDOUT CONDITIONS

The future buildout condition is defined as development to the maximum density allowed by current zoning. Table 3-6 summarizes impervious area by subbasin for predeveloped, existing and future conditions. There is the potential to triple the impervious area under current zoning in both the Judd Creek and Shinglemill Creek basins. Judd Creek is predicted to increase from 2.15 to 7.51 percent, and Shinglemill Creek is predicted to increase from 2.04 to 6.88 percent. However, the overall coverage of impervious area is still small for a developed watershed. The increase of impervious area in Judd Creek Subbasin 2 is significant, from 3.40 to 13.66 percent. At this level of development, changes in channel morphology and flood characteristics can be expected. Without mitigation for new development, there is the potential for increased flooding and degradation of habitat in Judd Creek Subbasin 2 and immediately downstream.

TABLE 3-6.
SUBBASIN CHARACTERISTICS TO ASSESS FUTURE FLOWS

Subbasin	Subbasin Area (acres)	Impervious Area (acres) Predeveloped	Existing	Future[a]	Percent EIA Predeveloped	Existing	Future
Judd Creek Watershed							
3	1213.71	0.00	25.72	59.57	0.00	2.12	4.91
2	998.14	5.70	33.91	136.36	0.57	3.40	13.66
1	1080.25	0.00	11.28	51.38	0.00	1.04	4.76
Entire Basin	3292.10	5.70	70.91	247.31	0.17	2.15	7.51
Shinglemill Creek Watershed							
4	801.37	4.29	26.57	78.25	0.54	3.32	9.76
3	418.56	0.32	4.90	18.39	0.08	1.17	4.39
2	310.39	0.00	2.80	16.97	0.00	0.90	5.47
1	315.53	0.00	3.43	13.35	0.00	1.09	4.23
Entire Basin	1845.85	4.61	37.70	126.96	0.25	2.04	6.88

Without any drainage controls to mitigate for future development, increases in peak flows would be expected. There is also the conversion of forested area to pasture and grass area, which will generate greater runoff. Consequently, future peak flows, especially for the more frequent events, are expected to increase, with a slight reduction of low flows due to some loss of subsurface storage when the forest canopy and forest duff is removed. However, current regulations should mitigate and minimize future peak flow increases.

3.4 CONCLUSIONS AND RECOMMENDATIONS

The HSPF model developed for this analysis of the basin should be viewed as preliminary; further data gathering, monitoring and calibration are recommended. The model should be refined using additional basin-specific information. However, the model may be used to indicate trends, such as base flows, and flow magnitudes as development occurs in the basin. The following additional efforts are recommended to refine the model for future use:

- Calibrate the model based on local precipitation data

- Survey channel characteristics (cross-sections, slope, overbank features, etc.).
- Obtain accurate topographic information for defining floodplain storage.
- Perform a drainage system inventory and survey culverts and bridges to identify other possible restrictions within the drainage basins and determine what drainage facilities maybe undersized.