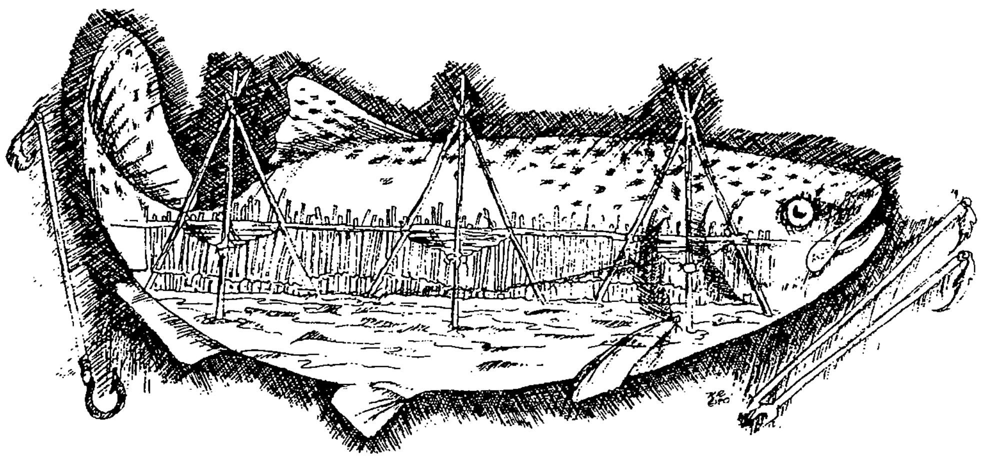
BIG SOOS CREEK LOW FLOW TREND AND WATER RIGHT ANALYSIS



Muckleshoot Indian Tribe
Fisheries Department

November 21, 1994

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BIG SOOS CREEK LOW FLOW TREND AND WATER RIGHT ANALYSIS

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Auburn, Washington
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ERRATA

1. Precipitation data for Landsburg was taken from King County Surface Water Management records, not from National Oceanic and Atmospheric Administration records.

2. Water year precipitation totals for Landsburg for 1991 and 1992 should be changed from 66.97 and 46.23 inches to 64.19 and 46.07, respectively (Appendix I, p. 23.) Therefore the r value for Landsburg should be changed from -0.06 to -0.08.

3. On p. 18 second paragraph, "precipiation" should be changed to "precipitation".

4. On p. 30 last paragraph, "Gren" should be "Green".

October 7, 1996

SUMMARY

Low streamflow in Big Soos Creek is a limiting factor for salmonid production. To determine whether low flows have declined over the past two decades, mean annual 7-day low flow in Big Soos Creek (U. S. Geological Survey records) and precipitation at the Sea-Tac International Airport and at Landsburg (National Oceanic and Atmospheric Administration records) were analyzed from 1967 to 1992. A statistically significant decline in these flows was found, which ranged from approximately 30 to 25 cfs. A similar analysis on precipitation illustrated that precipitation cannot completely explain the flow decline. A dry pattern in the 1980's and early 1990's at Sea-Tac is indicated, however, a significant decline was not found. Trend analyses on three streams with similar periods of record as Big Soos Creek were also conducted and no trends were indicated. Strong groundwater and surface interrelationships exist in the Soos Creek basin. Water right allocations of groundwater have increased substantially (from 1,195 to 19,548 ac.-ft./yr.) coincident with the low flow decline. Urbanization and impervious surfaces have also increased, which reduces groundwater recharge. It was concluded that Big Soos Creek average annual 7-day low flows have declined from the period from 1967 to 1992. A combination of factors, including surface water diversions, permitted and exempt groundwater withdrawals, loss of recharge from urbanization, and a normal dry weather pattern are contributing factors, but groundwater withdrawals have apparently exerted the strongest influence.

INTRODUCTION

The Soos Creek basin is located east of Auburn in King County and includes over 60 miles of streams (**Figure 1**). It is the largest tributary system in the lower Green River. Because of its rich fisheries, a tribal village was located at the confluence of Big Soos Creek and the Green River and was inhabited for several thousand years prior to European settlement. Since 1901, a major state salmon hatchery, the Washington State Department of Fish and Wildlife Green River Hatchery, has operated at river mile 0.7 of Big Soos Creek. A large proportion of present-day tribal and public salmon fisheries in south Puget Sound depends upon salmon production at the hatchery. In addition to releases of fish at the Green River Hatchery, the habitat upstream provides spawning and rearing for naturally produced coho, chum, and fall chinook salmon and trout.

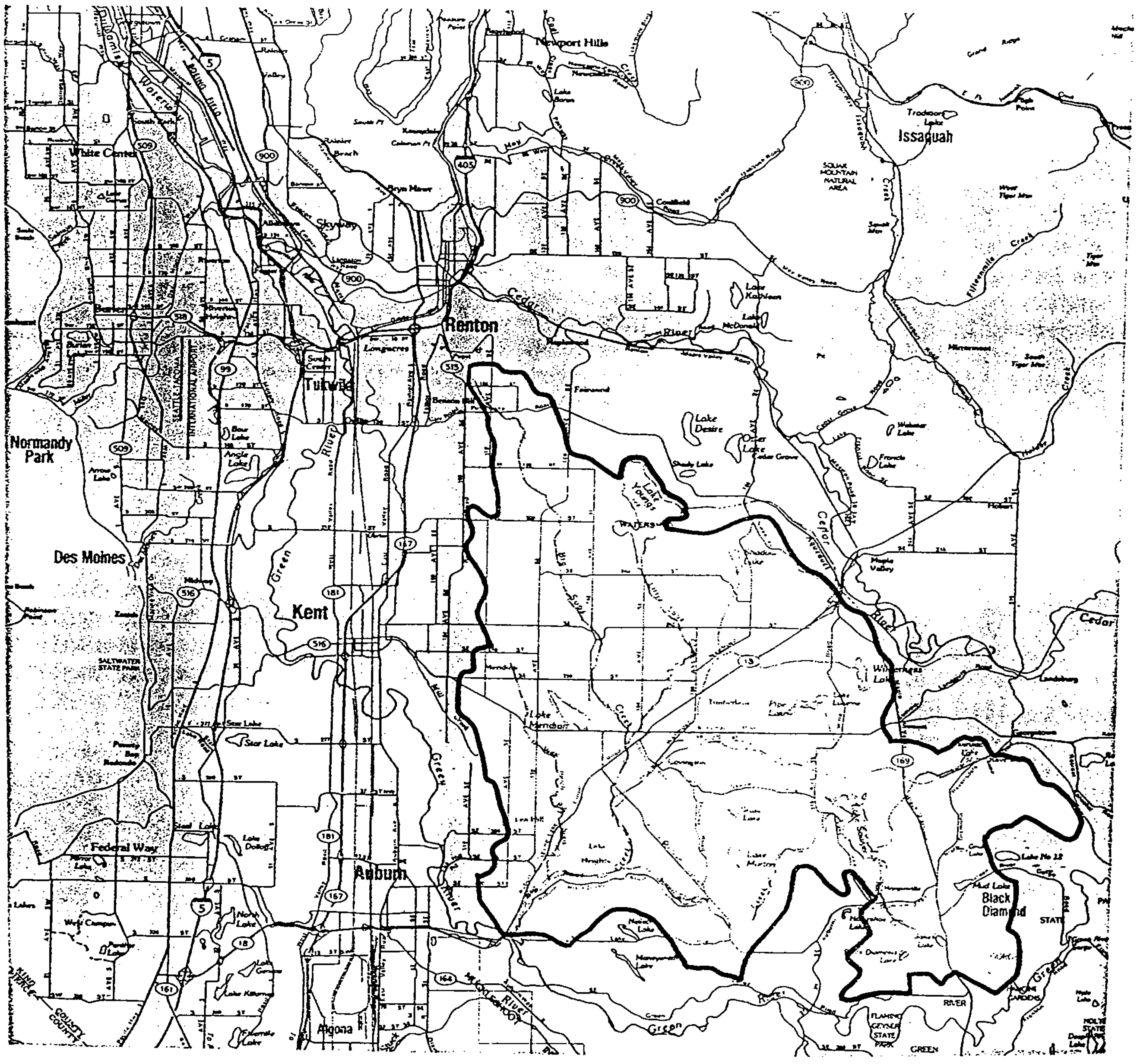
Low summer flow in the Soos Creek drainage is "the most restrictive factor to salmon production" and diversion of water for domestic and irrigation use is "a significant limiting factor" (Williams, et al, 1975). Low streamflow affects fish productivity at the Green River Hatchery, which uses Soos Creek as the sole water supply (Drivdahl, 1994). Low flows limit fish production by the loss of water critical for hatchery operations and by exacerbating water quality problems. Temperature increases and pollution from agricultural and urban runoff increase the vulnerability of fish to disease and mortality, reducing overall productivity within the hatchery.

Effects of low streamflow on naturally spawning salmon and steelhead include reductions in suitable spawning, incubation, and rearing habitat, reductions in food supply, impairment of upstream migration, increases in water temperatures, increases in susceptibility to water quality problems, and other effects. Coho salmon juveniles exposed to low summer streamflow conditions have been found to return in fewer numbers as adult fish available for harvest in Puget Sound (Smoker, 1955, and Mathews and Olson, 1980). Juvenile fish released from hatcheries to rear in streams are also subject to negative effects and lower survival under low flow conditions.

Low streamflows in the Soos Creek system usually occur in late summer and early fall during dry periods when groundwater is the only source of water to sustain flows. Much of the Soos Creek basin is underlain by alluvial and permeable glacial outwash sediments that contribute to a relatively large amount of groundwater storage (Hidaka, 1973). Dry season flows are sustained by this storage previously filled after evapotranspiration and surface runoff losses have occurred. Water-table aquifers in glacial outwash sediments are quickly recharged by precipitation and infiltration while aquifers confined by less permeable glacial tills are recharged at considerable slower rates (Dinicola, personal communication, 1993). Groundwater from both water-table and confined aquifers discharges to stream channels and is the main streamflow component during dry periods. As groundwater dominates dry weather baseflow in Soos Creek, a change in low flow over time is a direct reflection of a change in the groundwater regime of the basin.

In Wisconsin, an increasing trend in 7-day low flows was identified where agricultural practices have improved over time (Gebert and Krug, unpublished, 1994). The Muckleshoot Tribe believes that low flows in Big Soos Creek have declined over time due to single family, community and municipal wells, illegal and legal surface water diversions, and to recharge loss from urbanization within the basin.

FIGURE 1



Big Soos Creek is a major tributary to the Green River and the basin is located between the cities of Auburn, Kent, and Renton.

This analysis is an effort to determine whether 7-day low flows have declined in Big Soos Creek and if so, to identify potential causes.

METHODS

A trend analysis was conducted on Big Soos Creek 7-day mean annual low flow from 1967 to 1992. A similar trend analysis was conducted for three other streams, (Newaukum Creek, Huge Creek, and Raging River) located in the Puget Sound area and for two precipitation measuring sites, Sea-Tac International Airport and Landsburg. A widespread trend among streams would strongly indicate that climatic factors are responsible. Data from both precipitation stations and three of the streams were normally distributed and a Student's t test was calculated on the linear regression to determine a trend. Kendall's tau was calculated for data from Newaukum Creek as it was non-normally distributed. Kendall's tau can be used where no assumption is made regarding the distribution of the data, however, it is more appropriate to use linear regression and the t test where data are normally distributed (Campbell, 1989). The associated probabilities were determined for all sites. A probability value of less than 0.05 (i.e., a greater than 95 % chance that the trend is real) was chosen to indicate a highly significant trend.

The Big Soos Creek U.S.G.S gage (#12112600) is located at river mile 0.9, which is 0.2 miles upstream of the Green River Hatchery. Streamflow data has been collected on Big Soos Creek by the U.S.G.S. since 1962, but the starting year for this analysis was 1967, as water was diverted upstream of the gage for the state hatchery until 1966. All streamflow records were obtained from published records of the U. S. Geological Survey (U.S.G.S.) in McGavock, et al, 1984-87; Miles, and various co-authors, 1988-93; U.S.G.S., 1980-83; and Williams, et al, 1985. The 7-day low flow was calculated from daily discharge records as the average minimum flow that occurred for seven days each calendar year from 1967 to 1993. The 7-day low flow was chosen as this flow duration is less variable than daily flows and is a better representation of flows important to fish. It also represents baseflow augmented by groundwater input. Use of this streamflow duration does not indicate a desirable flow threshold for Soos Creek, nor is it necessarily directly tied to instream habitat needs.

Similar trend analyses were conducted for water year (October-September) total precipitation at the Sea-Tac Airport and Landsburg weather stations. Data at these sites were examined as long-term records in the Soos Creek basin are lacking. Actual rainfall within the basin ranges between amounts measured at Sea-Tac and at Landsburg. Precipitation data was obtained from annual summaries published by the National Oceanic and Atmospheric Administration.

An evaluation of state-appropriated surface and groundwater rights in the basin upstream of the U.S.G.S. Big Soos Creek gage was also conducted. This analysis consisted of identifying water rights located within the topographic watershed divide from Washington Department of Ecology records (July, 1993) and a cumulative total over time was determined. The Department of Ecology database lists permit dates, not the dates water certificates were issued. Certified dates can lag behind permit dates by several years, as the applicant must install facilities to put water to a beneficial use. The highest increase in water right permits occurred between 1976 and 1984, so all were likely certified within the analysis period (by 1992). Pending requests for new water rights were also totaled. An estimate was made of water usage from exempt wells, which do not require permits from Ecology if withdrawals are less than 5,000 gallons/day. Groundwater rights and estimated exempt well usage were totaled and compared to hypothetical groundwater yields. The percent of the Soos Creek basin in impervious surfaces, as determined by King County, Surface Water Management Division (King County, 1990) was also included.

Mean annual 7-day low flow values for all streams and total water year rainfall at Sea-Tac International Airport and Landsburg are in Appendix I. A list of surface water and groundwater rights in the basin follows in Appendix II. Appendix III contains information on water rights held by the major water districts that withdraw or plan to withdraw groundwater from the Soos Creek basin.

LOW FLOW TREND ANALYSIS

An analysis was conducted for several streams in the Puget Sound Region to determine the existence of a low flow trend from 1967 to 1992. Time is an important factor as extreme population growth in the watershed has increased the pressures on groundwater resources. Population growth increases pressure on groundwater sources for water supplies.
Growth also results in urbanization and increased impervious surfaces, which severely limits groundwater recharge.

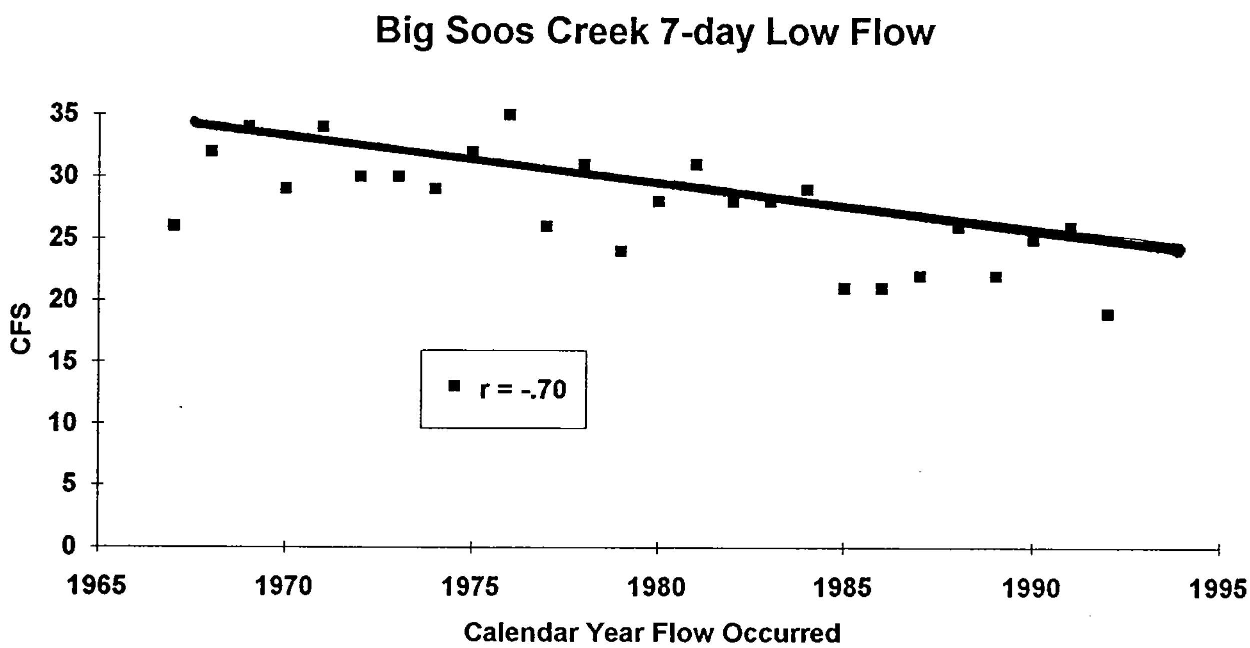
For the trend analysis, only streams with a similar period of record and gaging elevation to Big Soos Creek and located in the Puget Sound area were used. Linear regression and Student's t test were utilized for significance testing for normally distributed data (Big Soos Creek, Huge Creek, Raging River) and Kendall's tau test was used for Newaukum Creek as data was not normally distributed. A probability of **less than 0.05** was chosen to indicate a significant trend; that is, a **greater than 95%** chance a trend is not due to random variability. The correlation coefficient or Kendall's tau indicate the direction of trend (increasing or declining) and magnitude. Statistical methods follow those in Zar, 1974, and Campbell, 1989.

Results indicated that the 7-day low flow in Big Soos Creek has declined while low flows in other streams have not. This strongly indicates that factors other than a dry precipitation pattern are responsible for the decline in low flow of the Soos Creek system. Trend analysis results are as follows:

Big Soos Creek

A decline in the 7-day low flow has occurred over time. The average low flows decreased from 30 cfs for the period from 1967 to 1979 to 25 cfs for the 1980 to 1992 period. The t test on the regression slope indicated a highly significant decline with a probability of less than **.0001 or 99.9%** chance of a trend. The calculated correlation coefficient was **r = -.66 (Figure 2)**.

FIGURE 2



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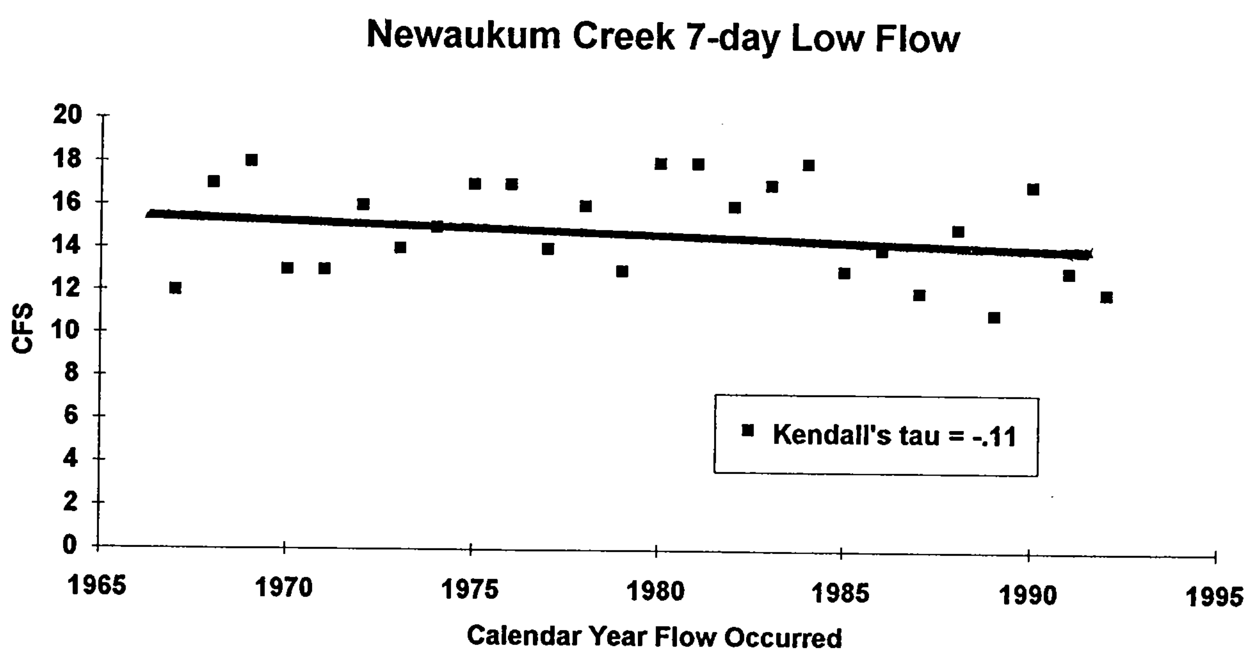


Newaukum Creek

Newaukum Creek is also a tributary to the Green River and has limited diversions for agricultural uses. However, it is very similar to Big Soos Creek in it's low flow characteristics and hydrogeology (Hidaka, 1973). Mean annual 7-day flows are not declining over time as shown by the Kendall's tau test with a probability of **.39 or a 61%** chance of a trend. Kendall's tau was **-.11 (Figure 3)**.

Huge Creek

Huge Creek is located on the Key Peninsula in the Minter Creek basin. The period of record is 1960 to 1968 and 1978 to 1992. Low flows for the 1978 to 1992 record were analyzed and a significant change in flows did not occur **(Figure 4)**, as indicated by a probability of **.13 or 87%** chance of a trend. The correlation coefficient was **r = -.31** which indicates flows may be on the decline, but are not yet statistically significant. Like south King County, the Gig Harbor rural area has also experienced high population growth in recent years.

Raging River

The Raging River is tributary to the Snoqualmie River. Low flows from 1967 to 1992 were tested with linear regression and a t test. A significant change in mean 7-day low flows did not occur during this time as shown by a probability of **.47 and a 53%** chance of a trend **(Figure 5)**. The correlation coefficient was very low, **r = -.02.**

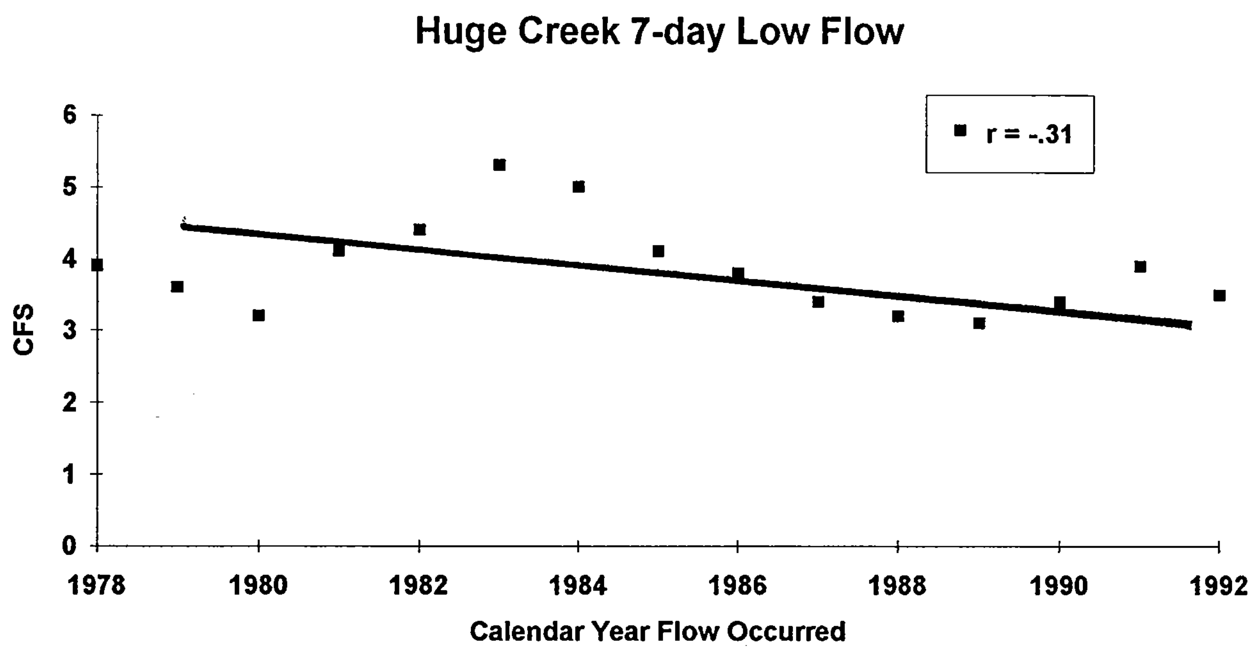
POTENTIAL CAUSES

The cause of the 7-day flow decline is likely due to: a declining precipitation trend; increased impervious surfaces and reduced recharge from urbanization; increased groundwater and surface water appropriations; or a combination of all of these factors.

Precipitation Trend Analysis

A trend analysis was also conducted for total annual water year precipitation at the Sea-Tac International Airport **(Figure 6)** and at Landsburg **(Figure 7)** for water years 1967 to 1992. Linear regressions and t tests were conducted as data from both stations fit a normal distribution. Correlation coefficients were **r = -.28** at Sea-Tac and **r = -.06** at Landsburg. Probabilities were **.09** at Sea-Tac and **.38** at Landsburg (i.e., **91% and 62%** chance of a trend, respectively). No significant trend in total annual water year precipitation at either site occurred. A declining trend at Sea-Tac is indicated at the 90% significance level, so precipitation cannot be ruled out as a possible factor contributing to the flow decline. However, as localized precipitation over the Soos Creek basin ranges between that measured at Sea-Tac and Landsburg, a potential declining rainfall trend at Sea-Tac cannot fully explain

FIGURE 4



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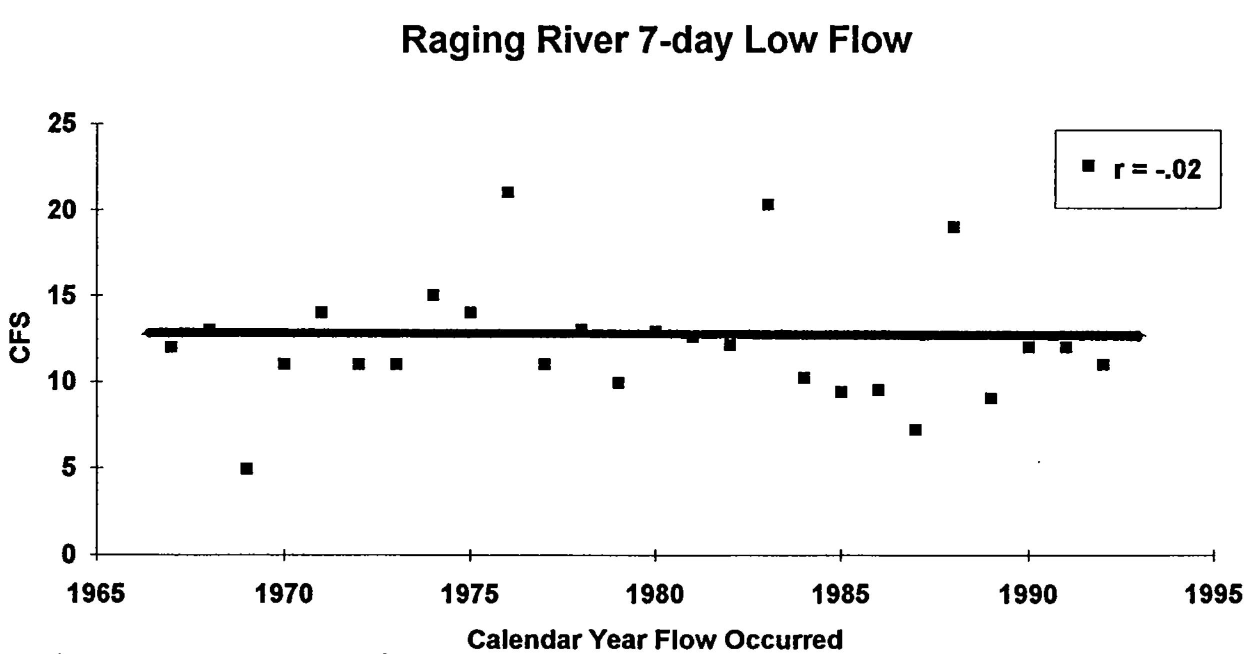
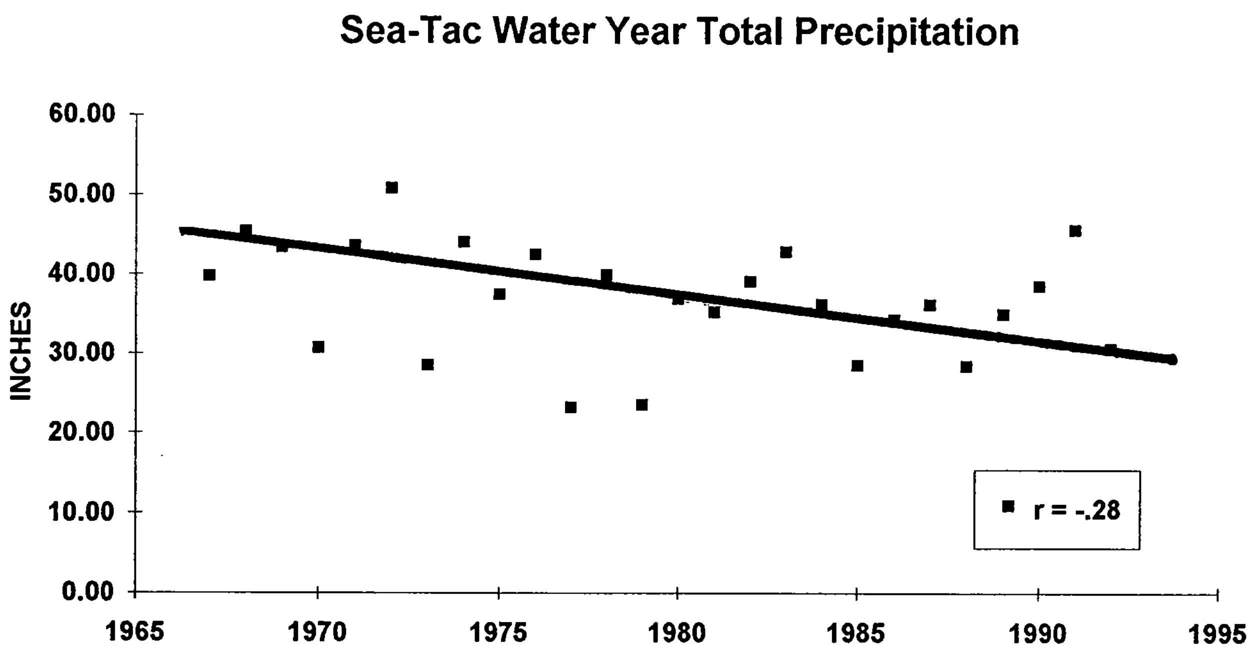


FIGURE 6



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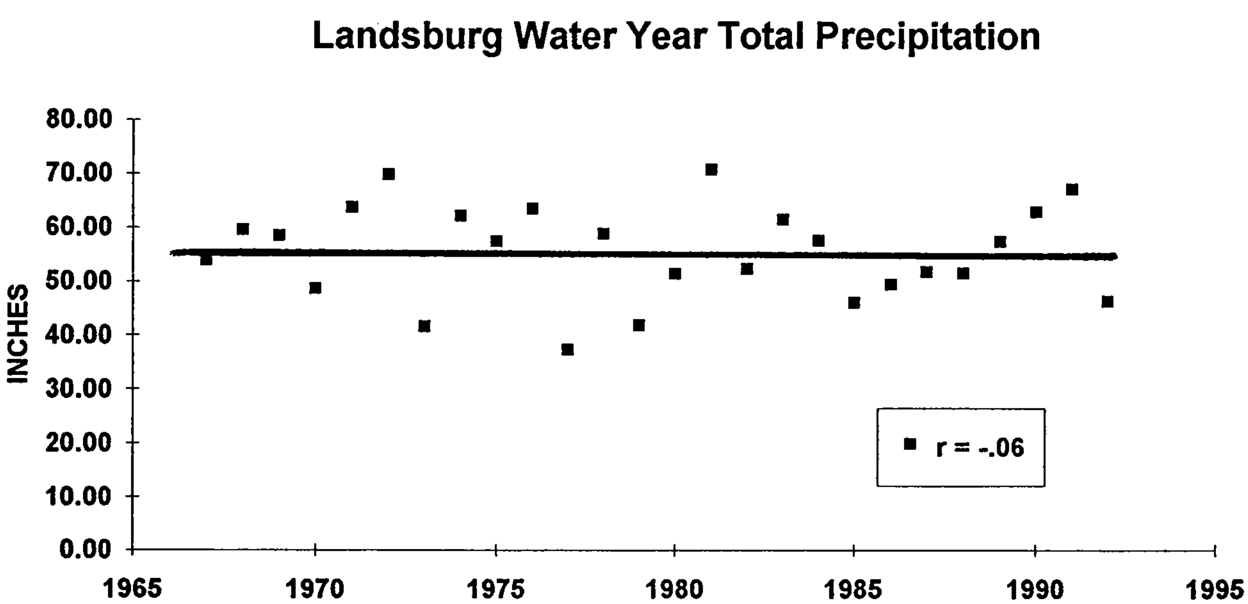


the low flow decline in Big Soos Creek, especially considering the absence of flow declines in other area streams. Low flow characteristics of streams are dependent on other factors than precipitation (Hidaka, 1973). However, it is likely that successive years of below normal rainfall are contributing to a loss of groundwater storage in the Soos Creek basin and changes in the groundwater regime are occurring. Any natural flow decline is exacerbated by groundwater withdrawals and loss of recharge associated with increased impervious surfaces in the basin.

Increased Impervious Surfaces

Population in the basin has increased by 34%, (71,050 to 95,350) during 1980 to 1990 (Muckleshoot Indian Tribe, 1993, draft). Growth and urbanization can affect low flows from the loss of recharge to groundwater by impervious surfaces and by exerting additional pressures on groundwater supplies. The potential for illegal diversions for lawn watering from residences located along streams also increases.

Increased impervious surfaces result in a cumulative loss of recharge to groundwater over time. King County Surface Water Management has conducted stormwater modeling in the Soos Creek watershed for basin planning purposes. Quantification of impervious surfaces were made for that analysis and that information for forested conditions, land use conditions in 1985, and projected conditions under build-out (no year specified), were estimated (King County, 1990). A three-fold increase (5 to 16 percent) in impervious surfaces from 1985 to future high-density development (**Figure 8**) was estimated. Recharge loss due to impervious surfaces will certainly continue with future growth and affect Soos Creek low flows, fish production, and water availability for domestic, and other, uses.

Increased Water Right Appropriations

Water right appropriations have increased minimally for surface waters (**Figure 9**) and dramatically for groundwater (**Figure 10**) from 1967 to 1992. During this time frame, several small surface water diversions were permitted and a larger one, 0.5 cfs was issued for non-consumptive use. Groundwater right appropriations (**Figure 10**) have risen substantially, from 1,195 to 19,548 ac.-ft./yr., a 16 fold increase. This equates to an increase from 1.7 cfs to 27 cfs. Several of these appropriations were high capacity municipal wells. All water right appropriations are exerting a cumulative impact on dry weather streamflows and are likely the major cause of the low flow decline in Big Soos Creek. The following section provides more information on water right appropriations.

WATER RIGHTS ANALYSIS

A water right analysis of the Soos Creek basin was conducted to document the quantity of water appropriated. An analysis of mean 7-day low flows in Soos Creek from 1967 to 1992 has shown a declining trend. Increases in groundwater withdrawals for municipal and domestic water supplies, including single-family "exempt" wells within the basin are likely contributing to the decline. The purpose of this analysis is to provide more detail into the quantification of surface

FIGURE 8

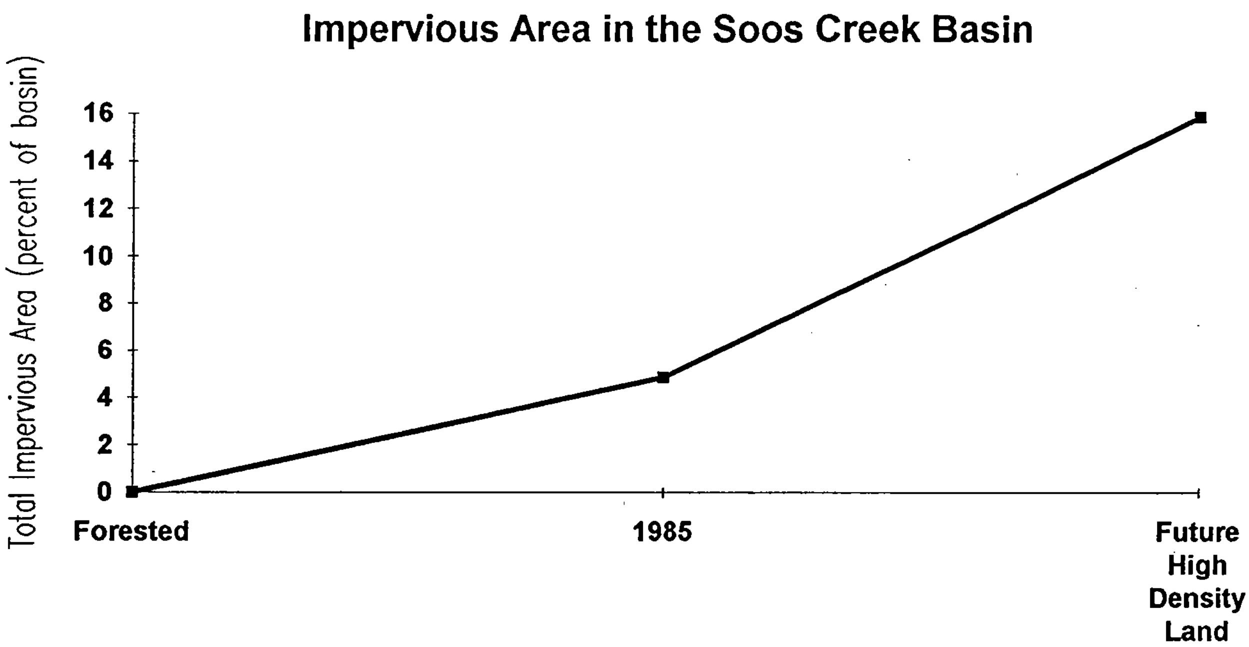
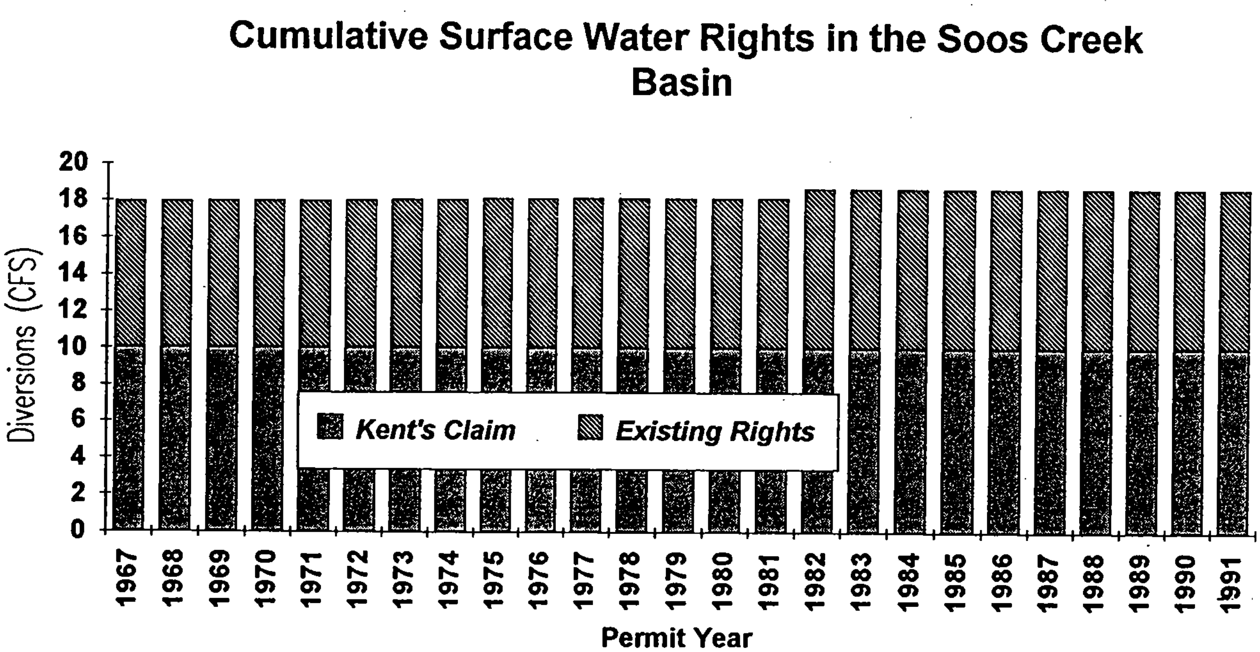


FIGURE 9



and groundwater rights to indicate the effect this may have on the flow decline. "Water right" as used here, refers only to permits and state-certified rights.

For this analysis, the state Department of Ecology database (July 28, 1993), which reports water rights by township and range for each Watershed Inventory Area (WRIA), was utilized. Quantities and flow rates for diversions from springs, Big Soos Creek and it's tributaries, and groundwater withdrawals from within the topographic basin were included. Rights issued downstream of the USGS stream gage were excluded. Water rights certified for lake withdrawals were also not included. The Ecology database only reports permit, not certified dates. It was assumed that the permitted date was close to the certified or date water was put to beneficial use. In reality, the certificate date may lag behind the permit date by several years. Several limitations to the use of water right information must be kept in mind. The rights do not necessarily reflect the actual use and numerous rights have been issued that may not still be in use. It is beyond the scope of this analysis to determine what rights are still in use. Until more information is available on any relinquishment of water rights, it was assumed these rights, as they were issued in perpetuity, are or have been, in use. All water rights were issued between 1926 and 1991. Surface and groundwater rights are listed in Appendix II.

The Ecology water claim register was also consulted. Over 1,600 claims are in the Soos Creek basin. Water claims could not be quantified for this analysis as the register does not always specify amounts (some quantification information is stored on microfiche at Ecology's headquarters office). Actual quantification can only occur with adjudication. The City of Kent's surface water claim was included here as it has a high instantaneous rate (10 cfs). However, the annual withdrawal limit is much less, at 965 ac-ft./yr. (City of Kent, 1988).

A comparison of current groundwater rights to estimated hypothetical yields were made to provide a guideline as to whether the basin is over-appropriated.

Surface Water Rights

There are 62 surface water rights in the basin which total 8.7 cfs for both consumptive and non-consumptive uses as of 1991 (**Figure 9**). Only 7 water rights are non-consumptive uses. The largest instantaneous flow rates for water rights are 1.0 to 1.5 cfs.

The City of Kent claims 10 cfs of water from springs which would otherwise flow into a tributary of Jenkins Creek, in the Soos Creek basin. The City of Kent asserts use of water since the early 1900's. This claim is included in **Figure 9**, along with existing surface water rights.

Total surface water consumptive rights and Kent's claim increased from 10-13.82 cfs during the period from 1926 to 1950 and from 13.82 to 15.14 for 1950 to 1977. No more consumptive rights were issued after 1977 as the basin was subsequently closed to further consumptive-use appropriations. The 7-day low flow decline in Soos Creek appears to occur later, i. e., around 1979 to 1992. Non-consumptive rights issued between 1979 and 1991 increased from 3.04 to 3.55 cfs. If any of the non-consumptive uses were actually consumptive, this would be partially responsible for the flow decline. Illegal diversions are also likely occurring as well. The City of Kent's spring withdrawals are also contributing to the low flow decline as demands on the system have increased with population growth.

Groundwater Rights

There are 102 groundwater rights in the basin, as of July 1993, which total 19,592 annual acre-feet/year or 27 cfs. Thirty-two applications for 17,144 gpm (24.7 MGD), are pending as of July 1993. Applications usually only specify an instantaneous rate. Groundwater rights have been issued with provisions for both an instantaneous withdrawal rate (gpm) and a maximum withdrawal amount (acre-feet/year). Cumulative existing rights are shown in maximum annual acre-feet in **Figure 10.** Overall, groundwater permits increased from **1,195 to 19,548** acre-feet per year (or **1.7 to 27 cfs**) from 1967 to 1990 (a 16-fold increase).

Shallow aquifers are in hydraulic continuity with surface water in the Soos Creek watershed (South King County Ground Water Advisory Committee (SKCGWAC), et al, 1991). Deeper aquifers also contribute baseflow to Soos Creek. The elevations of four major water-supply aquifers identified in the basin by the South King County Ground Water Plan range from 175 to 510 feet above mean sea level (amsl). The generalized groundwater movement direction is to Soos Creek, which drains elevations over 500 feet to about 75 feet amsl. Therefore deeper aquifers and water-bearing zones also discharge to Soos Creek and it's tributaries.

Withdrawal of groundwater in hydraulic continuity with Soos Creek, or tributaries and diversion of spring inflow are likely the primary causes of the low streamflow decline. This decline is expected to persist and worsen if pending groundwater applications for aquifers that discharge to Soos Creek are certified **(Figure 11).** If these are certified at the rates requested, groundwater appropriations will almost double.

The City of Kent, King County Water District #111 and Covington Water District obtain their supplies from groundwater within the Soos Creek basin. State-certified water rights between these three total 23.9 MGD (instantaneous rate) and 16,755 acre-feet per year. Pending water rights total 13.3 MGD (instantaneous rate). This includes applications submitted by the Soos Creek Water and Sewer District, which currently receives all supply from the City of Seattle, but is seeking to develop their own supplies. Additional information on each district's water rights is included in Appendix III.

Other Large Water Rights

Another large user is the Cran-Mar Trout Farm which holds a groundwater right (1.4 MGD) for springs tributary to Jenkins Creek. Several small water district's and community systems are located with Covington Water District's boundaries. The largest of these, Cherokee Bay and King County Water District #94, withdraw .4 and .7 MGD (instantaneous rate), respectively (Environmental and Engineering Services, 1989). All these withdrawals are included in the cumulative groundwater right totals in **Figures 10 and 11.**

FIGURE 10

Cumulative Groundwater Rights in the Soos Creek Basin

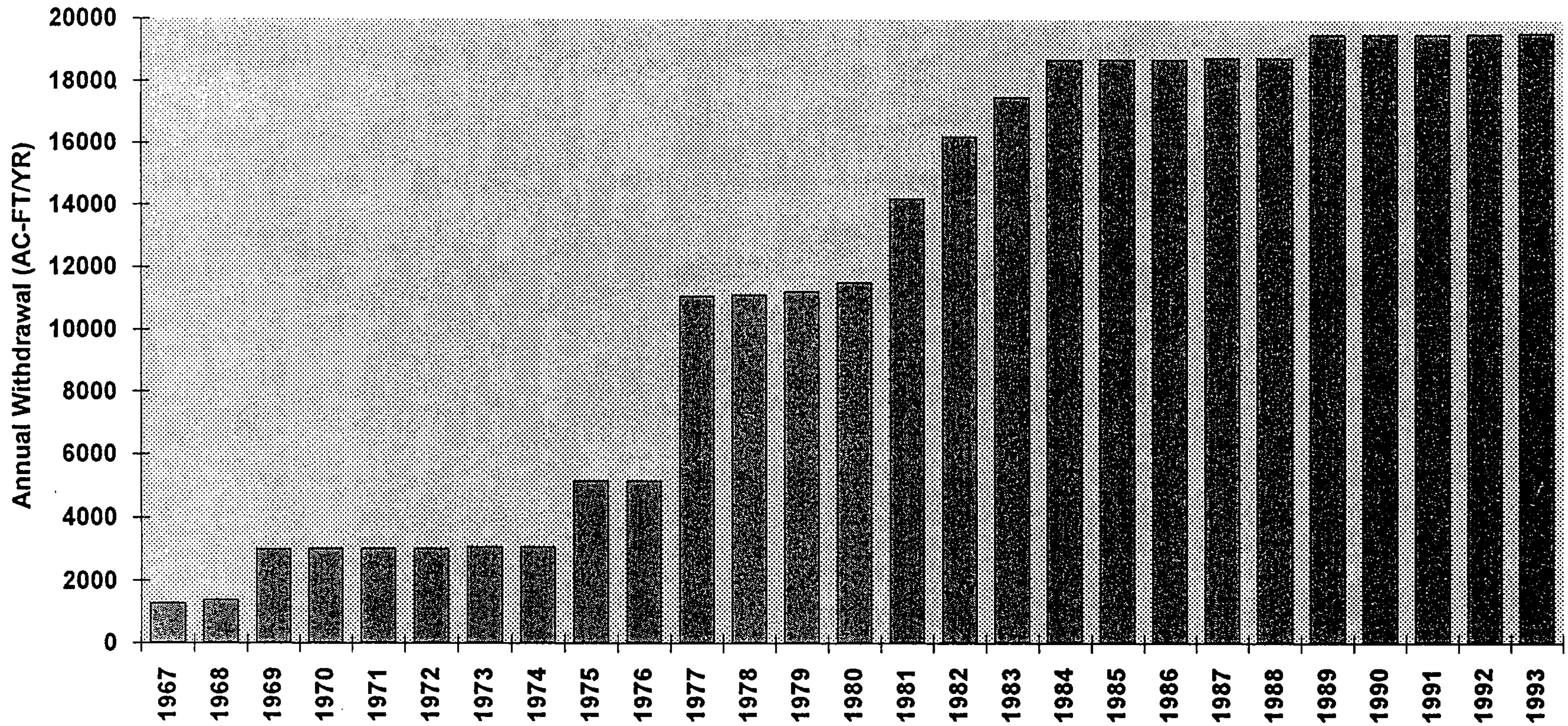
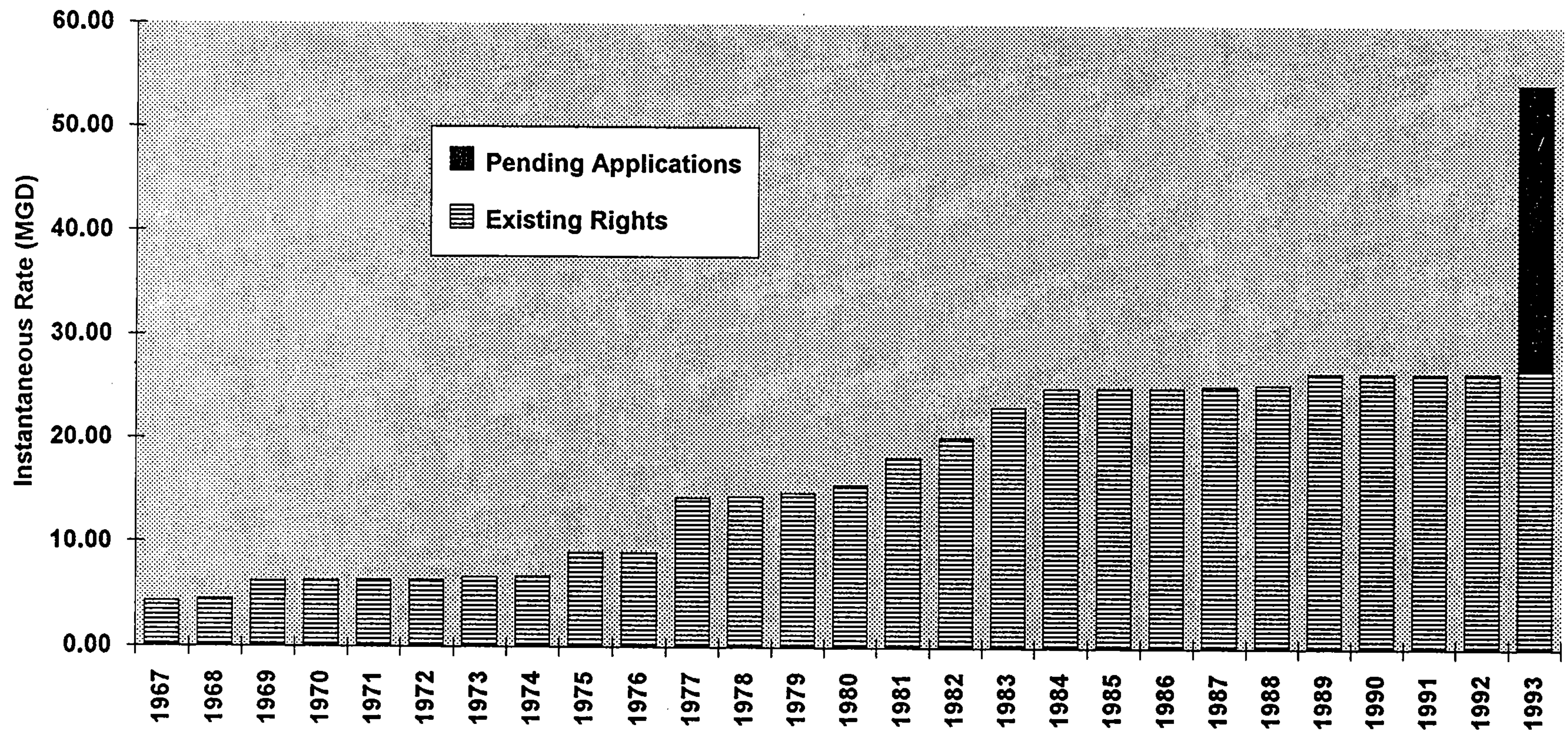


FIGURE 11

Cumulative Existing Groundwater Rights and Pending Requests



Exempt Wells

Approximately 25% of the population in south King County is served by small systems with 5 or fewer connections (SKCGWAC, et al, 1991). These systems are likely small enough to be exempt from the water right permitting process. Based on an estimated 1990 population of 95,350 in the Soos Creek watershed (Muckleshoot Indian Tribe, 1993, draft) and an average annual use of 132 gallons/capita/day used by the Covington Water District in demand projections (URS, 1991), 3,525 ac-ft/yr. of groundwater is estimated withdrawn from "exempt" wells. Covington's average annual use was used as the district's service area is the largest within the Soos Creek basin.

RECHARGE AND HYPOTHETICAL GROUNDWATER YIELD

Recharge in the Covington upland, which includes the Soos Creek basin, has been estimated at 20-22 inches per year (SKCGWAC, et al, 1991). Most of the recharge to groundwater is discharged to upland springs or returns to Soos Creek though shallow aquifers with the Green River serving as a regional discharge feature (SKCGWAC, et al, 1991). The groundwater divide on the north and west portion of the Soos Creek basin is similar to the topographic divide. Therefore, the basin is a relatively closed hydrologic system (SKCGWAC, et al, 1991).

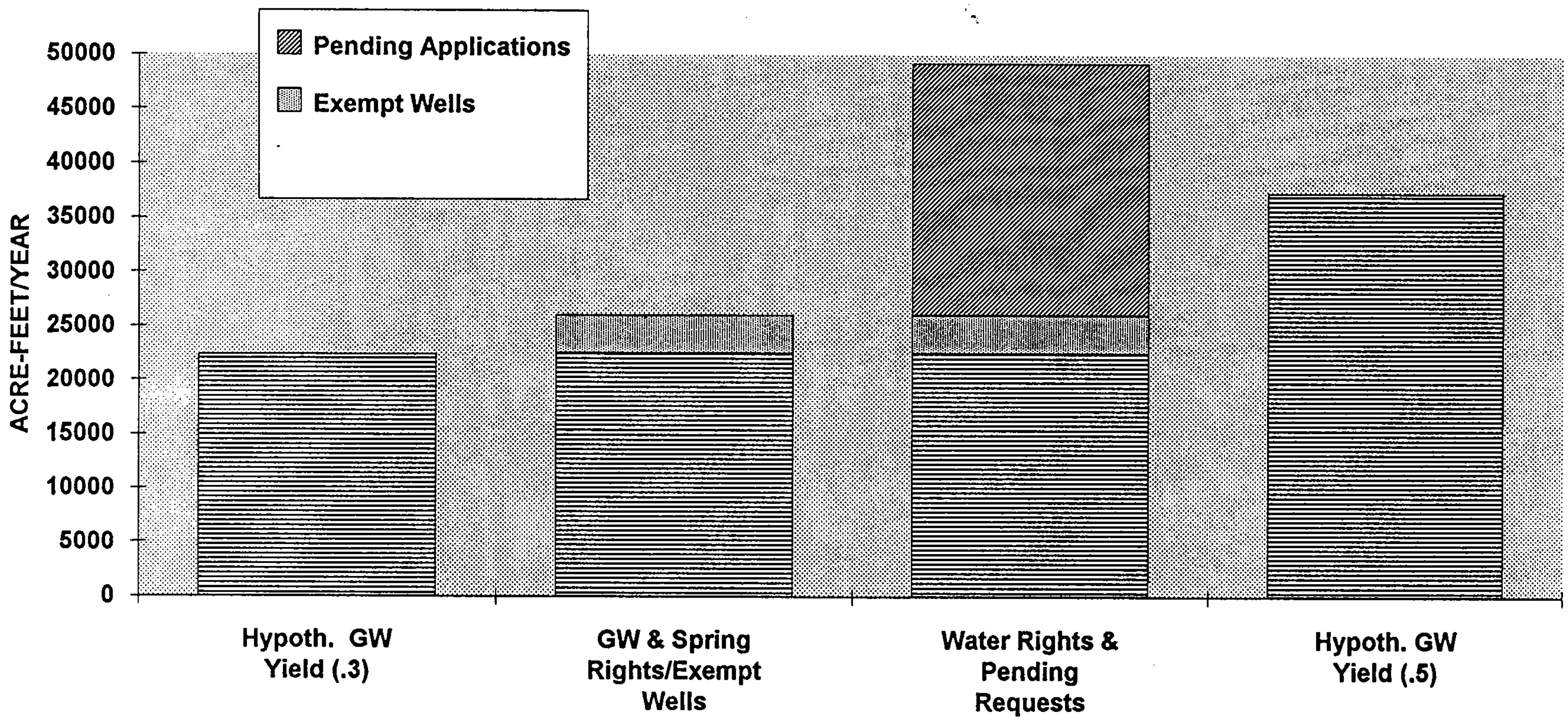
Comparisons of the hypothetical groundwater yield to current groundwater rights, estimated exempt wells, and pending applications were made (**Figure 12**). A hypothetical, potential developable, or safe yield are often used in planning purposes to estimate quantities of groundwater that may be available to develop without adversely affecting resources. There is little or no hydrogeologic validity to this assumption; however it's use continues in water supply planning. The concept is used here to compare to state-certified water right appropriations. The hypothetical groundwater yield is defined as:

Hyp. Yield = C * Recharge Rate * Recharge Area

An annual recharge rate of 21 inches per year, was used for this analysis. Assuming uniform recharge and infiltration over the entire basin, approximately 74,704 ac-ft./yr. or 66.7 MGD of recharge to aquifers would occur annually. Applying coefficients (C= 0.3-0.5) determined from long-termed studies in the Federal Way area, (SKCGWAC, et al, 1991) the hypothetical groundwater yield varies from 22,411 to 37,352 ac-ft/yr. Groundwater appropriations are 19,592 ac-ft/yr. with an additional 2,899 ac-ft/yr. from springs that are listed as surface water rights. Total groundwater and spring appropriations in the basin, upstream of the U.S.G.S. Big Soos Creek gage, are therefore 22,491 ac-ft/yr. Exempt well withdrawals are estimated at 3,525 ac-ft./yr., which brings the total to 26,016 ac-ft./year, which is 3,605 ac.-ft./yr. over the lower hypothetical groundwater yield value (**Figure 12**). Water claims would increase this amount substantially. Pending applications for groundwater developed in the basin total 24.7 MGD (instantaneous rate). If annual quantities are certified at 75% of requested instantaneous rates, an increase of 20,742 ac-ft./yr. in appropriations would occur. This exceeds the higher hypothetical yield by over 9,000 ac-ft./year. Dry season baseflow declines of Big Soos Creek would continue and intensify if these applications are certified; especially at requested rates.

FIGURE 12

CURRENT & PENDING APPROPRIATIONS VS. HYPOTH. YIELDS



	Ac-ft/yr	Ac-ft/yr	Ac-ft/yr				
Hypoth. GW Yield (.3)	22,411						
GW & Spring Rights & Exempt Wells *	22,491	* 3,525	0				
Water Rights & Pending Requests **	22,491	* 3,525	** 23,189	(value based on Inst. rate for 3/4 of the year)			
Hypoth. GW Yield (.5)	37,352						

The lower hypothetical yield is more appropriate to use as a "guideline" to determine over-appropriation than the upper value as adverse impacts, low flows and fish production losses, are occurring.

CONCLUSION

The annual 7-day low flow is declining over time (1967 to 1992) in Big Soos Creek with a pronounced decline in the latter period. The decline is highly significant with a 99.9% chance the trend is not due to random variability. The lack of a similar decline on several streams in the Puget Sound area and on water year precipiation at Sea-Tac strongly indicates that factors other than a dry rainfall cycle are responsible. However, successive years of below normal rainfall are likely contributing to a loss of groundwater storage in the Soos Creek basin. Loss of recharge with urbanization and illegal surface water diversions are also factors. Groundwater appropriations have increased by 16 times during the analysis period. Groundwater and spring withdrawals, based on the examination of state water right appropriations, appear to be exerting the strongest influence on the low flow decline.

Existing groundwater appropriations and exempt wells exceed the lower hypothetical yield value in the Soos Creek basin by 3,605 ac-ft./yr. Adverse impacts, such as dry season streamflow declines are already occurring in Soos Creek. This decline is occurring even as actual groundwater use within the basin may be less than is appropriated. Water imported into the basin from the Cedar and Green Rivers by water districts on these supplies that service homes on septic systems, apparently is not sufficient to offset this impact. Loss of aquifer recharge from urbanization within the Soos Creek basin is also increasing and exacerbating the impact, but is not the sole cause as impervious surfaces only totaled 5% of the basin by 1985.

Regardless of the cause, the annual 7-day flow is declining over time and the fisheries resource in the Soos Creek system is suffering. Until a comprehensive solution is found and implemented to prevent further declines, a conservative approach to water right issuance must be taken. The basin should be closed to further groundwater appropriations.

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APPENDIX I

ANNUAL 7-DAY LOW FLOW (CFS)

YEAR	SOOS CREEK	NEWAUKUM	RAGING RIVER	HUGE CREEK
	USGS 12112600	USGS 12108500	USGS 12145500	USGS 12073500
1967	26	12	12	
1968	32	17	13	
1969	34	18	5	
1970	29	13	11	
1971	34	13	14	
1972	30	16	11	
1973	30	14	11	
1974	29	15	15	
1975	32	17	14	
1976	35	17	21	
1977	26	14	11	
1978	31	16	13	3.9
1979	24	13	10	3.6
1980	28	18	13	3.2
1981	31	18	13	4.1
1982	28	16	12	4.4
1983	28	17	20	5.3
1984	29	18	10	5
1985	21	13	9	4.1
1986	21	14	10	3.8
1987	22	12	7	3.4
1988	26	15	19	3.2
1989	22	11	9	3.1
1990	25	17	12	3.4
1991	26	13	12	4
1992	19	12	11	3.5

PRECIPITATION (INCHES)

SEATAC	*Water Year Annual Total*
Year	(Inches)
1967	39.72
1968	45.36
1969	43.38
1970	30.66
1971	43.49
1972	50.83
1973	28.49
1974	44.00
1975	37.50
1976	42.52
1977	23.16
1978	39.93
1979	23.49
1980	36.90
1981	35.24
1982	39.11
1983	42.84
1984	36.14
1985	28.53
1986	34.26
1987	36.16
1988	28.46
1989	34.94
1990	38.52
1991	45.60
1992	30.62

LANDSBURG	*Water Year Annual Total*
Year	(Inches)
1967	53.93
1968	59.44
1969	58.45
1970	48.70
1971	63.72
1972	69.74
1973	41.62
1974	62.07
1975	57.35
1976	63.39
1977	37.33
1978	58.81
1979	41.90
1980	51.36
1981	70.64
1982	52.19
1983	61.40
1984	57.46
1985	46.01
1986	49.34
1987	51.77
1988	51.55
1989	57.29
1990	62.80
1991	66.97
1992	46.23

APPENDIX II

SURFACE WATER RIGHTS

Surface Water Rights			& City of Kent's Claim*		
YEAR	CFS	ACFT	USE	CUM./WO*	CUM./W*
1909	10.00		C		10.00
1926	1.00		N/C	1.00	11.00
1932	0.10		C	1.10	11.10
1939	0.02		C	1.12	11.12
1939	0.10		C	1.22	11.22
1941	0.05		N/C	1.27	11.27
1941	0.02		C	1.29	11.29
1943	0.01		C	1.30	11.30
1946	0.20		C	1.50	11.50
1947	0.07		C	1.57	11.57
1947	0.02		C	1.59	11.59
1947	1.50		N	3.09	13.09
1947	0.20		C	3.29	13.29
1947	0.05		C	3.34	13.34
1947	1.50		P/C	4.84	14.84
1948	0.03		C	4.87	14.87
1948	0.02		C	4.89	14.89
1949	0.01		C	4.90	14.90
1949	0.25		C	5.15	15.15
1949	0.15		C	5.30	15.30
1950	0.02		C	5.32	15.32
1950	0.15		C	5.47	15.47
1950	0.25		N/C	5.72	15.72
1950	0.01		C	5.73	15.73
1951	0.25		C	5.98	15.98
1952	0.01		C	5.99	15.99
1952	0.01		C	6.00	16.00
1952	0.10		C	6.10	16.10
1953	0.01		C	6.11	16.11
1956	0.01		C	6.12	16.12
1957	0.07	14	C	6.19	16.19
1958	0.04		C	6.23	16.23
1958	0.01	5.6	C	6.24	16.24

1958	0.01	5.6	C	6.24	16.24
1959	1.00		N	7.24	17.24
1959	0.01		C	7.25	17.25
1960	0.10	20	N/C	7.35	17.35
1960	0.01		C	7.36	17.36
1961	0.01		C	7.37	17.37
1961	0.02		C	7.39	17.39
1963	0.01		C	7.40	17.40
1964	0.006	3	C	7.41	17.41
1964	0.01		C	7.42	17.42
1965	0.04	2.7	C	7.46	17.46
1966	0.01	1.68	C	7.47	17.47
1966	0.50		N	7.97	17.97
1967	0.01	1	C	7.98	17.98
1969	0.02	1	C	8.00	18.00
1969	0.01	1	C	8.01	18.01
1971	0.01	1	C	8.02	18.02
1972	0.022	7.5	C	8.04	18.04
1972	0.01	1	C	8.05	18.05
1973	0.02		N	8.06	18.06
1975	0.01	0.5	C	8.07	18.07
1975	0.01	1	C	8.08	18.08
1975	0.01	1	C	8.09	18.09
1975	0.004	1	C	8.10	18.10
1975	0.02	1	C	8.12	18.12
1975	0.01	1	C	8.13	18.13
1975	0.02	2	C	8.15	18.15
1977	0.02	2	C	8.17	18.17
1979	0.02		N	8.19	18.19
1982	0.50		N	8.69	18.69
1991	0.011		N	8.70	18.70

C= Consumptive
N= Non-consumptive
P= Partial consumptive
S= Surface water

Total (cfs): 8.70
Total Consumptive (cfs): 5.15
Total Non-consumptive (cfs): 3.55
Total Incl. Kent Claim (cfs): 18.72

GROUNDWATER RIGHTS

	Groundwater Rights				
		CUM.		CUM.	
YEAR	GPM	GPM	ACFT	ACFT	USE
1932	10	10	9.7	10	C
1946	20	30	13.75	23	C
1949	35	65	28	51	C
1949	200	265	140	191	C
1950	150	415	60	251	C
1952	120	535	40	291	C
1953	200	735	78	369	C
1955	80	815	125	494	C
1956	140	955	50	544	C
1957	50	1005	40	584	C
1958	37	1042	54	638	C
1959	60	1102	90	728	C
1959	35	1137	17.6	746	C
1959	200	1337	180	926	C
1963	535	1872	94	1020	C
1963	10	1882	5.6	1026	C
1963	15	1897	11.6	1037	C
1964	70	1967	17.6	1055	C
1964	15	1982	1	1056	C
1964	40	2022	10.8	1067	C
1964	250	2272	56	1123	C
1965	10	2282	1	1124	C
1966	10	2292	1	1125	C
1966	5	2297	3	1128	C
1966	20	2317	2	1130	C
1966	12	2329	10	1140	C
1966	15	2344	3	1143	C
1966	40	2384	7	1150	C
1966	43	2427	4	1154	C
1966	10	2437	1	1155	C
1967	100	2537	40	1195	C
1967	365	2902	80	1275	C
1967	60	2962	5	1280	C
1968	80	3042	64	1344	C
1968	60	3102	34	1378	C
1968	10	3112	5	1383	C
1968	12	3124	4	1387	C
1968	15	3139	2	1389	C
1969	10	3149	1	1390	C
1969	1200	4349	1613	3003	C
1970	10	4359	1	3004	C
1970	15	4374	4.3	3008	C
1971	5	4379	2	3010	C
1971	50	4429	9.5	3019	C
1971	7	4436	1	3020	C
1973	26	4462	13	3033	C
1973	20	4482	6.72	3040	C
1973	30	4512	6	3046	C
1973	60	4572	17	3063	C
1973	35	4607	10	3073	C
1974	30	4637	6	3079	C
1974	15	4652	4	3083	C
1975	30	4682	12	3095	C
1975	60	4742	13	3108	C
1975	1200	5942	1920	5028	C
1975	40	5982	24	5052	C
1975	50	6032	40	5092	C
1975	50	6082	7	5099	C
1975	50	6132	11	5110	C
1975	40.00	6172	6	5116	C
1975	50	6222	20	5136	C
1975	20	6242	32	5168	C
1977	9	6251	4	5172	C
1977	3690	9941	5904	11076	C
1978	85	10026	42	11118	C
1978	20	10046	7.2	11125	C
1979	4	10050	6.4	11132	C
1979	200	10250	92	11224	C
1979	34	10284	9	11233	C

GROUNDWATER RIGHTS

1980	40	10324	7.5	11240	C
1980	488	10812	285.4	11526	C
1981	1600	12412	2560	14086	C
1981	20	12432	8.6	14094	C
1981	220	12652	125	14219	C
1982	40	12692	6.75	14226	C
1982	40	12732	8	14234	C
1982	300	13032	384	14618	C
1982	1000	14032	1600	16218	C
1982	10	14042	3	16221	C
1983	300	14342	336	16557	C
1983	400	14742	448	17005	C
1983	1300	16042	500	17505	C
1983	35	16077	4	17509	C
1984	12	16089	0.5	17510	C
1984	17	16106	3	17513	C
1984	275	16381	308	17821	C
1984	60	16441	35.7	17856	C
1984	900	17341	864	18720	C
1985	35	17376	3	18723	C
1985	15	17391	6	18729	C
1987	65	17456	5.4	18735	C
1987	15	17471	1.2	18736	C
1987	100	17571	45	18781	C
1988	30	17601	9.5	18790	C
1988	35	17636	4.8	18795	C
1989	100	17736	7.4	18803	C
1989	650	18386	728	19531	C
1989	29	18415	4.5	19535	C
1990	37.00	18452	4.5	19540	C
1992	15	18467	4	19544	C
1992	20	18487	4.5	19548	C
1993	130	18617	44	19592	C

C= Consumptive
N= Non-consumptive
P= Partial consumptive
S= Surface water

Total
(gpm): 18617
Total
(ac-ft): 19592

APPENDIX III

WATER DISTRICTS

There are four major water districts, and two cities, Kent and Black Diamond that supply water within the Soos Creek basin. The locations of the districts in relation to the Soos Creek watershed are shown in Figure **A-1**. Black Diamond diverts springs that flow into the middle Green River. King County Water District #111, Covington Water District and Kent withdraw groundwater or divert spring water while the Soos Creek and Cedar River Water and Sewer Districts currently receive 100% of their water supply from the City of Seattle. Water is imported into the basin from the latter districts via septic systems. Water rights held by the city of Kent, King County Water District #111, and Covington Water District and pending request are in Figure **A-2**. Although Kent has the largest quantity of water rights on paper, but Covington Water District actually withdrawals more water from the basin. Kent's average annual yield from the Kent Springs facility is 1.8 MGD (Kent Water System Plan, 1988) which when added to the other withdrawals in the basin totals about 3 MGD. Covington withdrawals to their full water rights (Covington Water System Plan, 1991) of 5.6 MGD (average annual). Total water right applications for all major districts is 23.4 MGD (instantaneous rate).

City of Kent

The City of Kent holds 15 MGD (based on instantaneous rates) of water rights and claims in the Soos Creek basin with a maximum annual withdrawal limit of 8,233 acre-ft./year (Table **A-1**). The actual supply yield from the Kent Spring facility is lower than certified rights. The 10 cfs claim is for the springs at this site (even though the instantaneous rate is high, the maximum withdrawal limit is only 965 ac-ft./yr., about equivalent to 1 cfs). Water from the springs are collected via an infiltration trench. Shallow wells are also utilized as supply at this site and the capacities have decreased. Aquifer loss or poor pump performance have both been reported as causes of a reduced yield (City of Kent Water System Plan, 1988). Operationally the facility is a dual system where either the wells or the infiltration gallery is used. The gallery dries up when the wells are pumped (South King County Coordinated Water System Plan, 1988). The estimated current yield from this facility is 1.8 MGD. When the Kent Springs transmission line is completed (1995), yield will increase dramatically to 6.3 MGD, for the wet part of the year (City of Kent Water System Plan, 1988).

Covington Water District

Covington Water District has certified groundwater rights for 6.2 MGD (instantaneous rate) with a maximum annual limit of 6,318 acre-ft./year (Table **A-2**). Six applications are pending for an additional instantaneous rate of 12.2 MGD (a seventh is pending in the Crisp Creek basin). All supply is from groundwater withdrawn from the Soos Creek basin. The well field near Lake Sawyer is the dominate supply source. Covington reports seasonal fluctuations in well levels (South King County Ground Water Management Plan, 1991).

King County Water District #111

King County Water District #111 (KCWD #111) holds groundwater rights for 2.8 MGD (instantaneous rate) with an annual withdrawal limit of 2,204 acre-ft./yr. (Table **A-3**). Three applications are pending for an additional 5.8 MGD (instantaneous rate). KCWD #11 is a small district and most of their wells are not very large producers (275 to 750 gpm).

Soos Creek Water and Sewer District

Soos Creek Water and Sewer District currently holds no water rights in the basin, but has submitted five applications for 5.4 MGD (Table A-4). The district is a purveyor of the City of Seattle from which all non-emergency supplies are received.

Cedar River Water and Sewer District

Cedar River Water and Sewer services a small area within the basin, but do not withdraw groundwater. Cedar River currently receives 100% of their non-emergency supply from Seattle. They have submitted applications for 6,000 gpm of groundwater in the Cedar River watershed.

City of Black Diamond

The city of Black Diamond diverts spring water that flows into the Green River from the south. Black Diamond pumps spring water across the Gren River Gorge and imports it into the Soos Creek basin, upstream of Lake Sawyer. Black Diamond has no applications pending for water rights in the Soos Creek watershed.

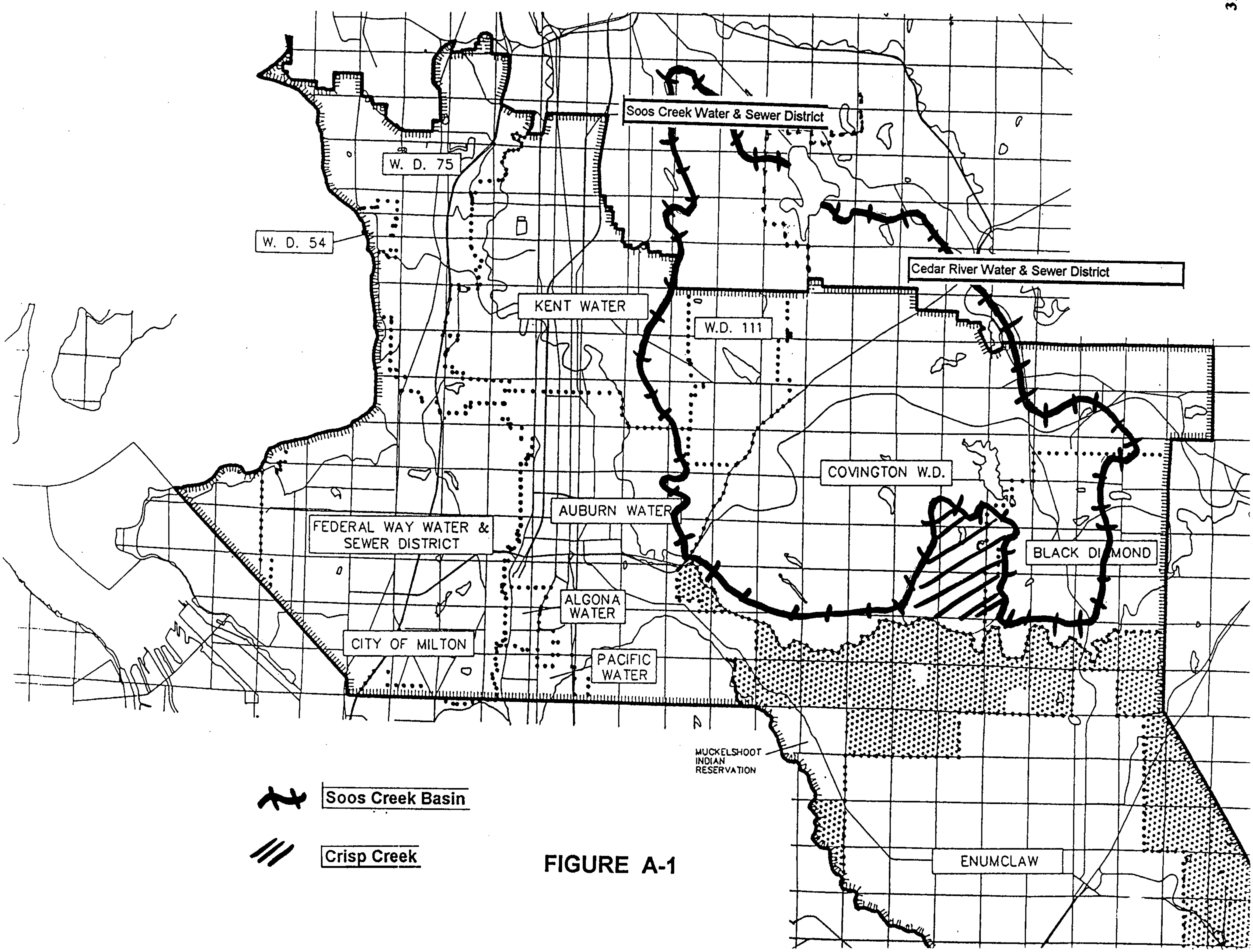
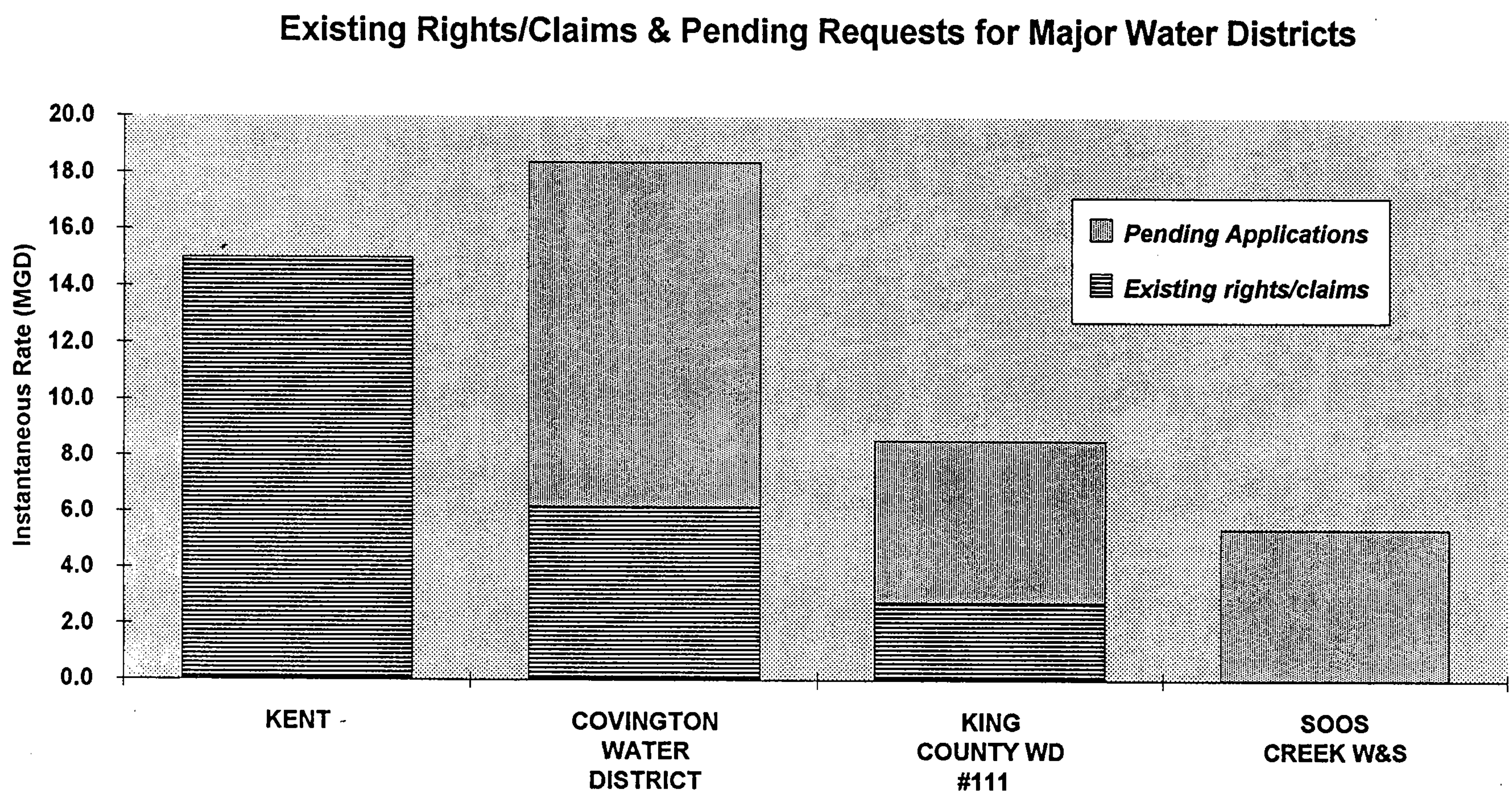

Soos Creek Water & Sewer District
W. D. 75
W. D. 54
Cedar River Water & Sewer District
KENT WATER
W.D. 111
COVINGTON W.D.
AUBURN WATER
FEDERAL WAY WATER &
SEWER DISTRICT
BLACK DIAMOND
ALGONA
WATER
CITY OF MILTON
PACIFIC
WATER
MUCKELSHOOT
INDIAN
RESERVATION
ENUMCLAW
Soos Creek Basin
Crisp Creek

FIGURE A-1

FIGURE A-2



WATER DISTRICT WITHDRAWALS - SOOS CREEK BASIN	Instant. MGD	Pending MGD
KENT	15.0	0
COVINGTON WATER DISTRICT	6.2	12.2
KING COUNTY WATER DISTRICT #111	2.8	5.8
SOOS CREEK WATER & SEWER DISTRICT	0	5.4

TABLE A-1

City of Kent							
Priority/Certificate Date	Source	Ctrl. #	Inst. Q (gpm)	Max. ann. ac-ft.	Inst. MGD	MGD (based on annual right)	In-serv. cap. MGD *
1977/1979	Kent Sprgs	G1-22956C	3690	5904	5.31	5.27	** 2.67
1982/1984	Soos Well	G1-24073C	900	864	1.3	0.77	1.3
1982/1986	Armstrg Sprg	G1-24189C	1300	500	1.87	0.45	1.87
		Total GW:	5890	7268	8.48	6.49	
1909 - claim	Kent Sprgs	Surface Water	4488	965	6.48	0.86	** 3.87
		Total GW & claim:	**10378**	**8233**	**14.96**	**7.35**	

* Taken from South King County Coordinated Water System Plan, 1989)

** Dual system. In-service capacity is about 2.5 MGD (Kent Water System Plan, 1988).

TABLE A-2

Covington Water District							
Priority/Certificate Date	Source	Ctrl. #	Inst. Q (gpm)	Max. ann. ac-ft.	Inst. MGD	MGD (based on annual right)	In-serv. cap. MGD *
1984	GW	G1-24502P	100	45	0.14	0.04	0.14
1959	GW	G1-05269C	200	180	0.29	0.16	
1968/1975	GW	G1-00629C	1200	1613	1.73	1.44	1.44
1974/1977	GW	G1-21694C	1200	1920	1.73	1.71	1.3
1978/1981	GW	G1-23250P	1600	2560	2.30	2.29	1.87
		Total:	**4300**	**6318**	**6.19**	**5.64**	**4.75**
Pending:							
1990	GW	G1-25642A	1000		1.44		
1987	GW	G1-25029A	1500		2.16		
1990	GW	G1-25643A	1500		2.16		
1990	GW	G1-25726A	1000		1.44		
1992	GW	G1-26699A	2000		2.88		
1989	GW	G1-25810A	1500		2.16		
		Total:	**8500**		**12.24**		

* Taken from South King County Coordinated Water System Plan, 1989)

TABLE A-3

King County WD #111							
Priority/Certificate Date	Source	Ctrl. #	Inst. Q (gpm)	Max. ann. ac-ft.	Inst. MGD	MGD (based on annual right)	In-serv. cap. MGD *
1984	GW	G1-24299C	275	308	0.40	0.27	0.40
1983	GW	G1-24302C	400	448	0.58	0.40	0.58
1981	GW	G1-23817C	300	384	0.43	0.34	0.43
1983	GW	G1-24301C	300	336	0.43	0.30	0.43
1984	GW	G1-24568C	650	728	0.94	0.65	1.01
		Total:	**1925**	**2204**	**2.77**	**1.97**	**2.85**
Pending:							
1988		G1-25263A	1500				
1991		G1-26086A	750				
1990		G1-25968A	750				
1989		G1-25374A	1000				
		Total:	**4000**		5.76		

* Taken from South King County Coordinated Water System Plan, 1989)

TABLE A-4

Soos Creek W & S District			
Pending:		Inst. Q (gpm)	Inst. MGD
		750	1.08
		750	1.08
		750	1.08
		750	1.08
		750	1.08
	Total:	**3750**	**5.4**